ASSESSMENT OF CLIMATE CHANGE EFFECTS ON FLOOD RISK BY USING GIS AND REMOTE SENSING (CASE STUDY: KABUL, AFGHANISTAN)

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Master's Thesis

Department of Environmental Engineering

Programme in Environmental Science

Supervisor: Asst. Prof. Dr. Zehra YİĞİT AVDAN

Eskişehir

Eskişehir Technical University

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ABSTRACT

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Geospatial technology such as Remote Sensing and Geographic Information System is a crucial tool in environmental monitoring such as water resource management, pollutions monitoring, and disaster management in the 21st century. In the present decade, Climate change is one of the most serious and critical issues which has hurt the environmental processes and living things, which include rapid urban floods and environmental degradation. Kabul City is one of the urban areas which is hugely affected by flood events every year.

This study aims to assess the occurrence of flood damages in Kabul city and its surrounding areas between the years of 2014-2019. This will assist in planning, modeling, and design of flood risk management and measures of protection, managing emergency in real-time and recovering from flood events, which in turn lowers the environmental damage. In this thesis, Assessment of Climate Change Effects on flood risk on the city of Kabul has been done via Using Remote Sensing (RS) and Geographic Information System (GIS) technologies. Further, the indexes of Normalized difference water index (NDWI) and Flood-pixel has been developed by image processing software (ENVI), which is one of the best methods for open water and Floodwater features delineation. A flood risk analysis map has been developed in the ArcMap software.

In conclusion, the data gathered comparatively from climate map analysis between the years (2009-2019) and satellite imagery analysis between the years (2014-2019) shows that some parts of the city have been under huge threat of flood occurrences, and this risk is increasing and will become an even greater threat for the Kabul city in the future. Hence, I recommend structural and non-structural measures for the control, prevention, and reduction of the flood risk level in the city of Kabul. RS and GIS easily offer relatively cheap, quick, and easily accessible data for researchers about the flood occurrence, which lowers the cost of flood risk management and monitoring.

Keywords: RS, GIS, Flood Risk, NDWI, Climate change.

ÖZET

CBS VE UZAKTAN ALGILAMA KULLANILARAK İKLIM DEĞIŞIKLIĞININ SEL RISKI ÜZERINDEKI ETKILERININ DEĞERLENDIRILMESI (ÖRNEK OLAY: KABIL, AFGANISTAN)

Mohammad Omid SEDIQI

Çevre Mühendisliği Anabilim Dalı

Çevre Bilimleri Bilim Dalı

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21. yüzyılda Uzaktan Algılama ve Coğrafi Bilgi Sistemi gibi geo-uzamsal teknolojiler su kaynakları yönetimi, kirlilik izleme ve afet yönetimi gibi çevresel izleme için önemli bir araçtır. Son yıllarda küresel iklim değişikliğinin canlılar ve çevresel süreçler üzerinde olumsuz etkileri hızlanmakta, yerleşim yerleri sel gibi çevresel bozulmalardan etkilenmektedir. Her yıl Kabil şehri birçok su baskınına maruz kalmaktadır ve bu durum Kabil şehrine büyük zararlar vermektedir.

Bu çalışmanın amacı Kabil şehrinde ve çevresinde 2014-2019 yılları arasında meydana gelen sellerin zararlarını değerlendirmektir. Bu çalışma, çevresel hasarı azaltmak için sel olayların risk yönetimi ve koruma önlemlerinin planlanmasına, modellenmesine ve tasarımına, acil durumun gerçek zamanlı olarak yönetilmesiyle sel olaylarının daha kolay bir şekilde atlatılması sağlamayı hedeflemektedir.

İklim Değişikliğinden kaynaklanan taşkın riskinin Kabil şehri üzerindeki etkileri Coğrafi Bilgi Sistemleri (CBS) ve Uzaktan Algılama (UA) teknolojileri kullanılarak belirlenmiştir. Çalışmada NDWI (Normaliz Edilmiş Fark Su İndeksi) ve Flood-pixel indeksleri, açık su ve taşkın suyu özelliklerinin tanımlanması için en iyi yöntem olan görüntü işleme yazılımı

(ENVI) tarafından hesaplanmıştır. ArcMap ortamında bir taşkın risk analizi haritası üretilmiştir.

Sonuç olarak, (2009-2019) yılları arasındaki iklim analiz haritası ve (2014-2019) yılları arasındaki uydu görüntüleri analizi karşılaştırmalı bir sonuç olarak toplanmış ve analizlerin sonucunda, Kabil şehrinin büyük sel olayları tehdidi altında olduğu ve gelecekte Kabil şehri için büyük bir sorun oluşturacağı düşünülmektedir. Kabil şehrinde taşkın risk seviyesinin kontrolü, önlenmesi ve azaltılması için yapısal ve yapısal olmayan önlemlerin alınmasını önerilmektedir. UA ve CBS, sel riskini yönetmek ve izleme maliyetini azaltmak için araştırmacılara daha ucuz, hızlı ve kolay erişilebilir veriler sunmaktadır.

Anahtar Sözcükler: UA, CBS, Taşkın Riski, NDWI, İklim Değişikliği.

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Thank you all.

DEDICATED

This is dedicated to my respectful supervisor, Assistant Professor Dr. Zehra YİĞİT AVDAN and my beloved family, especially to my parents who have always supported me in achieving my goals with their whole beings.

Mohammad Omid SEDIQI

14/08/2020

STATEMENT OF COMPLIANCE WITH ETHICAL PRINCIPLES AND RULES

I hereby truthfully declare that this thesis is an original work prepared by me; that I have behaved in accordance with the scientific ethical principles and rules throughout the stages of preparation, data collection, analysis and presentation of my work; that I have cited the sources of all the data and information that could be obtained within the scope of this study, and included these sources in the references section; and that this study has been scanned for plagiarism with “scientific plagiarism detection program” used by Eskişehir Technical University, and that “it does not have any plagiarism” whatsoever. I also declare that, if a case contrary to my declaration is detected in my work at any time, I hereby express my consent to all the ethical and legal consequences that are involved.

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GLOSSARY OF SYMBOLS AND ABBREVIATIONS

AOI	: Area of Interest
CSO	: Central Statistics Organization
DEM	: Digital Elevation Model
ERDAS	: Earth Resources Data Analysis System
ESRI	: Environmental System Research Institute
ETM	: Enhanced Thematic Mapper
FCC	: False Color Composite
FAO	: Food and Agriculture Organization of the United Nations
GIS	: Geographic Information System
GPS	: Global Positioning System
GCP	: Ground Control Point
GEO-TIFF	: Georeferenced Tagged Image File Format
GLS2000	: Global Land Survey 2000
IDW	: Inverse Distance Weighted
IR	: Infra-Red
IDE	: Integrated Development Environment
KRB	: Kabul River Basin
KM	: Kilometer
L-8, L1	: Landsat-8, Level1
LU/LC	: Land Use / Land Cover
LIDAR	: Light Detection and Ranging
MODIS	: Moderate Resolution Imaging Spectroradiometer
MCE	: Multi-Criteria Evaluation
MoWR	: Ministry of Water Resource
MSS	: Multi-Spectral Scanning
M	: Meter
NASA	: National Aeronautics and Space Administration
NASS	: National Agricultural Statistics Service
NMA	: National Meteorological Agency
NIR	: Near-Infrared

NDWI	: Normalize Difference Water Index
NEPA	: National Environmental Protection Agency
OLI	: Operational Land Imager
QGIS	: Quantum Geographic Information System
RADAR	: Radio Detection and Ranging
RS	: Remote Sensing
ROI	: Region of Interest
RGB	: Red, Green, Blue
SARs	: Synthetic Aperture Radars
SWIR	: Short Wavelength Infrared
SRTM	: Shuttle Radar Topography Mission
SDSS	: Spatial Decision Support System
SONAR	: Sound Navigation and Ranging
TOA	: Top of Atmosphere
TIRS	: Thermal Infrared Sensor
TIR	: Thermal Infrared
TM	: Thematic Mapper
UAV	: Unmanned Aerial Vehicle
UNICEF	: United Nations Children's Fund
USDA	: United States Department of Agriculture
UN	: United Nations
USGS	: U.S Global Survey
UTM	: Universal Transverse Mercator
UNEP	: United Nation Environmental Program
UNOCHA	: United Nation Office for the Coordination of Humanitarian Affairs
WLC	: Weighted Linear Combination
WFP	: World Food Program
WGS-84	: World Geodetic System-1984
WHO	: World Health Organization

1. INTRODUCTION

Flood is a type of natural disaster which cannot be prevented but, via application of Geospatial technology tools GIS (Geographic Information System) and RS (Remote Sensing), can assist the impact of the flooded area and also manage risk reduction for preparation of new strategic plans in the future. Disasters such as floods can cause loss of human/animal life and at the same time bring vast losses of economic and social disconnections all over the world. The international association entirely identified that sustainable development model must be integrate with natural disaster risk reduction strategies.

The Geospatial technology analysis performed for the computation of people exposure identified 147 countries with populations exposed to floods, where the people of South Asian countries are at the top of the list [1]. In 2018, the extensive damages resulting from natural catastrophes maturated to $US 71 billion [2]. All geophysical disasters has devastating effects on the environmental process, but on a global scale, flood has the most catastrophic effect on the environmental process [3]. Afghanistan currently rated as the poorest country in South Asia is vulnerable to both these natural hazards and climate changes. Just ten years ago, on the 28th June, 2007, a flash flood ravaged eight provinces of Kabul Basin and killed more than 113 people where the worst casualties were in Kabul and Panjshir Provinces (90 deaths, unknown injuries, more than 600 damaged houses and thousands of hectares of agricultural lands were affected) [4]. Due to the weakness of disaster preparedness, an avalanche killed 300 people in Afghanistan; the 2015 avalanche also led to the resettlement process, where an un-estimated amount of people inevitably left the Upper Kabul [5],[6]. This process led to the formation of settlements in previously uninhabited or less inhabited areas along the Kabul riverbank.

Worldwide, natural disasters on average kills 60,000 humans [7]. According to the report of the world bank in 2016, Afghanistan is one of the most vulnerable countries, facing different natural disasters such as floods, earthquakes, landslides, droughts and avalanches. In addition, these kinds of natural disasters lead to food insecurity, which is one of the main issues in Afghanistan, where on average, $US 280 million worth of economic damage is caused to the agriculture sector each year. In fact, at least 59 % of the population is affected by climate-related shocks and natural disasters [8].

The accessibility of information about disaster risk is individually essential for a fragile state like Afghanistan where 4 out of every 5 people rely on natural resources for their subsistence. Flood is one of the most frequent natural hazards historically known in Afghanistan and annually, flood damages average an estimated $US 54 million; giant range flood episodes can cause more than $US 500 billion in damage. Since 1980, earthquakes in Afghanistan has affected more than 10,000 people. Around 3 million people are at risk of landslide hazards in very high regions in Afghanistan. Besides, since 2000, 6.5 million people have been affected by drought; severe drought can cause $US 3 billion in agricultural damage and lead to intense food deficiency across the country [9]. The lack of infrastructure (especially flood prevention & control structures), hygiene drinking water, safe irrigation zone, and employment/work possibilities are just a few of the challenges that the inhabitants of these rural settlements are facing besides the constant risk of being affected by natural hazards such as flash floods, landslides & avalanches. The risk of floods increasing via climate change and it's a worldwide phenomenon. According to the last analysis of FAO and UN in 2017 it showed that, by the end of this century, communities will face repeated flooding, which is already happening in more than 90 countries. According to the report of OECD (Organization for Economic Cooperation and Development) floods cause more than 40 billion dollars in damage annually all over the world [10]. As a result, all disaster incidents affect environmental processes which in turn causes air pollution, water pollution, deforestation, and diseases such as cholera, hepatitis and loss of endemic species habitats.

At present, geospatial booms such as satellite, airborne and other ground-based data are increasingly used in water and waterbody extraction. In addition, a lot of new technologies have been developed and used to detect waterbody and varying climate change factors. These technologies have low-cost positioning systems such as GNSS (Global Navigation Satellite System), GPS (Global Positioning System), GIS, variable-rate technologies and open-source RS satellite imagery data. Nowadays, satellite imagery data provide up to date return frequency visits from sixteen days to one day. Therefore, spatial resolution from very high and high resolution (10 meters, 5 meters and 0.31 meter), mean resolution (100 meters, 80 meters, 30 meters and 20 meters) and low resolution (1 kilometer, 500 meters and 250 meters), to the spectral resolution diverse contain the spectrum region (NIR (near-infrared), infrared, visible, SWIR (short wave infrared) and micro-wave); the width and number of spectral bands (hyperspectral, multispectral, and panchromatic); resolution of radiometric (16 bits, 12 bits, 8 bits and 6 bits); the sensor type such as Radar (radio detection and ranging), Sonar (Sound Navigation and Ranging), Lidar (Light Detection and Ranging), thermal and optical.

1.1. Objectives

In this study, ArcGIS version10.5 software, ERDAS Imaging Software, and ENVI software were used to estimate the climate change impact assessment (flood risk estimation) on the environmental process as a case study in Kabul City. This study was initiated by the researcher and supervisor, whose aims are to find sustainable and viable solutions to the above-stated problems. Besides tackling the most basic environmental facility issues such as water supply, sanitation and drainage, this research intends to consider the needs of the local population as well as the physical boundaries of sustainable rural development with environmental regulations. The embankment of upstream Kabul river and upper part of Kabul City which is under risk of flooding has been utilized by people due to the lack of flat areas; the area is known to be risky for irrigation and unsuitable as a residential place due to shortages of environmental facilities. Previous evidence and events show that the upper parts of Kabul City including the upstream river are currently at high risk of being flooded in addition to not being a suitable residential place according to the Kabul City master planning as it is on the side of Kabul river.

For a successful planning of Kabul's future development, it is essential to know what impact severe storm events could have on urban areas. Based on this background, the main objective of this study is to create a flood risk map and flood hazard zoning for Kabul City, including outlining areas with frequent, rare and exceptional flood hazards. Furthermore, a framework of environmental protection measures addressing the major flood-related issues is developed. The following section gives an overview of the strategy that is applied to accomplish the goals of the study.

The present research focuses on urban areas such as Kabul City, which was badly damaged by the 2014 and 2019 flood crisis. The aim of this study is to assess the events of flood damages to urban areas such as Kabul city and surrounding areas of the city between the years of 2014-2019. This will assist in the planning, modelling and designing of flood risk management and measures of protection, managing emergency in real-time and recovering from flood damages.

Geospatial technology (GIS, RS, ENVI) and some other software (Microsoft office,) were used. In addition, this research study provides some guidelines for flood event risk mapping in developing countries. In conclusion, the goal of this research work is firstly, finding and determining the capacity of geospatial technologies such as GIS RS, GPS for the assessment of climate change effect (flood risk assessment) on the environmental process; secondly, finding the suitable indices such as NDWI, Flood-Pixel for waterbody extraction and specification of the flooded areas; thirdly, one via open-source software with spatial analysis evaluation between Lnadsat8 imagery and Planet-Scope imagery for flood-prone areas.

1.2. Organization of the thesis

The present thesis is organized into four chapters as follows:

• The first chapter is the Introduction: Chapter 1 as an introduction describes the background, objectives of the research and limitation.

• The second chapter is the Literature Review: Chapter 2 explains the theory behind the software and models applied in this study. The literature review deals with the applicability and the limitations of the used models.

• The third chapter is the Theoretical Information: In chapter 3, the objectives provide general information about climate change, the impact of climate change on the environmental process, flood, types of flood, flood hazard, flood risk, vulnerability, GIS, RS and historical flood disaster on a global level.

• The fourth chapter is Methods and Materials: In chapter 4, the approach, methodology and the model input data are presented in detail. This chapter also describes the methods for the development of environmental protection model in detail.

•The fifth chapter is Results, Discussion, Recommendations and reference: In chapter 5, the assessment of the results of flood via GIS and RS are presented and discussed. Simply, it describes the steps of the analysis and the results.

1.3. Limitation and Problem Statement

Academic research level and quality at the Government of Afghanistan is at its lowest level. Majority of the areas have not been technically analyzed in terms of natural disasters and environmental sanitation. This problem has many causes, some of which are indicated such as: lack of available funds, insufficient data, administrative corruption, knowledge level, insufficient expertise, etc. In the flood risk assessment and modelling section, we are using the hand calculation methods from the 20th century, which has very poor amount accuracy. The Government of Afghanistan has initiated scholarships for its employees to enhance and upgrade the level of knowledge and quality of academic researches. As the result of this strategy, environmental engineers in the flood risk assessment and modelling section had been able to use digital technologies and some open-source software's such as GIS, RS, ENVI and satellite imagery data related to this issue. But still, they are using older methods, in which the site data is not considered, and usually, assumptions are made.

GIS and RS, which is now the base for environmental element modelling, is an un-used or less used tool. The simple method is using of ENVI software with assumed data (e.g. Curve Number, Lag time, Cross-Sections, Area, Peak of Flood, etc.). In this present research, the newest technology for flood risk assessment method for small and medium urban area watersheds has been used, which is fully described in the Fourth Chapter (Methodology). Briefly, it can be noted that, this method uses the actual data which is overserved via RS (such as DEM "Digital Elevation Model" & Satellite Imagery) and combined RS & site surveying (Soil & Land use data) which leads to more accuracy in research. At the same time, these data are assumed or even neglected in usual researches. Finally, the limitation in this research work was limited satellite imagery sources with unsuitable data and time for the study area and non-existent of satellite imagery for mentioned areas such as rapid-eye imagery, radar sat imagery and planet-scope imagery. Also, sometimes open-source software's didn't process the imagery and stopped.

2. LITERATURE REVIEW

Flood is a kind of natural disasters which is occurring in our environment urgently and affect environmental process. Nowadays, different techniques and methods have been applied to assess the flood risk, such as applications of RS, GIS and HEC-Geo RAS. Presently, the impact of flood event is expected to increase because of economic growth, population growth, climate change, and global warming issues. In the result of these influences affect the processes of the environment, such as water treatment, air pollution, deforestation, and degradation of the ecosystem.

2.1. The General Review of Related Studies

RADARSAT images and GIS tools were used for finding the maximum mapping of Malaysia flood-prone area of the Kelantan River Basin using several dialectic models of regression. The purpose of this study is to map the most flood-prone area of the Kelantan Basin. In this study, Methodology preoccupied: First, the floodplain region is extracted from RADARSAT 1 images based on existing ground data reports and field memo. Secondly, by examining the factors interdependent with flood inundation areas, the spatial database was created from a geological map, hydrological map, topographical map, land cover map, GPS data, Spot 5 satellite images, precipitation data and DEM (Digital Elevation Model). Nine significant extracted parameters from the analysis of logistic regression were calculated and mapped to determine the rank of each of the factors and rankings for the area prone to flooding.

The results showed that mapping flood-prone areas, which can be called a sensitivity map, can be done at 1: 25,000 scale, which is comparable to some typical mid-scale flood vulnerability maps. Flood-prone areas in these maps correspond to spaces that can be flooded by significant floods of approximately 100 years. Qualitatively, the model appears to have consistent results with an observed accuracy of 84% [11].

Holed that basis on the Flood extend, this plan is to demonstrate, develop and accredit an information system for flood planning, management, and forecasting via using of remote sensing technology data with the support of flood risk and vulnerability maps for different throwback periods (10 years, 20 years, 50 years and 100 years). In addition, access to physical vulnerability and population vulnerability of the lowest executive and administrative section exposed to floods and using the over results performs in the study area for flood hazard analysis. Their methodology involved satellite data, geographic data, hydrometeorological data, census data, and field survey data. This research methodology includes data gathering and database needed for vulnerability and risk analysis.

It was evaluated that the flood width rate isolated from satellite data imagery is in accordance with the model of HEC-RAS. It can be expected as the satellite images were captured to receding limits of the flood event regarding maximum flood peak had been happened around two days before the satellite photos were captured. However, the result of work is engaging. The flood width taken from satellite image and HEC-RAS matches very well, although the diameter was low in the satellite image. GIS, RS, GPS, altogether with the technique of flood modeling have well applied to build the first evermore set of flood event risk map for the down overtake of the Sri-Lanka, River of Kalu Ganga [12].

The RS and GIS techniques for flood monitoring and damage assessment were applied. Sindh province is located in the southern part of Pakistan, with an area of 140915 km^2. The study area lies between two monsoon–the south monsoon from the Indian Ocean and the northeast monsoon. In addition, the annual average rainfall of this province is about 6–7 inches (15–18 cm). The Sindh province flood was originated mostly because of rains and observed the highest ever recorded monsoon rain in this province, started from 11th August 2011 to 14th September 2011. The objective of this paper was to analyze the procedure for mapping of Flood inundate areas using MODIS data during Sindh flood 2011 to estimate the affected land cover/land use types and estimate the affected number of people; In addition, damage assessment of Flood and to improve the efficiency of flood disaster management and monitoring. The study used below data and software:

- Topographic maps had been used for extracting different type of info-layers such as rivers, road, vegetation areas, railway tracks, lakes and other land use/ land cover categories .
- MODIS images (Moderate Resolution Imaging Spectro-radiometer) onboard AQUA and TERRA images of 250 m resolution comprising bands 1, 2 and 7 were acquired and used as the principal input to map the flood affected areas.
- ArcGIS 9.3 and ENVI 4.5 software were used for For processing and analysis.

- For an estimate of the affected people, district wise population density was used.
- Spot 5 images had been mosaicked and used for visual verification of flooded areas.

The methodology adopted for this research was that the MODIS images were acquired from NASA's website free of charge, and a maximum likelihood supervised classification of the images covering Sindh province was carried out and then the required inundated class was converted into a shapefile.

The result showed temporal and cumulative flood extent maps were prepared during flood event and used as the primary input to determine the damage with the help of GIS analysis technics and tools. It was found that heavy-handed Flood happened in Shahdadkot by 1597.50 km^2, Inundated and Badin it by 3820.39 km^2, Dadu by 1887.57 km^2, Jacobabad by 1352.32 km^2, Sanghar by 2494.18 km^2 and Mirpurkhas by 1836.26 km^2, is cumulative. Additionally, the above-mentioned provinces contributed 61% of the total inundated area among 23 provinces in Sindh. In addition, the overall damage assessment of flood extent was found to be 21201 km^2 affected 498.47 km^2 of forests, 5329 settlements, 1500.44 km of the road network, 382.05 km of railway tracks, 16440.48 km2 of agricultural land, and 5.88 million people with the death toll close to 2000 shuman. So, the application of RS and GIS would be an essential tool for monitoring flood risk and specifying flood affected areas because this methodology needs less time and economic resources to apply and get the results. This work can be significant and valuable information for immediate disaster response, mitigation, and rehabilitation [13].

Explained the technique of GIS and RS for assessment of flood hazard in the Yamanapuram river basin, Kerala, India. Vamanapuram river basin located in Thiruvanathapuram district with 787 Sq.km catchment area. The annual average rainfall was about 1500 mm. Aim of the present work was to prepare flood hazard zone map of Vamanapuram river basin using FRI (flood risk index) considering factors such as (slope, soil type, hydrology, rainfall, land use, landform, and drainage density) and multi-criteria evaluation method via application of GIS, GPS and RS. In addition, the preparation of this hazard zone map will be effective for the emergency planning of this district, because nowadays, India is facing repeated flash hazards in some parts. In this research, ERDAS IMAGINE 9.1 and ArcGIS 9.3 software’s and materials such as LANDSAT ETM+ satellite imageries and DEM were used, in addition, the MCE (multi-criteria elevation) methodology was applied. For the preparation of the zoning map some factors were used like soil, rainfall distribution, land cover/ land use, number of roads per micro watershed, micro watershed, derange density, and slope. Field survey and GPS were used to prepare the land cover/ land use map. For modifying the road network data, Google Earth was used. ERDAS IMAGINE and ArcGIS tools were used to prepare the thematic maps, then for flood hazard zone mapping the weighted overlay analysis was applied. Raster Calculator tool in ArcGIS was used for calculation of flood-prone areas and overlaying of all maps. The result showed that remote sensing and GIS is a cheap and essential way to create flood hazard map zone and risk maps of the Flood-prone areas, and these assess us to do specific planning for flood events before and after occurring the event. It means by using remote sensing and GIS techniques we can easily map, model and analyze the flood risk and the prepared hazard map will specify the hazard area categories for us, and we can reduce the risk level. In the this study the drainage density are classified into four classes: low 0-1km/ km^2, moderate 1-3 km/ km^2, high 3-5km/ km^2 and very high 5 km/km^2. The land use map include forest, water boy, vegetation. Lowest weight two is assigned for the forest, and high weight eight is assigned for a water body. The study area rainfall was classified into four classes, such as 3000-3500 mm high, 2500-3000 mm moderate, and <2500 mm low. Watershed slope angle were 0 to 63° and classified into three class like 40-63° high, 20-40° moderate and 0-20° low, also in this research, it was found that 90% of the flood event has happened in high and very high zones [14].

The 2012 flooding event of Nigeria, which devested coastal area of Nigeria in addition to those the central river valleys of Nigeria country, has researched. It was remarked in the research that the event of Flood at downstream and valley of Benue river was earnestly destroying fallowing the water release from the Dam of Lagdo, which located at the upstream River of Benue in the Cameroon Republic. The objectives of this research were to carry out assessment based a GIS for flood hazard and community's vulnerability in the Flood Prone Areas, State of Adamawa. In this research, the data collection method employed, such as the application of Geo-information techniques, which implicate the use of GPS for capturing the coordinates of 120 societies which cut among several local and administrative areas settled along the valley of Benue river in State Adamawa. These societies were connected to the user of the ArcGIS program for generating the Benue valley river digital map to recognize every one of the communities which stayed in Flood vulnerable area. In conclusion, flood event vulnerability was classified into four groups: low vulnerable, very low vulnerable, highly vulnerable, and very highly vulnerable. Finally, 29 communities representing that 32.5 % of people on highly sensitive areas were located, 46 cities representing that 38.33 % of people on the flood plain areas are classified as vulnerable. While the remaining 35 communities representing that 29.17 % of the people were found to be located outside the buffer zones within the Benue River Basin, which are also classified as vulnerable areas. Escape way and suitable location for emigre; camps were recognized during the flood event while database creation and analysis for flood vulnerability were also developed [15].

The GIS and RS techniques to generate and develop the middle course of the River Kaduna, the flood map have been used. This research work purpose: was to determine the vulnerable areas of flood phenomenon. The research demonstrated the integration of remotely sensed imagery, digital elevation modeling, and topographic data for the mapping of flood vulnerability. Therefore, the integrated approach of techniques Geographic information system and remote sensing for flood event management. The high accuracy resolution imagery was needed for a Vivid visualization of the vulnerability extent; hence from the Google Earth application, the high-resolution imagery was obtained, and the image process and analysis were carried out on the software of Arc GIS 9.3. The research work also conducts an interview with parts of the people within the area of the study to aid in achieving inferences and making appropriate recommendations. The meeting contains 50 conforming drawn from 5 flood-prone areas in Banarwa, Kaduna, namely, Railway, Saba, Tudun Wada, and Station. Applying a structured guideline for residents of Kaduna city areas, prone to flood phenomena from Kaduna River, were interviewed. The method of Random sampling was employed for interviewees selecting. Finally, the result represented a vulnerable map of Flood, which based on the model of digital elevation of the middle stream of the River. Also, for the produce of the vulnerability map, the reclassification tool was used. It must be noted that by Yeb and Aggarwal flood region of the Kaduna River and flooding risk area was identified [16].

The Flood hazard management via application of Remote Sensing and Geographical information system at Sindh province of Pakistan have been observed. Sindh River is the longest River that stretches to about 3180 km (1976 miles) long in southeastern Pakistan and the primary source of irrigation for fertile agricultural lands in Pakistan. The River's annual flow is around 207 cubic kilometers (km^3). The study area located in the southeastern part of Nepal and seven districts of Sindh province. Annual rainfall averages about seven inches, falling mainly during July and August. The objective of this research work was to demonstrate an effective method to correctly specify Flood-prone areas, flood hazard areas, and appropriate areas for flood shelter sites to minimize flood risk impacts. Conceivable scope of flooding and relevant location flood shelter sites sketched and mapped, using the satellite remote sensing and ArcGIS software model maker for Sindh Province in Pakistan.

In this research work, the Methodology applied was: MODIS (moderate resolution imaging spectroradiometer), A topographic map, DEM (SRTM) Shuttle Radar Topography Mission. To analyze flood-prone area and shelter areas, MODIS re-projected UTM Zone 47 and for object-based image analysis (OBIA) e-Cognition developer software used. Besides, several segmentations were tested with a different parameter to find the result. For each object, information was derived average NDVI (Normalized difference vegetation index), land, WM (water mask). Then the objected image linked to the class object and classification link was stored. From DEM (digital elevation model) was generated slope data layer because the slope is an essential topographic factor that guides the flood potential of spatial areas. The settlement, flood rage digital elevation model, flood map, land cover, and the road used to model appropriate location for flood shelter. In ArcGIS model builder flood shelter and flood hazard model developed. To categorize the extent of flood object-based GIS and RS used.

The result showed that flood shelters suitability analysis and Flood hazard mapping are vital essential elements for decision-makers, a planner inappropriate land use planning and using of satellite RS and GIS is the suitable potential to analyze and provide required results. The total flood inundated area in Sindh province was 7579 km^2 (965 km^2 in Shikarpur district, 667 km^2 in Khairpur district, 838 km^2, in Naushahro Feroze district, 306 km^2 in Ghotki district, 1013 km^2 in Larkana district, 788 km^2 in Sukkur district and 3002 km^2 in Jacobabad district). Also, it showed that a very high flood hazard area (6216 km^2) out of a total area of 46138 km^2 of Sindh province and 1369 km^2 region specified to below flood hazard prone. Finally, the 2010 Sindh province flood in the history of Pakistan has described the unfortunate environmental catastrophe. A flood event is a natural disaster that cannot stop. Still, the Risk of Flood will reduce, and flood mapping via remote sensing and GIS cane useful for disaster preparedness like emergency response [17].

The flood risk assessment and flood hazard in the Chamoli district of India via the application of GIS and satellite remote sensing has studied. Chamoli district is one of the most significant regions of India , and the elevation range in this district is from 800-8000 m. The maximum land-use area is covered by agriculture, and forest. The goal of this research paper was to determine flood hazard and flood risk assessment at the level of the landscape via using satellite imagery from 1974-2013 in the District of Chamoli, Uttarakhand, India. Also, this paper had two aims: the first one was to prepare land use map on 1/50,000 scale and vegetation type via using satellite imagery (Landsat data) in both seasons (dry, wet) with 30 m spatial resolution. The second one was risk assessment, and flood hazard was absorbed in the regions of Himalayan for management and protection planning.

The material has used Landsat satellite imagery data, ERDAS imaging ver. 9.2 feather overlap function for image mosaic, GIS for the specification of Flood inundated areas. The method has used dark pixel subtraction, histogram equalization, haze correction, noise correction, image contrast, and line striping for satellite imagery, environmentally or radiometrically correction. The closest neighbor resampling method had used for the processing of satellite images. Furthermore, Landsat imagery is changed into FCC (false-color composite). DEM is used to calculate flood-prone areas and flood frequency. The aspect and slope were produced to specify the vulnerability of flood risk and hazard assessment, according to DEM. The study area (8030 km^2) had extracted by using the district boundary. The aspect and slope maps were intersected with land use/ vegetation map. The intersected land use/ vegetation, aspect, and slope maps were generated to find out the flood risk, hazard and vulnerability in the study area.

The result of this research paper showed that GIS and Remote Sensing techniques are best method to classify the flood event extend because Flood is a natural disaster. We cannot stop this natural phenomenon, but we can be minimalized and reduce the impact of a flood event. For flood risk and hazard assessment in this research, land use/ vegetation map at the level of landscape type was used and it was the main input for this study. Besides, land use/ vegetation type map was prepared using satellite data (Landsat) and techniques of on-screen visual interpretation. So, land use/ vegetation type maps had classified in eight classes (barren land, forest, snow, agriculture, scrub, settlement, and water body). The maximum area was covered by agriculture 19.14 % (1537.00 km^2), waterbody 12.78 % (1026.00 km^2), forest 33.77 % (2712.00 km^2) and snow 12.95 % (1040.00 km^2). Also, River cross-sectional decreased, and Alaknanda river depth was decreased from 35 m to 11 m. high erosion of soil specified in the upstream of the basin.

Furthermore, affected areas were classified (high, medium, low) according to vulnerability and flood hazard; for preparation of flood risk and hazard maps, flood frequency map was generated from 1974 to 2013. Finally, it suggested: for flood risk assessment and management, the foremost step is flood risk mapping so that this step will be essential for urban planning and environment [18].

The purpose of this research is to perform an assessment of flood vulnerability for Flood prone zone within the flat river low-lying valley of the DEP river watershed via using of Geographic information system (GIS) and Remote sensing. In this research paper, the following objectives, as a result, were achieved:

1.Evaluation of flood spat of habitations.

2. Assessment of Flood spat on the land uses.

The methodology adopted involves merging of RS analysis for ERDAS image 9.2 and Arc GIS 9.3 for GIS analysis. Satellite imagery data, such as land-sat ETM had downloaded from Global land cover website for present study. Finally, the research results, it was observed that the most flood-affected activity was agriculture with an area covered from 68.82km2 to 146.10km^2 for 2-year to 1000-year return periods.

In general, areas close to rivers should have prohibited for cultivation during the rainy season or any other activity during the rainy season [19].

The techniques of RS and GIS for Assessment of Flood Hazard zone at the Subarnarekha river basin, India has been applied. The mention River located in the East part of India, this river basin covers 20610 km^2 and flowing on the three states such as West Bengal, Orissa Jharkhand & Subarnarekha. The work has based on both primary data (Geology, Soil, Topo sheet, DEM, Landsat 7ETM+) and secondary data like GPS survey. Also, It was used different software like Arc GIS, EARDAS, and Microsoft office for creating the final risk map. The methodology ware adapted using MCE (multi-criteria evaluation) technique. For running MCE flood causative factors such as soil type, slope, elevation, geology drainage density rainfall, and land use has weighted and developed. Flood hazard map was generated and used appropriate feature class for different class. weighted values via technic of weighted overlay was calculate in Arc GIS 10.1 Model Builder. Landsat-7 ETM+ data applied in EARDAS software for supervised classification to creating land cover/land use of the area. This study aimed to determine a cost-effective method to produce a hazard map of flood porn areas in the Subarnarekha river basin via using GIS technology, and regulated Flood inundates area zoning to assess the damage. Also, it had founded a settlement, coastal ecosystem, and agriculture land vegetation is more affected due to Flood. Flood hazard and slope are opposite relations, and higher area slope has less affected the flood hazard and lower slope area; it has higher affected the flood hazard. The final flood hazard map divide into five class; Moderate, High, Very High, Very Low, and Low. The main findings of this work; the downstream part of the Subarnarekha river basin is high to very high flood hazard risk. West and East Singbhum district in Jharkhand and West Medinipur District in West Bengal was totally under the High flood hazard risk zone [20].

The Flood hazard and risk assessment of lower sub-basin, Ethiopia via application of Geographical information system, and Remote sensing had studied. Awash sub-Basin is located between 100 33' to 120 15' N latitude and 390 51' to 410 49' E longitude: in this sub-basin, the slope ranges from 0 to 63.38 degree and it's one of the largest and main rivers in Ethiopia. The rainy season in Ethiopia is between June and September, and 80% of the rains are received. This study aimed to assess flood hazards and risk of lower Awash sub-basin via using techniques of Remote sensing and GIS. Flood factors (elevation, slope, land use/land cover, drainage density) were computed for flood hazard analysis by the Weighted overlay method. The Methodology adopted for flood risk assessment was the following materials: 1.profeil work: Downloading images, base map preparation, georeferencing, projection, and secondary data collection, 2. fieldwork: covered land cover type and agroecological zones in sub-basin. During the field survey, the GCPSs (ground control points) taken and other field data collected for assessment of flood porn areas, soil type, land cover/land use, topography. 3.post fieldwork: In this phase, Elevation, soil, Slope, land cover/land use, and drainage density were used to model the flood risk and hazard mapping of Lower Awash Sub-basin using satellite Remote Sensing data and GIS technology. Assessment of flood risk was done for mention basin using flood hazard layer and the two elements at risk, namely population, and land use. In this research paper, the following materials (Hardware's and Software's) has used:

-Different satellite imageries such as Land Sat, SPOT, SRTM, DEM 90meter

-Topographic maps at 1:50,000 scale and Base maps (Land use land cover in hard and soft copy).

-Laptop computer with some software such as ERDAS IMAGIN 9.1, Arc GIS 9.3, IDRISI-32, Arc Hydro 9.3, Global Mapper 8.3.

- GPS and Digital Camera.

-Field observation & collection format.

In the result of the field survey and literature, the flood causative factor (soil type, slope, drainage, elevation, and land cover) has specified. Used the flood hazard layer and two elements at risk (land use, population) for assessment of flood risk because these two elements (sensitive land and persons) mostly located in flood hazard areas. The main finding, according to the map of flood risk, had estimated that 1,358,520 ha (59.33%), 231,881ha (10.12%), and 699,305ha (30.54%), of the study area had exposed to high, moderate and low flood risk. The analysis showed that study area high flood risk level faced such as (93.73%) cultivated land, (62.66%) grazing land, and (94.87%) settlement area. Downstream of the Awash sub-basin (Afambo woredas, Aysayta and Mill) were within very high flood risk. In the lower slope, the Risk of Flood was high, but in the more upper hill, the risk was low [21].

The assessment of flood risk via application of Geographic information system and Remote sensing on the downstream of Gombe Petropolis areas of Nigeria had studied. Gombe Metropolis is Capital City, located at the center of Gombe state, and it has a boundary with Kawada, Akko, and Yamaltu. Also, it has annual 650-1000mm rainfall within 650-1000mm. The purpose of this study was to test the flood risk nature on the main downstream areas of Gombe metropolis and specifically investigate the specific change of land cover/ land use type in various regions of residential with affirmation on the density of construction in several floodplains area. Further, zones of flood risk were found out and developed a flood risk map into Gombe Metropolis. Also, be able to find the flood risk factors in Gombe metropolis for substantial built-up of environment and engagement of floodplains in the downstream areas. Hence, founded two cause of flood risk hazards such as human activities(vulnerability) and natural activities. Finally, specific sustainable flood control measures for affected areas recommended.

The Methodology used application of Remote Sensing and GIS for developing urban areas in addition to creating a flood risk map of the main downstream areas of Gombe metropolis. Further, to specified land cover/ land-use change from 2003 to 2014. The Satellite image data supplies to hold flood disaster information of land cover and cheapest than traditional methods. The material used, such as GIS, the land sat 7, and 8(ETM) images of 2003 and 2014 with 30m resolution, for image process ERDAS Imagine (Image processing software) was used, Topographic map. The result of this research paper showed that in recent years flood risk has been increasing in the metropolis. Bare land 22km^2, rock surfaces 8.7km^2, vegetation area 3.4 km^2 has decreased between 2003 to 2014, but the cultivation area has increased by 7.7 km^2 (from 54.6 km^2 to 62.3 km^2). Also, the residential area sealing rate was absorbed as high that was the essential flood vulnerable areas in the metropolis. Land use/ land cover change has a critical point for runoff and Flood in the city. However, the flood-prone area as 50m buffer zone that found a lot of buildings has located in Flood inundated area such as MUAK (0.49 km^2), GRA/GAB (0.39 km^2), UF (0.30 km^2), BAR (0.52 km^2), TW (0.43 km^2) and totally within 50m buffer 3.2 km^2 building coverage located. In addition, flood risk index appointed that BAR is very high flood risk while GAB /GRA, DAW, TW, and PAN areas within the high flood risk zones also local regions such as JEK, JAN, BOL, MUAK, MAD and HERWA within moderate flood risk zone. Finally recommended residential area located within 50 m buffer from the streams should remove to come sustainable mitigation of flood risk in Gombe metropolis [22].

3. THEORETICAL MODEL

These objectives of this chapter are to provide the general information about climate change, the impact of climate change on the environment, flood, types of floods, flood hazard, flood risk, vulnerability, GIS, RS and historical flood disasters on a global level.

3.1. Introduction

Flood is an unusually high stage of a river flow which occurs due to meteorological combination caused by a runoff from rainfall or melting of snow in large quantities to be confined to the average river or stream water elevations.

Flood is a type of metrological disaster and one of the most comment global hazards that affects our environment and sensation system besides affecting the lives of people and their livelihoods. According to the WFO organization, flood is defined as the existence of waterbody in areas which are usually dry and flood disaster is an amount of water which exceedingly interferes or disrupts social and human activity due to water level increases which has a major impact on the well-being of human lives. Massive increases of water level in the river, lake, reservoir, stream or coastal region, dam, and any case where land surface usually not covered by water become covered by water [23]. Actually, flood is water overflowing onto the often-dried land surfaces. Flood has different occurring cases such as heavy precipitation, fast snow melting, levees or breaking of dams. In addition, flood may only happen with a few inches of water, or it may cover a building up to the roof top. The most widespread and common of all weather-related natural event is flood. Flood doesn’t occur in specific places but can happen anywhere in the world where there is a receiving of precipitation. Nowadays, one of the most common death causes per year from high level natural phenomena is flood. The impact of flood apart from human death is that it can devastate and damage homes, agriculture, and crops. Besides these damages, flood can displace families, livestock’s and pets, as well as disrupt business and life cycles. Indeed, flood condition or occurring situations are changeable for example: flood happens as a result of prolonged rains, severe thunderstorms, inadequate drainage or failure of levees, spring snowmelt, and the collapse of dams. The flood event impact can be local such as small communities (affecting neighbor hoods) or very large such as river basin or many states or cities. Some flood events develop slowly - giving time to evacuate and prepare - while others such as flash floods can quickly expand, even in moments. While flood cases cannot be prevented, a phase can be taken to minimize injury or prevent loss and accelerate the process of recovery; for flood controlling we have structural and non-structural measures. These two measures can attempt to keep related hazards and floods away from the environment and humans or decrease the level of risk [24].

3.2. Flood types according to causes and sources

Usually the outcomes of floods are from a mixture of hydrological and meteorological extremes, such as extreme flows and precipitation. Flood has different types according to the duration of precipitation and the affected area size [23]. The bellow table showed the flood type by cause.

Table 3.1. *Flood types and causes (Adapted from European Region health effects and their prevention report WFO,2013:17).*

Cause	Example
Heavy or intense rainfall	Slow-onset flood (fluvial), Flash flood (rapid onset), Pluvial or surface water flood affecting sewers and urban drainage, Groundwater flood.
Thawing of ice	Glacial meltwater, Snowmelt
Dam failure	Dam break, Dam overtopping
Tidal wave or wave extremes	Storm, Tsunami

Although they can happen as a result of human activities such as development and unplanned construction in floodplains or dam cracking and embankment as a result of weak planning without the observation of building codes. In addition, in most regions of the globe, humans migrate from rural to urban areas. Flood categorizations and descriptions differ and are based on a source's combinations, impact and causes. Based on this composition, floods can be usually specified into fluvial (river) floods, pluvial (overland) floods, groundwater floods (fracture of artificial water systems), and coastal floods. Flood characterized to the urban-flood are slow rise-flood, flash-flood, semi-permanent-flood and mostly flood based on the speed [25]. The table below is a description of the summary of flood by type and causes.

Table 3.2. *The types and causes of floods event (Adapted from World Bank, GFDRR Guide for the 21st Century, city and flooding, 2003:58).*

Types of flooding	**Causes Naturally occurring**	**Human induced**	**Onset time**	**Duration**
Urban Flood	Coastal, Fluvial Groundwater, Pluvial, Flash	Saturation of drainage and sewage capacity Lack of permeability due to increased concretization Faulty drainage system and lack of management.	Varies dependin g on the cause	From few hours to days
Pluvial and overland flood	Convective thunderstorms, severe rainfall, breakage of ice jam, glacial lake burst, earthquakes resulting in landslides.	Land used changes, urbanization. Increase in surface runoff.	Varies	Varies depending upon prior conditions
Coastal (Tsunami, storm surge)	Earthquakes, Submarine Volcanic eruptions Subsidence, Coastal erosion	Development of coastal zones Destruction of coastal natural flora (e.g., mangrove).	Varies but usually fairly rapid	Usually a short time however sometimes takes a long time to recede
Groundwater	High water table level combined with heavy rainfall. Embedded effect	Development in low-lying areas; interference with natural aquifers.	Usually slow	Longer duration
Flash Flood	Can be caused by river, pluvial or coastal systems; convective thunderstorms; GLOFs.	Catastrophic failure of water retaining structures. Inadequate drainage infrastructure.	Rapid	Usually short often just a few hours
Semi-permanent flooding	Sea level rise, Land subsidence.	Drainage overload, failure of systems, inappropriate urban development, Poor groundwater management.	Usually slow	Long duration or permanent

Flood disaster has many types and kinds according to causes and sources. Some important explanations on flood phenomena according to sources and causes are listed below:

River flood is dependent on the vast water level in streams, rivers, canals, mountain streams, lakes, containing floods due to snow melting. Excess water flows into rivers and flows into adjacent low-lying areas of vicinal lowlands or floodplain areas.

Rain flood is kind of flood which is associated with the area flooding directly from precipitation (rain and snow), so this kind of flood may contain huge water or stream water in non-urban areas. The flood is associated with flooding an area with water which is coming directly as a result of rain or melting snow. This may include urban stream water or high water in non-urban areas. Rain flood produced from rainwater and is coming from melted snow, ice and rain.

Flash flood is a kind of flood which has the most harmful impact on human and the environment because it happens fast with increasable speed and power. The destructive power of the flash flood is unpredictable. Actually, a flash flood occurs in a short amount of time with the rapid rise of water in dry creeks or riverbeds and the human ability for forecasting this event is weak, because flash floods suddenly happen, causing an uncertainty in time for any preventive action. The area which has a high densed population are under the high level of risk from flash flood events. The construction of houses, residence buildings, driveways and highway parking lots enhance runoff via decreasing the extent of precipitation absorbed via ground. That time this runoff increases the potential of the flash flood. During massive rain, the speed and power of wind can devastate buildings and flood roads. Little spots, thus, such as underground parking garages, underpasses and undergrounds can become injuring and death traps. The neighboring areas of the river are at the highest level of flash flood risks, especially during spring through heavy rain fall. When the river water at this season suddenly releases a flash flood which could occur in the downstream areas, it will be a massive risk for the ecosystem next to the river [24].

Urban Flood is a type of flood which is caused by a precipitation process especially by rain that falls on bare land area and its impervious surface. Nowadays urban flood damage is a concerning subject for both developing and developed nations, because the enormous negative impact of urban flood to the environment is increasing day by day and urban flood is one of the most common causes of environmental degradation. It is hence essential to know the cause of and side effect of several types of flooding which occur in an urban area. The urban environment is subject to the same natural forces as the presence of urban settlements deteriorates the problem. Also, we can see the limit level of the forest and open soil area in the urban areas where these element limitations can increase the flood effect on the urban area and be a complex problem for our environment.

Flood causes in all river system are less or more the same [27]. Generally, the causes of urban flooding is snowmelt, flash flood, heavy precipitation, over-bank flow, river flood, lack of proper drainage systems, and unplanned development [28]. The risk of urban flood is damages to the housing, building, roads, and drainage systems apart from being a danger to human lives and having a direct impact on economic loss such as unemployment and industrial damages. Also, it has a side effect on the environment including pollution of water resources, air pollution and degradation of ecosystems. So, it is essential to understand how to make strategic plans for urban flood disaster and how to mitigate the impact of this phenomenon into the environment.

3.3. Disaster

Disaster is a result of a situation which comes from human-enforced conflict or environmental phenomenon that produces personal injury, stress, economic disruption and physical damage of high magnitude catastrophe which causes an intensive negative impact on goods, human services, community capability and the environment. It is essential to remember that disaster is not by itself a phenomenon though it is referred to as such via the event which caused them. Example, earthquake is a kind of natural disaster; if it does not negatively impact the building with the populated area, it does not count as a disaster or as a short disaster which is a severe disorder in the functioning of a society or community [29]. Furthermore, a disaster is an outcome from the combination of vulnerability, hazard and insufficient measures or capacity to decrease the chances of risk potential. Generally, disaster is divided into two-parts: first one is a natural disaster and the second one is a man-made disaster.

3.3.1. Man-made Disaster

The man-made disaster is a kind of disaster due to human negligence such as war, complex emergencies/conflicts, environmental degradation, transport and industrial accidents, explosions, pollutions, dam failures, displaced population, and famine. These man-made or technological disaster is caused by humans unintentionally or intentionally or due to the lack of concentration or negligence. The table below is a description of the summary of the types of man-made disaster.

Table 3.3. *Types of Man-made disaster.*

Man-made Disaster		
War Disaster	**Environmental Disaster**	**Technological Disaster**
Conflicts	Ecosystem degradation	Transport &Industrial accidents
Bomb blast, Suicide attack	Water, Air, Soil pollution	Factory explosions
Genocide, Disease, Epidemic	Deforestation	Nuclear radiation
Terrorism	Desertification	Toxic wastes

3.3.2. Natural Disaster

Natural disaster is a kind of disaster caused due to natural phenomena and can be divided into three types: geological disasters, hydrometeorological disasters, and biological disasters. Geological disaster is a result of earth phenomena or process which causes injury, loss of life, economic and social disruption, property damage, or degradation of the environment. A geological disaster includes landslides, volcanic eruption and earthquakes. Hydrometeorological disasters consists of meteorological and hydrological and is as a result of natural phenomena or process of atmospheric event which may cause injury or loss of life, property damage, environmental degradation or economic and social disruption. A hydrometeorological disaster includes floods, avalanches, droughts, storms, and wave surges. Biological disasters are a result of biological vectors or from organic origins. A biological disaster such as toxins, disease, human/animal epidemics, bioactive substances, and pest attacks may cause injury, loss of life, social and economic hazard and environmental degradation [30]. Crisis and disasters are classified in different ways and classes according to the UN (united nations) office for Disaster Reduction. Disasters are classified into three categories: the first one is a major disaster such as volcanoes, earthquakes, tremors and floods; the second one is a visible disaster such as an epidemic and famine; and the third one is a sudden disaster such as nuclear or industrial disasters or those events which are in advance the results of development of technology. The table below is a description of the summary of the types of a natural disaster.

Table 3.4. *Types of Natural disaster.*

Natural Disaster		
Geological disaster	**Hydrometeorological disaster**	**Biological disaster**
Landslides	Floods,	Toxins
Earthquakes	Avalanches	Disease
Volcanic eruption	Droughts	Human/Animal Epidemics

3.4. Risk

The eventuality of damaged subsequences or awaited losses (property, injuries, deaths, subsistence, environment damaged, or disrupted economic activity) as a result of interactions between human-induced or natural hazard and vulnerable situations [31], or risk, is the probability that an event will happen given the vulnerability and hazard [29]. Therefore, the risk of disaster is the result of the three compound elements which are Risk, Coping Capacity and Vulnerability [32]. This interaction is illustrated in the following formula: (Adapted from ISDR, 2004:42).

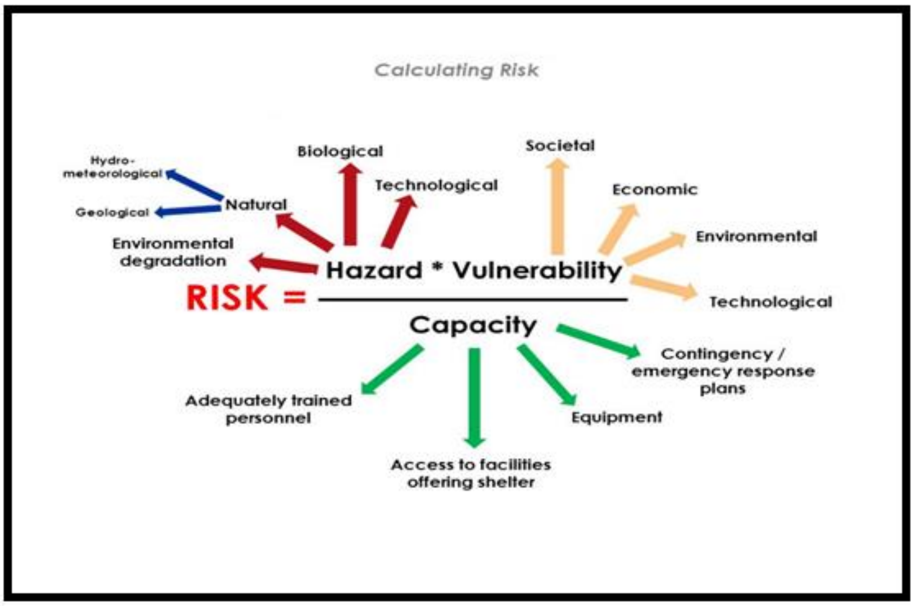

Figure 3.1. *The Formula of Disaster Risk.*

3.5. Flood Risk Management

The decision-making procedure under uncertainty is called flood risk management. This includes a deliberate selection of flood risk management plans, measures and strategies designed to reduce flood risk. Flood risk management is the proceeding of data and collecting information appraisal of options, assessment of risk, evaluating alternatives and decision making, reviewing decisions and implementing to mitigate, control, redistribute the flooding risks, and is a necessary action for environmental protection. For providing appropriate protection in case of flood events, it has long been identified that Risk is a primary focus or consideration [33]. However, a human cannot eliminate or control flood events, but can only mitigate the event of flood; due to this, flood mitigations are preferred to flood control. Thus, in general, we have two methods or measures for flood risk mitigation which are structural measures and non-structural measures [34]. Here are some examples of flood mitigation measures:

Flood non-structural measures such as flood forecasting, flood warning/monitoring, community awareness, community preparedness, emergency response plans, flood insurance, post-flood recovery and reconstruction. Also, using floodplains must be done sensibly and should not be used for living but used for agricultural purposes only.

Flood structural measures are River channel improvements, Detention basins, Levees or dikes, Upper watershed management, Flood diversion channels, and Flood control dams. In addition, it is the usage of structural technology intensively such as the protection of soil from erosion, of land surface reshaping, increasing of infiltration and delay of flow or runoff snowmelt or rain waters [34]. The above approaches are useful and one of the best methods for controlling the level of damage and keeping humanity safe from flood hazards [24].

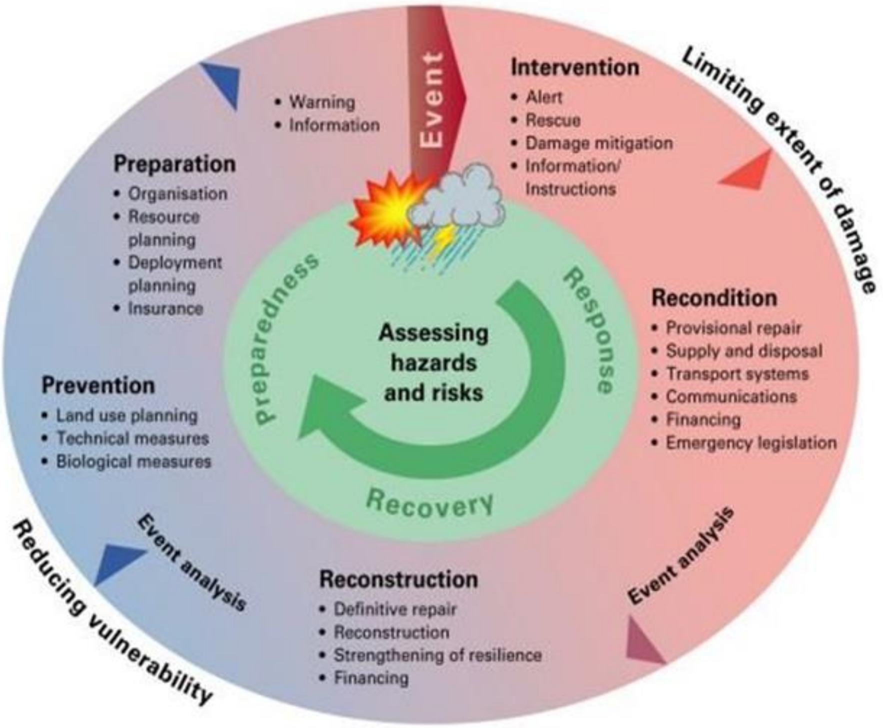

Figure 3.2. *The cycle of Risk Management (Integral Risk Management Cycle, FOCP 2003).*

3.6. Hazard

A Potentially harmful physical event, human activity or phenomenon, which may cause the injury or loss of life, social disruption, environmental degradation, economic damage, and property damage. There are two types of Hazard as follows: Man-Made Hazard and Natural Hazard. Also, natural Hazard can be further divided into three class, geological (tsunamis, volcanic activity, earthquakes), biological (epidemic diseases), and hydrometeorological (drought, Flood, tropical storms) origin. Man-made Hazard can be induced as a result of human activity processes (fire, climate change, environmental degradation, technological hazards and mining of non-renewable resources). Man-made Hazards can be sequential, single or combined in their effects and origin [31], and is known as the occurrence of the potential of a man-made or natural disaster/event which has negative subsequences. A hazard is a terrible event or condition that has potential or threat for causing damage to property, injury to life, and damaging of the environment.

3.7. Vulnerability

Vulnerability is the capacity of systems, structures, or persons to be damaged by a hazard. Vulnerability is the inability to take risks or respond in the event of a disaster.

For example, humans who are living in the plains area are more vulnerable to flood events than humans who are living in the higher areas [35]. Flood events has four types of vulnerability such as Economic Vulnerability, Social Vulnerability, Physical Vulnerability and Environmental Vulnerability. The vulnerability formula is explained below:

$$Vulnerability = \frac{Capacity+Risk}{Hazard} \tag{1}$$

The last few decades show that the rate of rapid urbanization is one of the most significant, according to WHO 2000 report, and by the year 2025, approximately two-thirds of the world's population will live in cities. The poses of rapid urbanization are one of the main challenges of our environmental safety due to rapid urbanization as human vulnerability increases toward disasters such as floods. Also, these quick urbanization increases environmental degradation level day by day [32].

3.8. Disaster Management

Disaster management term is a collective or common term that includes all aspects of responding to disasters and emergencies both after activity and before activity. It is possible to control the source of danger and Hazard of technology can be prevented. Natural Hazards can be reduced by some structural measures and non-structural measures. In addition, environmental monitoring and Hazard are linked closely. Disaster assessment (social, physical and ecological impacts) is a crucial point in disaster management which must be considered during the term of disaster management [36]. Disaster management is a method that involves processes or activities after, during and before a hazardous event and are designed to reduce or prevent the disaster impacts and side effects on the environment besides recovering the losses of elements or processes [37]. The method of disaster management is mostly interpreted as a cycle comprised into four major phases: preparedness, mitigation, recovery and response that showed in the bellow.

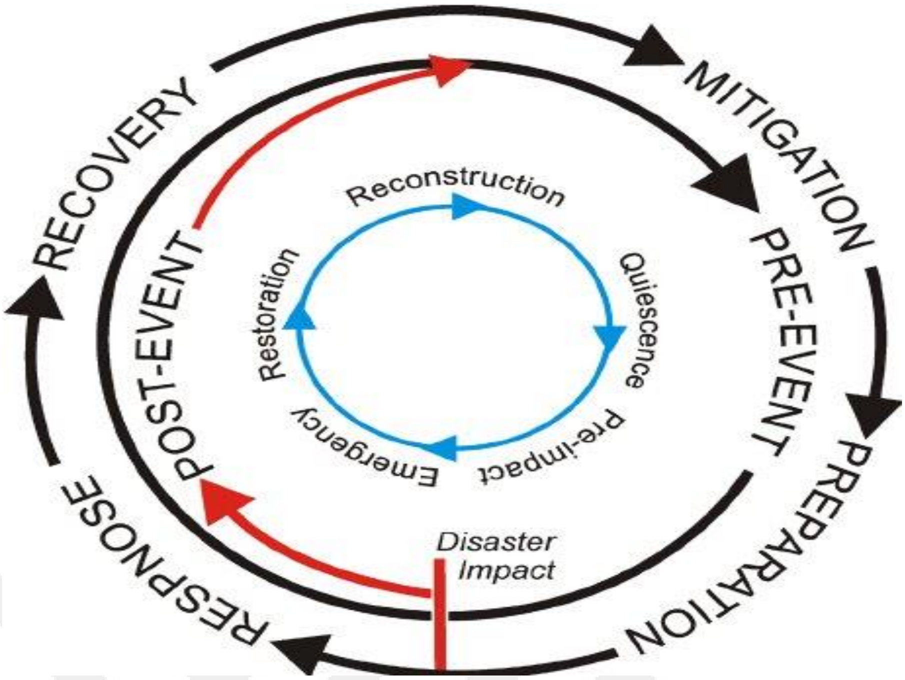

Figure 3.3. *The cycle of Disaster Management(Adapted from Alexander, 2000).*

- Preparedness- is the process of how to respond and plan. For example, emergency training/exercises, warning systems, and preparedness plans. Response - Efforts to minimize the hazards created by disaster. Examples are search and rescue, and emergency relief.
- Mitigation- is the process of minimizing the disaster effects. For example, zoning and building codes, public education about flood disaster and vulnerability analyses.
- Response is the process of endeavor working to minimize the created risks by a disaster. Examples are emergency relief and rescue and search.
- Recovery is the returning process of community to the normal situation. For example, grants, medical care, temporary shelter or housing.

3.8.1. GIS and Kind of GIS Data

GIS consists of two parts, the first one is Geographic, and the second one is the information system. Geography is the scientific study of spatial patterns and earth processes. Geography science seeks to recognize the distribution and location of people and physical events on the earth surfaces [38]. The information system is the combination of computer software, hardware, communication devices and people. Thus, the aim of the information system is providing information for those who need the information to perform analysis and to make decisions. GIS is one of the computer-based information systems which used to analyze and represent the geographic data digitally. GIS definition according to ESRI 1990 (Environmental systems research institute) is collection of software, hardware, people, and data to efficiently store, capture, analyze, manipulate and display all forms of referenced geographical information.

GIS are an integrated software parcel mainly designed for use with geographic data that makes a wide range of information handling functions [39]. The GIS component which includes people, data, hardware, software and device (computer system) is shown in the figure below and.

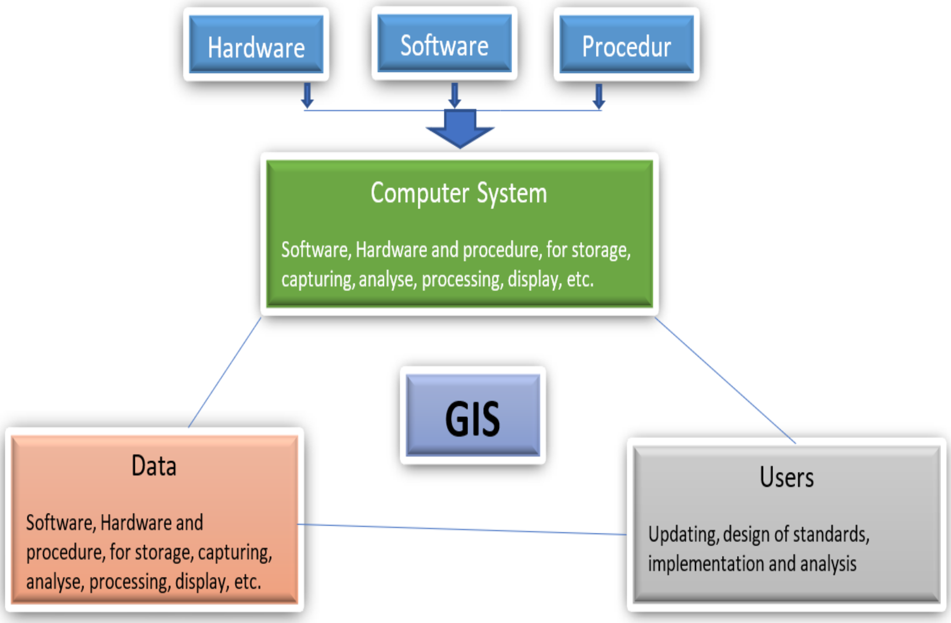

Figure 3.4. *Main components of GIS(Adapted from ESRI,1990).*

GIS has two kinds of data, which are Raster data and Vector data, and all geographic information can be stored in the format of Vector or Raster. Graphical data can be stored in a raster or vector format [40].

3.8.2. Usage of GIS

By using GIS technology, we can understand what has happened, what is happening and what will happen, because that location is essential in human lives. Using GIS technology, we can view, understand, question, visualize and interpret data or information in visual ways that will improve relationships in patterns which allows us to make better decisions. For example, meteorologists use GIS to understand the pattern of Flood, or of a hurricane in order to predict where and when they might occur in the near future. A city plan maker or planner can choose the best location for the hospital or new park via GIS technology so that is built in the place where they're needed. In addition, today GIS is the essential technology for our daily activities in our field. In general, GIS technology has differences in usage area such as Environmental science, Environmental engineering, agriculture, biogeography, ecology, oceanography, geophysics, political science, sociology, Engineering, Hydrology, climate change, disaster management, army and many more areas [41].

3.8.3. Application of GIS for Flood Determination

Flood is a type of natural disaster which is categorized as a hydrometeorological disaster and the yearly effects of flood risk on humans and the environment in different parts of the world are at high levels. Researchers and governments in most of the countries in the present decade has been trying to analyze and visualize the Risk of Flood via GIS technology as GIS has a wide range of usages and is one of the most important technologies which we use for water management especially Flood determination and flood hazard mapping. Mapping of Flood hazard, flood shelters and flooded prone area by GIS technology are primary steps for land use management before the occurrence of flood events in our environment. Some steps we can do in Arc-Map are preparing Slope, derange, Flow accumulation rainfall intensity, reclassifying flood condition factors, thematic map, weighted overlay of layers and finally producing a hazard map.

3.8.4. Remote Sensing and Kinds

Remote Sensing is generally taken from two words, Remote and Sensing. Remote means far away and Sensing means observing, believing or acquiring some information. Remote Sensing means providing or obtaining information about any objects or things from a distance which humans cannot reach and cannot touch. Remote Sensing in the world of geospatial science is the observation of the earth without any touch using sensor capacity from high above its surface. Definition of remote Sensing according to NASA: Remote Sensing is the measurement and acquisition of information/data on some properties of an object, material phenomena by a recording device not in intimate contact with features or physical [39]. Remote Sensing is the observation of environmental target objects from a distance away by a device or tools without touching the objects [42]. Remote Sensing is generally classified in two classes: first one is Active Remote Sensing which provides its own energy by itself (an example is Radar and Lidar), and the second class is Passive Remote Sensing, which is used for sensing the object, it uses natural source of energy such as the sun and the sun is the best source of energy for this type of remote sensing (an example is Optical Satellites). Furthermore, Active Remote Sensing has more advantages then passive Remote Sensing because it has the ability to obtain the measurement anytime but passive remote sensing just works during daytime (we are not able to see the object during nighttime) [43]. The figure below shows the two classes of Remote Sensing.

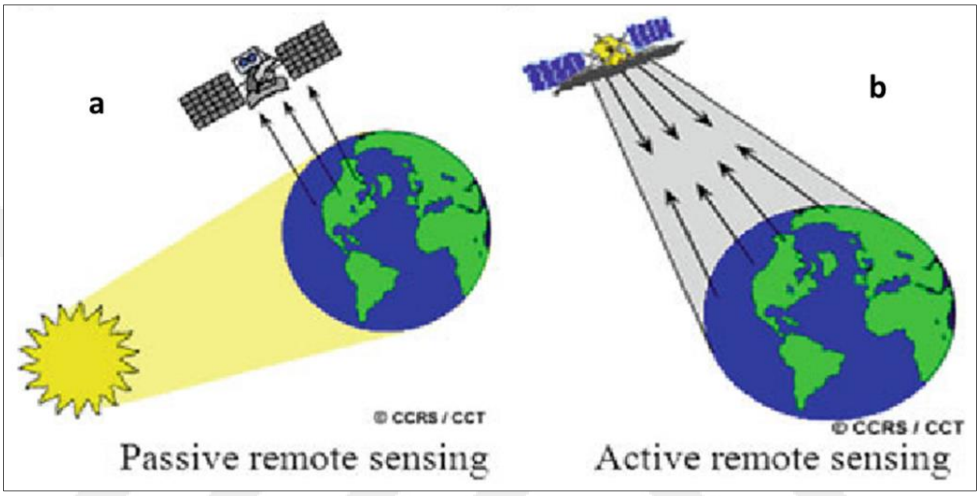

Figure 3.5. *Passive and Active Remote Sensing (Canada Center for Remote Sensing (CCRS)).*

Remote Sensing has a wide range of usage in different fields such as environmental monitoring, space exploration (Sun, Mars, Moon), Land use/Land cover, Agriculture, Deforestation assessment, climate change impact assessment, Metrological image assessment, Oceanography, Natural resources determination (Gold, Oil, Boron, Natural gas), Hydrology (groundwater and surface water level), Dams and reservoirs Investigation, City and Regional Planning, Traffic and Geology academic researches [44]. Accordingly, Remote Sensing has a lot of advantages in different parts of human life. Furthermore, the Elements involved in Remote Sensing are as follows:

- Illumination or Energy Source (A)
- Radiation and the Atmosphere (B)
- Interaction with the Object (C)
- Recording of Energy by the Sensor (D)
- Transmission, Reception, and Processing (E)
- Analysis and Interpretation (F)
- Application (G)

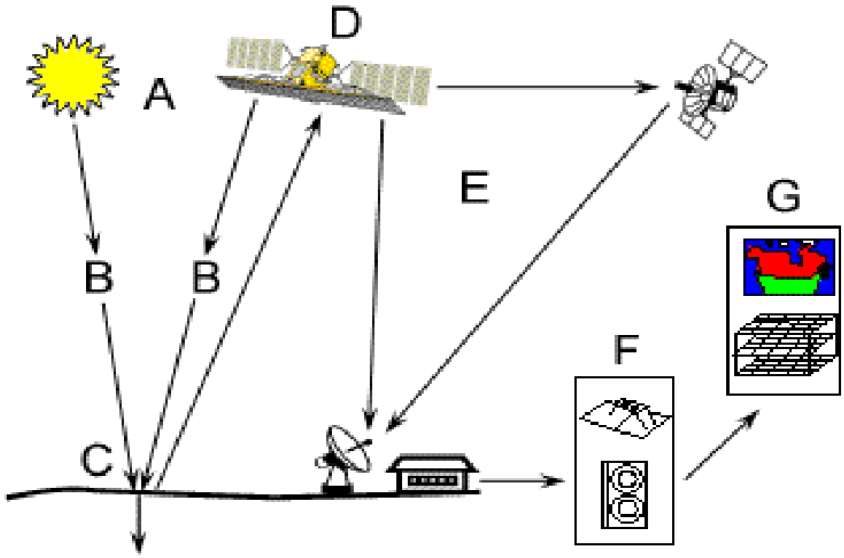

Figure 3.6. *Remote sensing System elements (Canadian Centre for Remote Sensing, Fundamentals of Remote Sensing).*

3.8.5. Application of Remote Sensing for Flood Determination

Today, obtaining information about objects which are on the earth are an easy way via Remote sensing technology, and this process of obtaining information is a result of the electromagnetic energy reaction with the purpose on the planet. Remote Sensing technology sensors has no direct contact with the observed event or objects, but it has indirect contact with objects. Electromagnetic radiation has played a mean function to carry information in Remote Sensing, and the output information as an image form and this image via image processing represents the information for us to decide about the event or objects [45]. So, today for Flood determination, Radar and optical satellites imager are used, and the results of both imageries are enough to manage flood risk and predicate prone areas in the future. For example, the calculation of some indices from satellite imagery provide the flood peak, floodwater and flooded area via the usage of some programs like ENVI and Erda's imaging. So, flood risk reduction in the urban area is needed for the use of remote sensing technology.

4. METHODOLOGY AND MATERIALS

The aim of this chapter is to provide the general information about methods, data that used for flood risk mapping, in addition general overview of the study area.

4.1. Study area Description

In This section of study area description is to give a general overview about Afghanistan and Kabul city; water, climate, topography, climatically zones, geography, geology, soil and land use/land cover.

4.1.1. Geography of Afghanistan

The Islamic Republic of Afghanistan is a landlocked country in the southwest of Asia. The Geographic coordinates of Afghanistan are between 33° 93' N (latitude) and 65° 70' E (longitude). The population of Afghanistan has been 38 million, according to the world population report of the United Nations report in 2019 [46]. The total area is 252972 sq. miles (652,864 sq. kilometers) [47]. Its neighbors Pakistan to the South and East, Tajikistan, Turkmenistan and Uzbekistan to its North, the People's Republic of China to its northeast and the Islamic Republic of Iran to its west [45]. Furthermore, Afghanistan's boundaries with these neighbors are as follows: Tajikistan 749 miles/1,206 kilometers, Uzbekistan 85 miles/137 kilometers, Turkmenistan 462 miles/744 kilometers, Pakistan 1,510 miles/2,430 kilometers, Iran 582 miles/936 kilometers, China 47 miles/76 kilometers, Total 3,436 miles/5,529 kilometers [46]. Afghanistan has 34 cities, the five largest are Kabul, Kandahar, Mazar-e-Sharif and Herat and Jalalabad. Figure 4.1 showed the location of Afghanistan.

Figure 4.1. *Afghanistan location in Asia Region(Adapted from https://earthexplorer.usgs.gov).*

Afghanistan is landlocked and has no coastline. However, it has many lakes and river basins, the main five of which are the Amu Darya river, the Harirud river, the Helmand river, the Northern river basin and the Kabul river basin. The Amu Darya river basin is the longest river in the central Asia region which has 1491 miles (2400 kilometers) long. This river forms the northern border of Afghanistan with Uzbekistan, Turkmenistan and Tajikistan and finally before discharging into the Aral Sea in Uzbekistan.

The second-longest river basin of Afghanistan is the Helmand river basin at 808 miles (1300 kilometers) long. Helmand river basin originates from Hindu Kush mountains, 25 miles (40 kilometers) west part of Kabul city and is separated from the Kabul river basin by the Unai Pass. Helmand river basin circulates in the southwestern part of Afghanistan and from there it leaves the country and enters Iran. The Harirud river basin is 404 miles (650 kilometers) long, and it circulates in the west of the country originating from Hindu Kush mountain range in central parts of the country and flowing to the west to the Herat city. Then, it leaves the country and enters Iran which further it makes the border between Iran and Turkmenistan.

The last water bodies of the country are the Kabul river basin which has a length of 285 miles (460 kilometers). This is the major river basin of Afghanistan circulating in the eastern part of the country. Kabul river basin has risen from the mountain range of

Hindu Kush and flows to the east of the country. It joins the river basin of Indus in Pakistan [48]. Afghanistan river basin showed in figure 4.2 in the bellow.

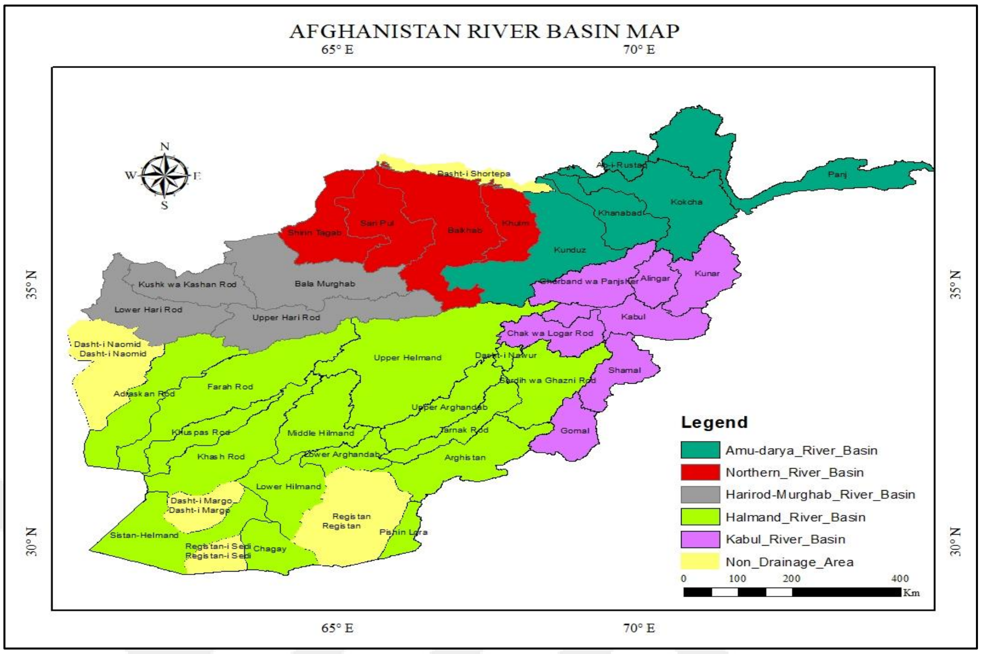

Figure 4.2. *Afghanistan's water bodies basin(Adapted from https://earthexplorer.usgs.gov).*

Afghanistan surrounded by mountain ranges and is a mountainous country. Afghanistan's main mountain ranges are as following; Hindu Kush mount, Baba mount, Suliman mount, Sefidkuh, Siahkouh, Tyrbnd Turkestan, Pamir, and Firoozkuh. The mountains of Hindu Kush are one of the main topographic features that mark Afghanistan which runs from the northeast to southwest of the country. In general, elevation in this range of mountains decreases from the northeast part to the southwest part. The Noshaq mountain peak is the highest point in Afghanistan and located in the northeastern part of Afghanistan which has 24557 ft (7485 meters) elevation. The Noshaq mountain peak is the 52nd highest peak in the world [49]. Hindu Kush's mount highest point is the Tiraj Mir peak which is 7708 meters high. In addition, the second-highest mountain's peak of Afghanistan is Shah Fooladi which is 5142 m high and located in the Baba mountain range [48]. The elevation of each peak elevation with its Latitude and Longitude is explained in the table below.

Table 4.1. *Afghanistan Highest Mountains peak (Adapted from Geo names, info@geonames.org).*

Name	Elevation	Latitude/Longitude
Noshaq, Badakhshan	7,482 m	23.435/71.84
Lunkho	6,872 m	36.78/72.416
Kuh-e-Bandaka, Badakhshan	6,812 m	36.179/70.983
Bada Tungi, Badakhshan	6,513 m	36.877/72.959
Koh-e-Tuloksa, Nuristan	6,435 m	35.866/71.081
Pir-Yakhha-ye Darah, Badakhshan	6,414 m	36.23/70.966
Koh-e-Belandtarin, Badakhshan	6,286 m	37.146/73215
Sakar sar	6,271 m	36.899/74.245
Qalah-ye-Sorkhi, Badakhshan	6,171 m	36.142/70985

Afghanistan's lowest point is the northern plain which has approximately 850 ft (260m) elevation. Besides, this region has vast fertile lands and makes up the country's greatest agricultural production as shown in the figure 4.3.

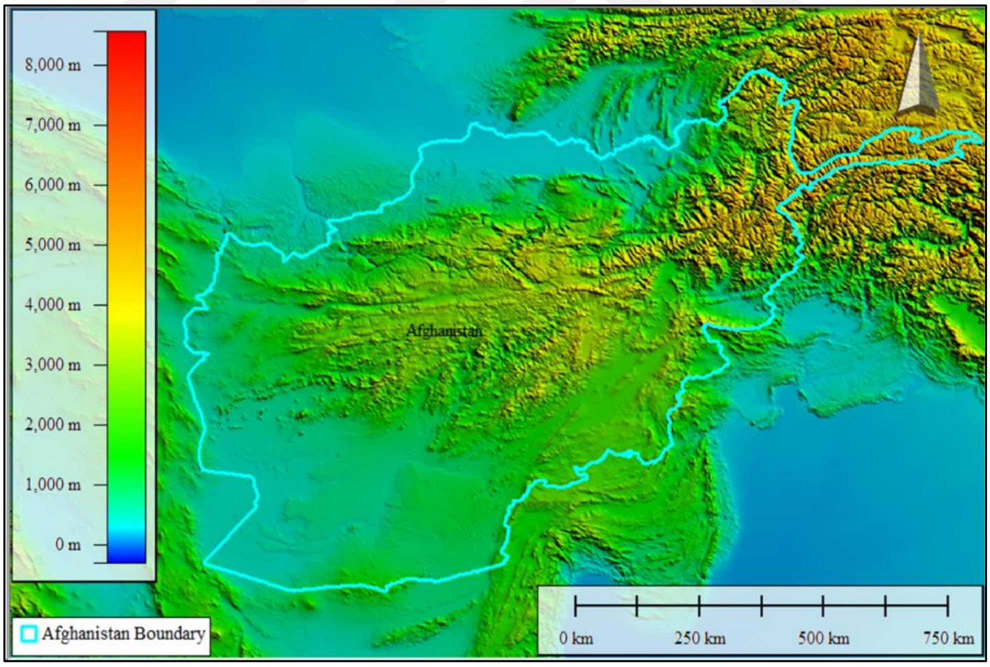

Figure 4.3. *Afghanistan highest and lowest Elevation (Adapted from Global Mapper).*

The climate in Afghanistan varies according to region and season. It changes from arid and semiarid climate with hot, sunny, dry summers to cold and relatively rainy winters and in spring it is highly wet and moist. The reason for these drastic changes is that Afghanistan is one of a mountainous country. The country's mountainous regions in the northeast of the country have subarctic with cold and dry winters. The southern part of the country, which is the arid plateau has the lowest precipitation and highest temperature, which extends into Pakistan and Iran. The fundamental reason for the variability of climate in Afghanistan is its altitude and location; for example, in the southern parts of the country because of high altitudes, the weather is mostly cold and because of their desert lands it is also dry. The far east of the country, however, is relatively rainy both in the winter and summer seasons, and one reason for it is Indian monsoon which affects the climate of the cities. In Afghanistan, as general amount of precipitation is low, desert or semi-desert lands are formed; but in eastern regions of the country, in some areas where it exceeds 20 inches (508millimeters) per year, while in the far east of the country (Nuristan and Kunar province) which these provinces have a close border with Pakistan it exceeds 40 inches (1000mm) [50]. The center-north part of the country and mostly the south part during the winter season which faces Mediterranean origin, as a result, that brings a bit of rain and snow, especially in mountains. In the spring season, especially in March, the rainfall increases, and it is often wettest month. While from June to September the rain amount decreases so much that it may never rain. Easternmost part, especially in the east of Kabul, due to the latest monsoon that affects India and Pakistan, rainfall amount is increasing, mostly in July and August. The temperature in the summer season can reach 120°F (49°C) in addition, mountainous region in the northeastern low-temperature range is from 5°F (-15°C) in winter to 32°F (0°C) in summer season [49]. The temperature range in the Wakhan Corridor is between 9°C (48°F) in the summer season and -21°C (-6°F) in the winter season. The monsoon that comes from the southeast of the country affects tropical masses of the air. Generally, it happens between July and September in the mountainous regions near Pakistan's borders. So, these air masses in the southern and central parts of Afghanistan, increase the causing of humidity and precipitation. The annually average amount of precipitation in Afghanistan, according to the world bank report in 2016 is 12.24 inches (311 mm) [51]. The Precipitation and water Sources are shown in figure 4.4.

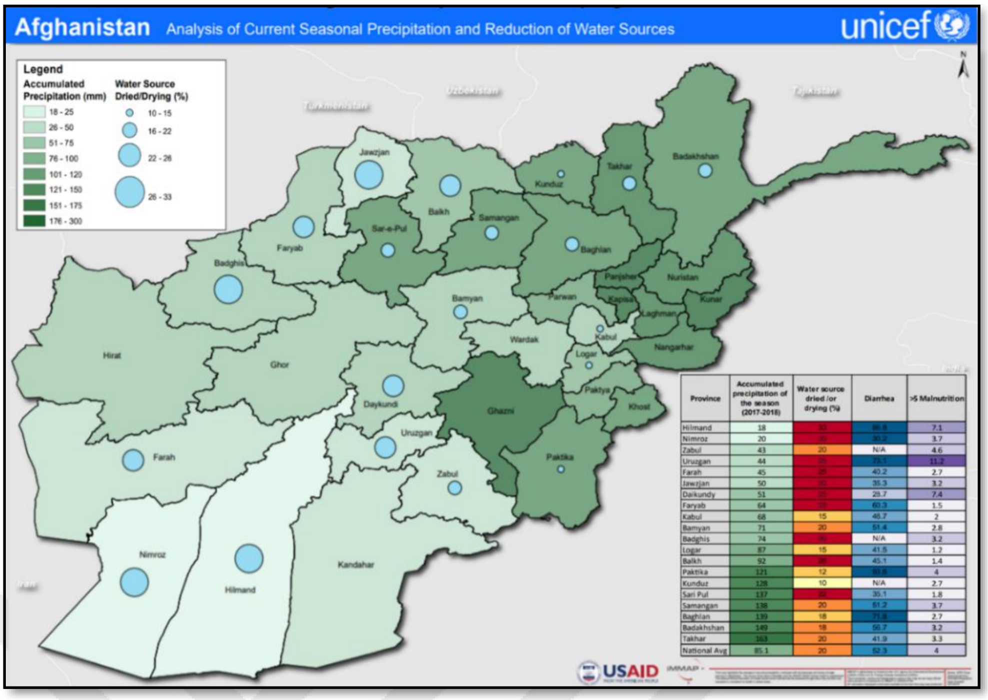

Figure 4.4. *Afghanistan Precipitation and Water Source Map (IMMAP,2018).*

4.1.2. Kabul City

The study area for this research is Kabul city which is the capital and largest city of Afghanistan located in the eastern part of the country. The geographic coordinates (DMS) of Kabul is between 34°31'41.27"N (latitude) and 69°10'20.39"E (longitude) and situated 1800 meters (5900 feet) above the sea level. Kabul city formation section being part of the Kabul province is divided into 22 districts. Kabul province has a 4585 square kilometers area. Kabul city is located in Kabul province and has a 1024 square kilometers area with a high population density. The total population of Kabul city was estimated at 4.860 million by Afghanistan National Statistics and Information Authority in the year 2018-2019 [47]. Location of Kabul City is shown in figure 4.6.

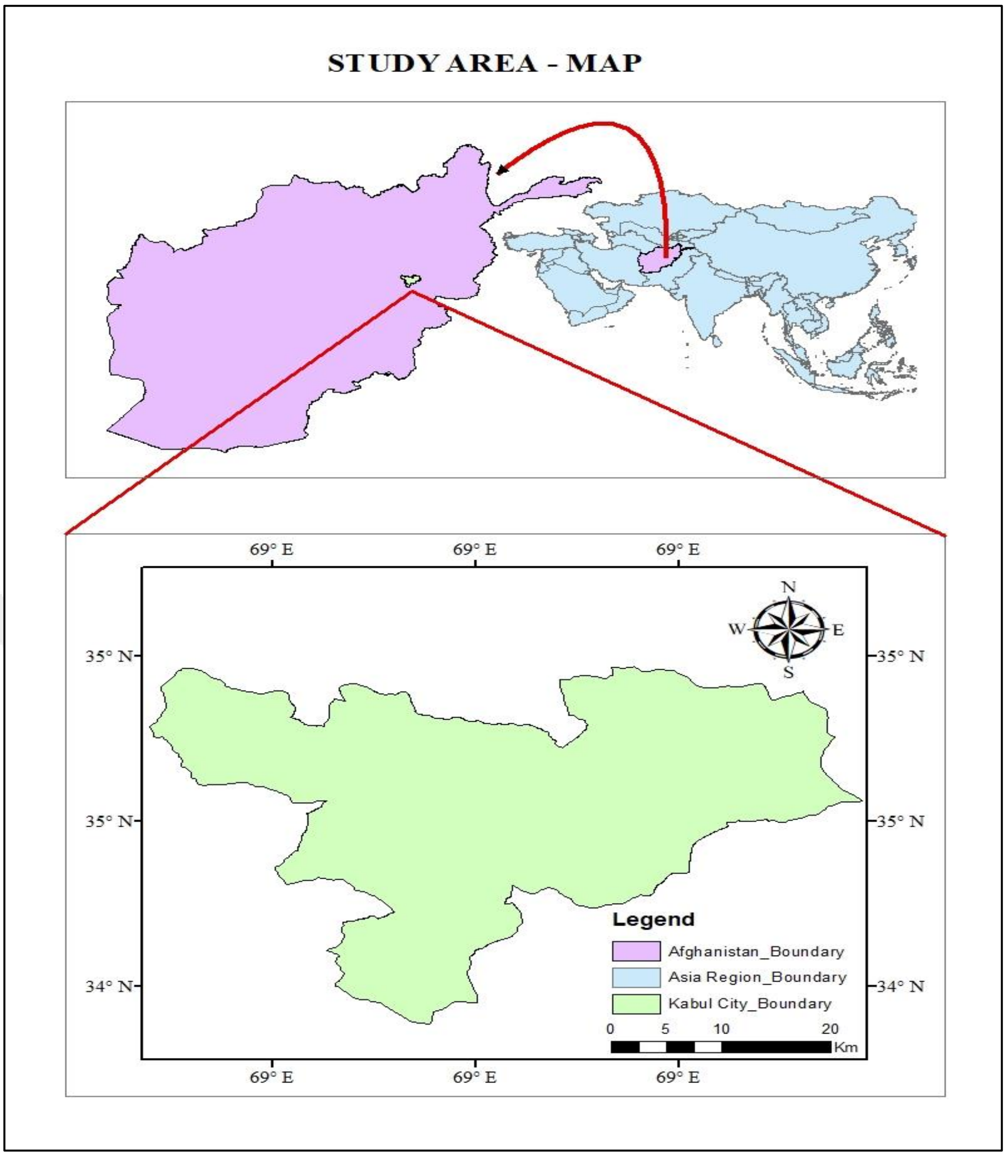

Figure 4.5. *The research Study area Map (Adapted from https://mapcruzin.com).*

4.1.2.1. Geography of Kabul City

Kabul city is in the east-central part of Afghanistan, in a triangular valley between the mountainous regions of Sherdarwaza and Asmayi with altitude 1800 meters (5900 feet) above sea level. Kabul city is the capital of Afghanistan and the largest urban area in the country. Kabul city is shaped by several districts of the Kabul province. Kabul city is surrounded by many mountains; Paghman mountain (Kuh Paghman) in the west, Qourugh mountain (Kuh Qourugh) in the southwest, Sherderwaza mountain (Kuh Sherderwaza), Asmayi mountain (Kuh Asmaye), Aliabad mountain (Kuh Aliabad) in the center, Safi mountain (Kuh Safi) in the northeast and the Bagrami, Shina, Lata-band, Tangi-Gharo are among the most important ones. Important Hill of Kabul is Bebe-Mahro

Hill, Maranjan Hill, Tajbeyk Hill, Qalibland, Kulola-Poshta Hill, which reduce land smoothness in the city. The highest mountain peak in Kabul is the Paghman mountain peak which has 4700 meters altitude, the other mountain peak altitudes in Kabul is around 2000-3000 meters. So, the rest flat area of the Kabul is a kind sedimentary soils (Sand, Silt, Clay) and its arable which form agricultural land for cultivation [52]. Kabul City Topographical map is shown in figure 4.7.

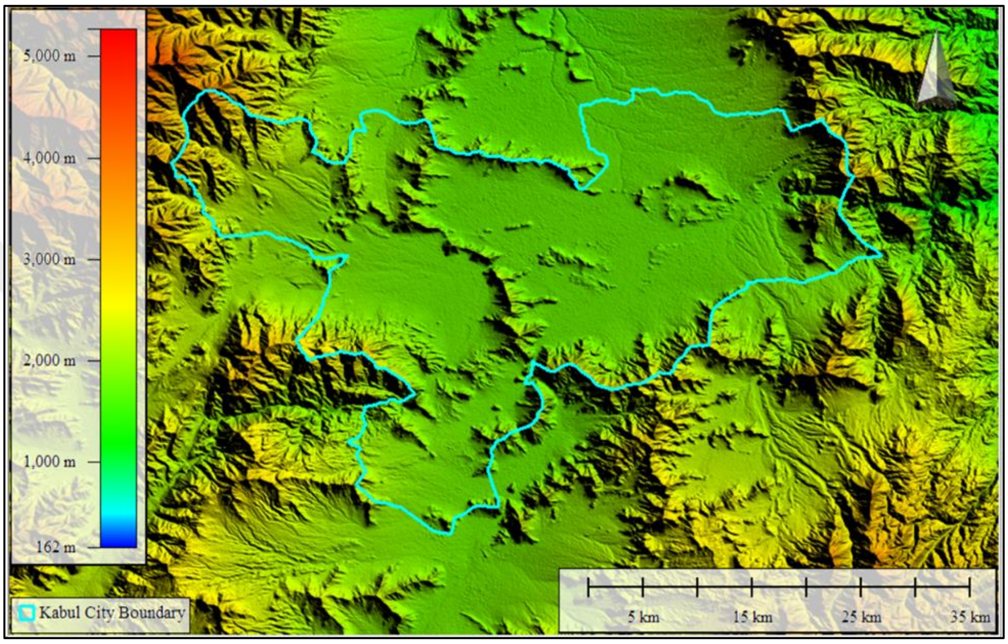

Figure 4.6. *Kabul City Highest and Lowest Elevation Map (Adapted from Global Mapper).*

Climate of Kabul city is arid and semiarid. Precipitation in the Kabul city occurs in winter as it starts snowing. The Spring season in Kabul starts in March and ends in May, when humidity is high because of too much precipitation. The Summer season begins in May and ends in August when humidity is very low and it can cause the heat to decrease, the related values are shown in Table 4.2. The Fall season is dry and warm that begins in September and ends in October. Winter season is moderate-cold which starts from November and ends in the march [53]. In the Table 4.2 climate condition of Kabul explained in monthly basis in accordance with Monthly Temperature, Precipitation and humidity in 2019 based on Meteorological station data.

Table 4.2. *Kabul city monthly climate condition in 2019 (Afghanistan Meteorological Department,2019).*

Month	Temperature (°C)			Precipitation (mm)	Humidity (%)
	Maximum Temperature	Minimum Temperature	Mean Temperature	(Rain+Snow)	Relative Humidity
Jan	6.6	-4.2	1.2	57.6	60
Feb	6.5	-2.4	2.05	61.5	67
Mar	12.3	0.5	6.4	49.4	64
April	21.7	9.1	15.4	68.5	63
May	26.2	10.4	18.3	35.2	54
June	30.5	15.2	22.85	0	42
July	35.7	18.6	27.15	1.5	43
Aug	34.2	18.1	26.15	24.3	45
Sep	31.7	14.6	23.15	0	48
Oct	22.3	6.9	14.6	19.4	58
Nov	13.8	1.9	7.85	44.3	65
Dec	10.3	-1.4	4.45	51.6	70

Kabul climate and weather are like Moderate regions climate which has four seasons in a year. In July, maximum temperature rises to 38°C degree and in Jan temperature drops to -25 °C degree. In winter season in November, it has high precipitation, especially the snow. In spring, especially in March and April high rainfalls are witnessed in the city, although they do not exceed 200 millimeters in Kabul city, thus indicate moderate, semi-desert and arid mountain climate in the Kabul city [52].

Afghanistan's climate is the same as the continental and regional climate. However, the local climate variations are because of its mountainous geography which causes many changes in the climate at a local level. In the different parts of Afghanistan, it has a varied climate because of many areas of the country covered by vast mountain regions such as Hindu Kush mountain, Baba mountains and Pamir mountains with 5000m altitudes are permanently covered by Glacier and Snow. Also, some areas of these mountains, especially in spring, witness rainfalls and in winter, expect high snowfalls. According to these weather variabilities, the Afghanistan climates are classified in 6 climate zones. [54]. Afghanistan climatically zones features are explained in Table 4.3.

Table 4.3. *Climatically zones feature in Afghanistan*

Zone	Name	Precip. (mm)	Dry (months)	Frost(months)
1	Badakhshan (without Wakhan)	300-800	2-6	1-9
2	Central and Northern mountain	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 + Southern Lowlands	<100-300	6-12	0-3

Source:(Adapted from http://www.cawaterinfo.net/afghanistan/afg3_e.htm).

In Conclusion, Kabul city located between the mentioned mountains belongs to Kabul province and Kabul basin (also Kabul province) covered by the highest mountains which affect the climate of Kabul. The main factor of Kabul's climate variation which causes climate-changing in this city is the location of Kabul between the mountains with high altitudes and the second issue is the Kabul river which belongs to Kabul basin having an essential effect on Kabul City climate. According to above-mentioned factors, Kabul basin climate can be divided into three climatic zones as follows: Mountainous zone, Middle hill zone, and Foothills and desert or plain zone. In general Kabul province and Kabul city belongs to the middle climate zone. In the middle hill zone in the summer season, the temperature exceeds 20 °C while in the winter season, the average temperature falls below 0 °C [55]. These zones base on Kabul Basin altitude showed in figure 4.7. for Kabul City.

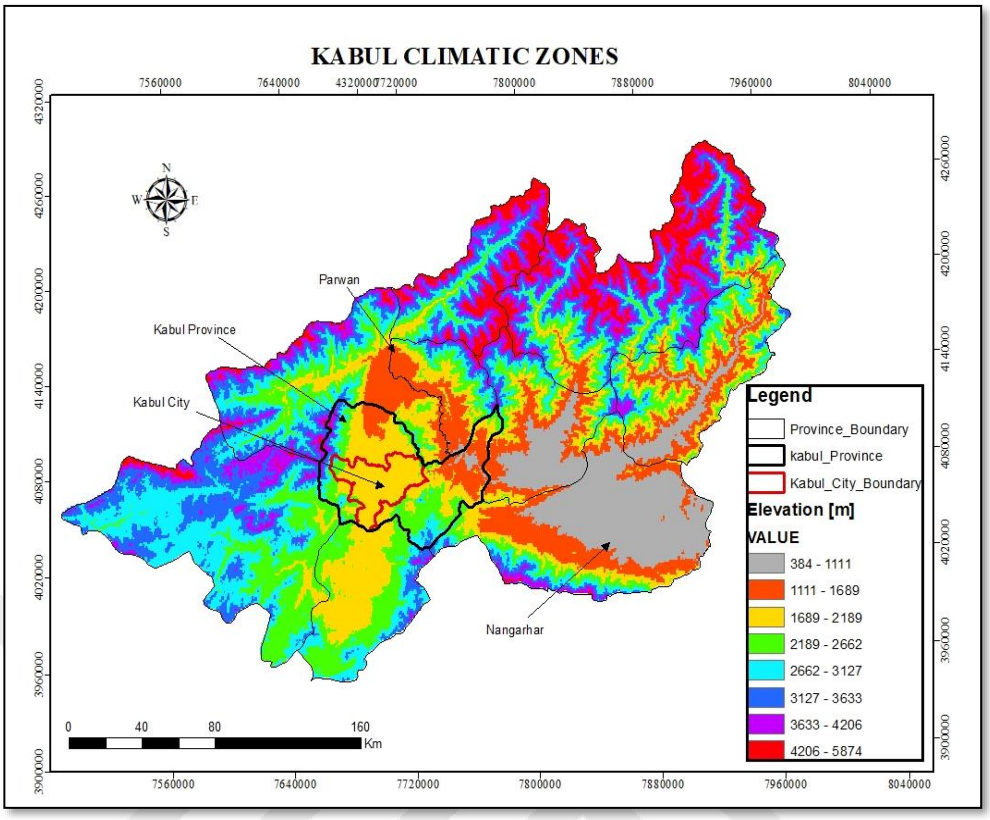

Figure 4.7. *Designation of the Kabul Climatic Zones(Adapted from https://earthexplorer.usgu.gov).*

Kabul city has different water sources such as: Water coming from Tangi Saydan river, the Logar river, the Paghman Chamchamast river, Joisher water source, Lalander water source, and underground water sources. These water resources in Kabul are used for different purposes like drinking, agriculture and industry. The former used these water sources for irrigation of agriculture such as wheat, barley, Corny, and Gardens. Water resources in Kabul are essential for agricultural irrigation and help in the cultivation process. The second significant usage of these water resources in Kabul is for drinking, sanitation and industry. Without any manageable plans if people and governments do not take necessary precautions together for this essential element it will be a big phenomenon in the near future for the people living in Kabul. Unfortunately, even today Kabul's citizens face lack of water. In some parts of the city, for normal daily life and sanitation, people cannot find enough water.

Kabul river is very important for the city as an environmental and economic factor. The economic benefit of the Kabul river is in terms of electricity generation through Naghlo Dam which has the capacity to generate more than 90000 Kilowatts electric power per hour, Mahipar Dam is another example which has a capacity of 60000 kilowatts per hour, Sorobi Dam with capacity of more than 22000 kilowatts per hour is also worth mentioning. Generally, these sources of electricity are used for enlightenment of the city and also other various industries [52]. Kol-e-Hashmat Khan in south of Kabul city is the important wetlands of Kabul city which provides natural beauty for the city. In addition, it's one of the crucial shelters in Kabul city for birds which some of them came from other regions, but now at this wetland, the bird species shallow and some of them immigrates to other regions.

Qragha Dam in the western part of Kabul city is a critical ecosystem that has a positive effect on the city’s environment. This environmental essential positive effect such as the clean city atmosphere from air pollution and a suitable source of water for irrigation of agriculture in Kabul city [56]. The Kabul river flows between the Kabul city, and it provides natural beauty for Kabul city.

Figure 4.8. *Kabul City (Qargha Leak, Kol-e-Hashmat Khan, Kabul Riverside) aerial view).*

Kabul, in general, has a complex geology because of the mountains surrounding it. Kabul basin arose during the Paleocene as a result of the plate movement. Kabul basin is underlain and surrounded by metamorphic rocks which belongs to Kabul block [57]. Around 1600 km^2 area covered is by this basin and topographically it has different altitudes, from the shallow flat area in the east to the high and rugged mountainous area in its northern part. The northern and western regions of the Kabul basin are dominated by Gneisses, Precambrian, amphibolite's, mica slates, marbles and quartzites. In the southern and eastern parts of the basin, the Precambrian phyllites are found and its sediment thickness according to geophysical surveying is up to 600m. The Butkhak is one of the parts of the Kabul formed by different clastic material beds, such as, red gravels, sandstones, breccias and conglomerates. In its western region, the ground surface of the Kabul basin is 1830m above sea level while its eastern outlet is 1770m. The coarse-grained zone sediments a width of 2.5 km, and a length of 9 km has been confirmed parallel running to the Kabul river. This zone includes one of the most important factors for Kabul aquifer.

The Kabul river aquifer entailing of three horizons; sandstones, and conglomerates covered by a slim layer of gravel and sand and is a main part of the aquifer. Further, include rock consists of the loess layers, and the layers of loess have 1-5 m thickness. In the higher parts of the basin, thickness of gravel and sand layer is 2-9 m while in the lower parts of the basin it rises up to 20 m and sandstone and conglomerate have 30-65 m thickness. The bed of gravel just located in Darulaman Basin - Paghman river is around 4 km wide, 10 km long, and 45 m thickness [58]. In conclusion, the Kabul basin ground formed from sand, gravel and rocks like; slates, quartzite, schist, granites, gneisses and boulder beds while its mountains are composed of metamorphic bedrock.

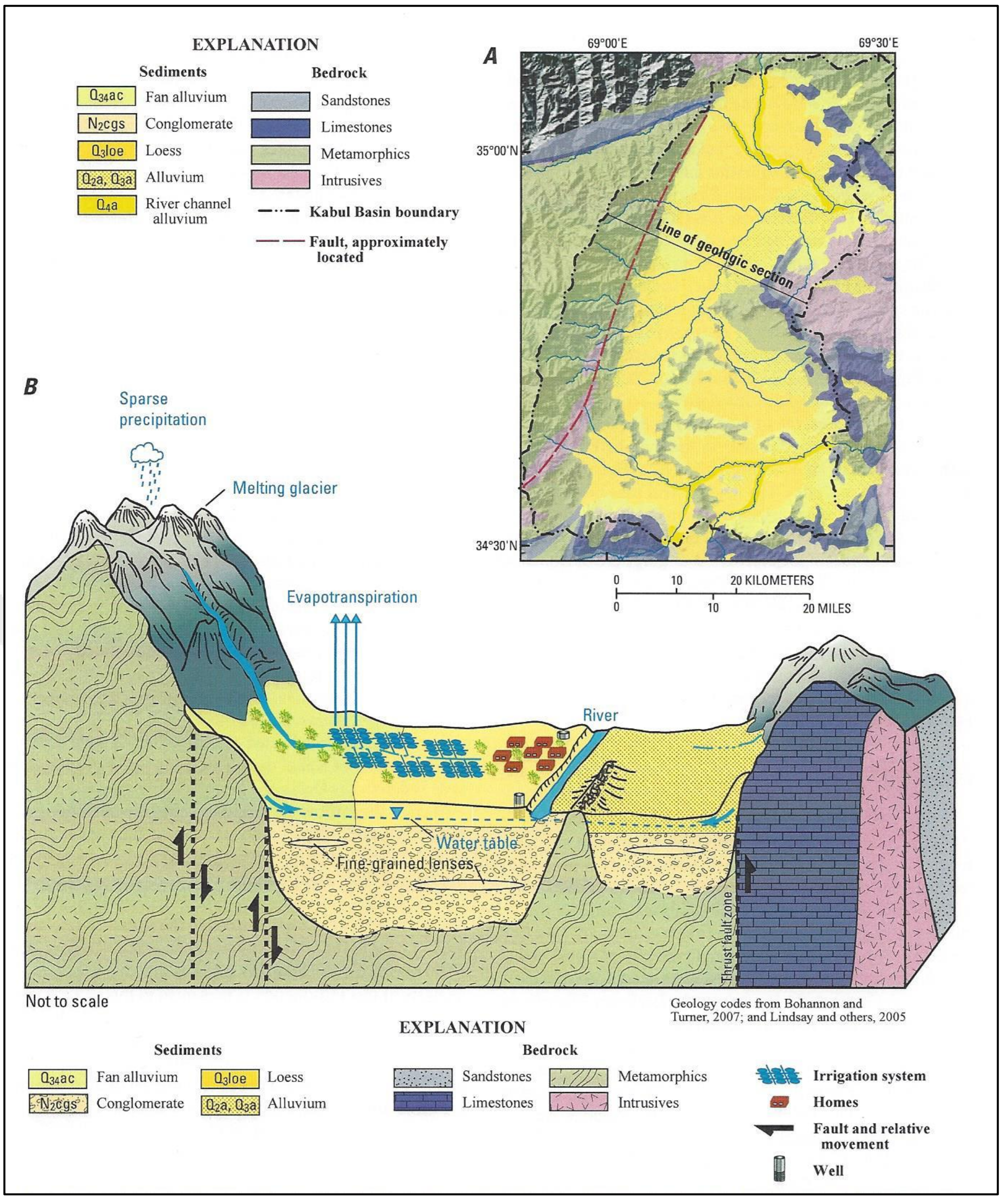

Figure 4.9. *Kabul basin Planar view (A) and Generalized Hydrologic cross-section view (B). (Scientific Investigations Report 2009–5262.USGS).*

In general, according to soil texture map made by FAO, it looks that in most areas in Kabul city, the soil texture is loam and clay [59]. Most of the Kabul city district soil texture is loam and sandy loam and soil horizon profile A is between 0-30cm made from clay 12.8% and soil horizon profile B are between 30-100cm made from 11.8% clay [60]. The soil type explained in the bellow figure as briefly inside of the Kabul city.

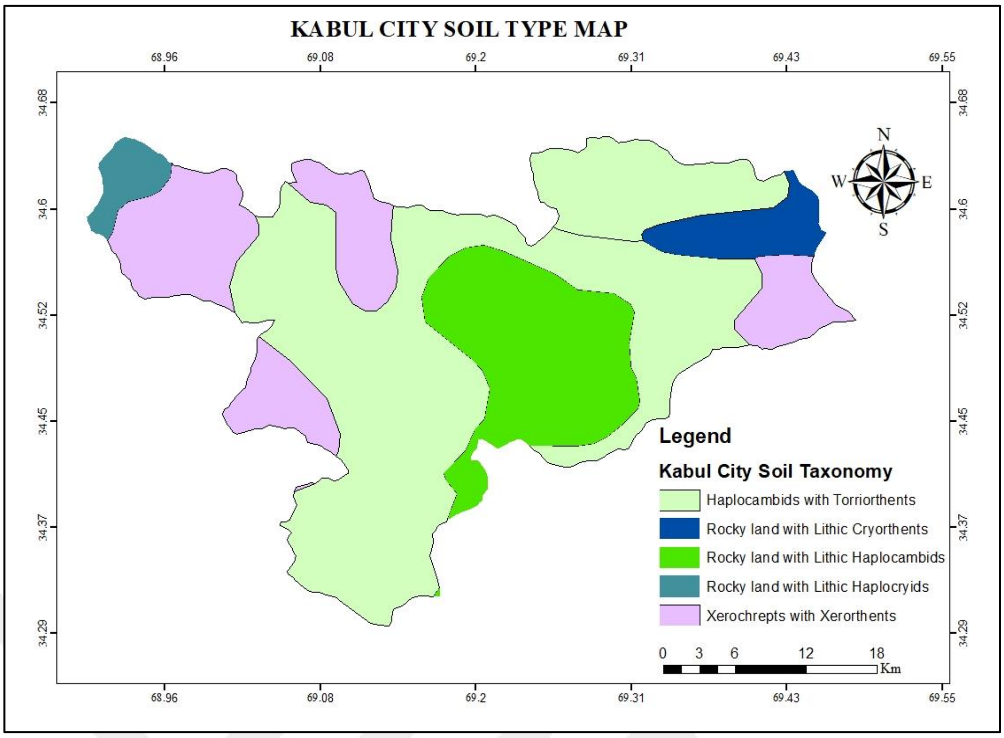

Figure 4.10. *Kabul City Soil Type (Adapted from* https://www.nrcs.usda.gov*).*

Landcover and land use are one of the physical materials of the earth's surface. In general, the landcover includes elements such as vegetation, grassland, water bodies, bare land, Rangeland and some other things. In this case, the landcover atlas helps us to make a better decision for our project, especially, environmental studies and land use management [61]. Land use term means how humans use the land, and term of land-cover means the materials found on the earth's surface, especially bio-physical materials. Further, for safe Environment from Pollution and degradation in Kabul city, the use of Land use/Landcover information via using remote sensing technology is extremely useful and required for estimation of population, site selection for industrial, residential, or commercial, protected area, and national parks. Furthermore, land use land cover information should be organized according to the standardized scheme of land use land cover. So, Kabul city landcover map Prepared and developed by FAO which explained different type of land cover in the below.

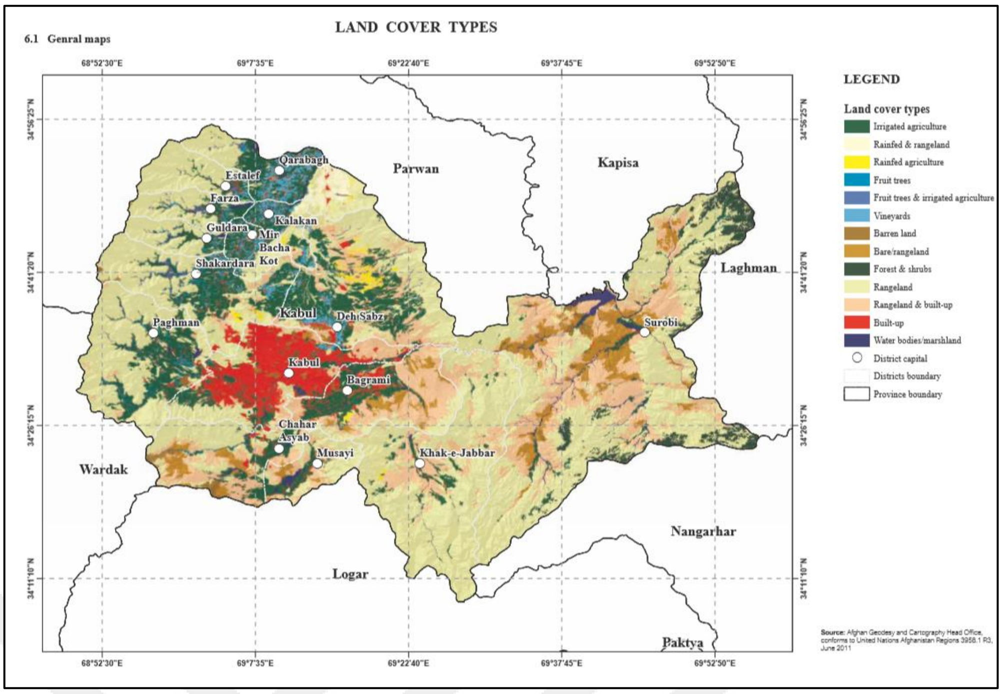

Figure 4.11. *Kabul landcover types (Afghanistan Soil Atlas, FAO,2020)*

4.2. Materials and Data Source

In this research which focuses on the assessment of climate change impact on environmental processes, the different materials and data sources were used to find and process the objects which we need for our result and decision-making process. The materials and data used in this research are explained below:

4.2.1. Landsat-8 OLI

Satellite imagery such as; free download of Landsat 8 OLI (Operational Land Imager) C1 Level1 with specification such as; 30 meters resolutions, elevation source, is GLS2000 and with GeoTIFF format based on Flood occurring date from the website (https://earthexplorer.usgs.gov/) of the Geological Survey (USGS) archives of Landsat imagery, United States of America produced by NASA EO-1 satellite since 2013. For the present study area, all Landsat 8 OLI is at row 36 and path 152 or 153, Zone 42N and with cloud cover percent between 0 – 45 % which showed in the below table all the Description of each collected Landsat-8 images that is used for the present study area explained in table 4.4.

Table 4.4. Description of the collected Landsat-8 OLI images.

NO	Sensor ID	Path	Row	Cloud Cover (%)	Agusisition Date	Ephemeris Epoch Day	Zone	Datum
1	OLI TIRS	153	36	5.8	8-Oct-2014	281	42N	WGS84
2	OLI TIRS	153	36	2.02	28-Oct-2014	297	42N	WGS85
3	OLI TIRS	153	36	3.8	27-Dec-2014	361	42N	WGS85
4	OLI TIRS	153	36	40.51	13-Feb-2015	44	42N	WGS86
5	OLI TIRS	153	36	7.46	8-Aug-2015	220	42N	WGS87
6	OLI TIRS	153	36	2.65	16-Feb-2016	47	42N	WGS88
7	OLI TIRS	152	36	1.7	29-Apr-2016	120	42N	WGS88
8	OLI TIRS	153	36	3.8	4-Apr-2016	95	42N	WGS88
9	OLI TIRS	153	36	23.48	6-Mar-2017	65	42N	WGS89
10	OLI TIRS	153	36	1.63	7-Apr-2017	97	42N	WGS89
11	OLI TIRS	152	36	45.85	31-Mar-2017	90	42N	WGS90
12	OLI TIRS	153	36	10.5	25-Mar-2018	84	42N	WGS91
13	OLI TIRS	153	36	10.95	26-Apr-2018	116	42N	WGS91
14	OLI TIRS	152	36	6.38	22-Apr-2019	112	42N	WGS92

The Landsat 8 OLI (operational land imagery) and TIRS (thermal infrared sensor) images launched on 11th February 2013. Landsat -8 OLI includes two thermal bands and nine spectral bands and has a spatial resolution of 15 to 100 meters [62]. The details of each band are explained in the table 4.5 below.

Table 4.5. *Landsat 8 bands specification and wavelength (https://eos.com/blog/band-combinations-for-landsat-8.*

Senor	Spectral Band	Use Area	Wavelength	Resolution
OLI	Band 1	Coastal/Aerosol	0.45-0.515	30m
OLI	Band 2	Blue	0.450-0.515	30m
OLI	Band 3	Green	0.525-0.600	30m
OLI	Band 4	Red	0.630-0.680	30m
OLI	Band 5	Near Infrared	0.845-0.885	30m
OLI	Band 6	Short Wavelength infrared (SWIR1)	1.560-1.660	30m
OLI	Band 7	Short Wavelength infrared (SWIR2)	2.100-2.300	30m
OLI	Band 8	Panchromatic	0.500-0.680	30m
OLI	Band 9	Cirrus (SWIR)	1.360-1.390	30m
TIRS	Band 10	Long Wavelength infrared	10.30-11.30	30m
TIRS	Band 11	Long Wavelength infrared	11.5-12.50um	30m

4.2.2. Planet-Scope Imagery

The second satellite imagery source is plane-scope imagery. Free download of Planet-scope imagery with following specification; 3 meters resolutions (pixel size), ground sample space with 3.7 m, Geo-TIFF format, UNIT data type, daily Revisit time, BIP Interleave, UTM-Web Mercator Projection, and data type Level 3A, from the website (https://www.planet.com/) that is produced by planet-scope Labs and planet labs which is itself one of the private American companies providing service in this field. We can only access data from this production of plane-scope for Afghanistan starting from 2017 and with some limitations. For the present study area, all Planet-scope imagery which is used at the row between 4000-6917 and path between 8105-9424 and 0 – 1.97 % Clouded coverage. Details showed in the below table 4.6.

Table 4.6. *Description of the collected Planet-scope images.*

No	Row	Columns	Cloud Cover	Sensor Type	Acquisition Date	Datum
1	4132	8369	0 %	OPTICAL/EOP	21-Aug-2017	WGS-84
2	8971	4495	0.197 %	OPTICAL/EOP	17-Jan-2019	WGS-84
3	6917	9424	0.02 %	OPTICAL/EOP	21-Apr-2018	WGS-85
4	4517	8253	0 %	OPTICAL/EOP	31-Mar-2019	WGS-86
5	4036	8105	0 %	OPTICAL/EOP	27-Apr-2019	WGS-87
6	4392	8819	0 %	OPTICAL/EOP	4-Jul-2019	WGS-87

The Planet-scope images Archive since 2009 [63]. Planet-scope image lab includes spectral bands (Blue, Green, Red, NIR), and has a 3-5 meters optical resolution [64]. The other Characteristics description of each band are explained in the below table 4.7.

Table 4.7. *Characteristics of Planet-Scope imagery (Planet labs2019).*

Mission Characteristics	**International Specs Station Orbit**	**Sun-synchronous Orbit**
Orbit Altitude (reference)	400 km (51.6° inclination)	475 km (-98° inclination)
Max/Min Latitude Coverage	± 52° (depending on season)	±81.5° (depending on season)
Equator Crossing Time	Variable	9.30 - 11.30am (local solar time)
Sensor Type	Three-band frame Image or four-band frame Image with a split-frame NIR filter	Three-band frame Image or four-band frame Image with a split-frame NIR filter
Spectral Bands	Blue: 455 - 515 nm Green: 500 - 590 nm Red: 590 - 670 nm NIR: 780 - 860 nm	Blue: 455 - 515 nm Green: 500 - 590 nm Red: 590 - 670 nm NIR: 780 - 860 nm
Ground Sample Distance (nadir)	3.0 m (approximate)	3.5 - 4 m depending on flock
Frame Size	20 km × 12 km (approximate)	24.6 km × 16.4 km(approximate)
Maximum Image Strip per orbit	8,100 km^2	20,000 km^2
Revisit Time	Variable	Daily at nadir (early 2017)
Image Capture Capacity	Variable	340 million km^2/day
Camera Dynamic Range	12-bit	12-bit

Materials downloaded from ALOS PALSAR DEM with 12.5 meters resolutions from the website (https://vertex.daac.asf.alaska.edu/) which initially are provided by NASA and SRTM DEM (Shuttle Radar Topography Digital Elevation Model) with 90 meters resolutions which is available in the following website: (https://earthexplorer.usgs.gov/). The second source of data and materials used in this research is the hydrological data, station base which is offered by the Water Resources Department, Ministry of Energy and Water of Afghanistan. The third source of data is metrological station base data provided by Afghanistan Meteorological Department. The fourth source of the data provided by the Ministry of the disaster of Afghanistan. The final data are gathered by visiting the sites that were affected by flood in Kabul city in-person and the regions that are in danger to get affected in the future by this phenomenon.

4.2.3. Software

The equipment and software which was used for this work are included in the below list:

The first one is the software part list which includes (Arc-GIS, ENVI, EARDAS IMAGINE AND Microsoft office 360 such as Microsoft Word 365 and Microsoft Excel 360) explained in detail:

4.2.3.1. Arc-GIS Version 10.5

Arc-GIS software version 10.5 was used in the present research work. ArcGIS is one of the geospatial software in which we can edit, view, analyze and manage geographic data. The ESRI company develops ArcGIS for mapping on desktop, web and mobile. GIS is called the science of where. So, the main focus of GIS is on location intelligence and analytics of the geospatial data. Furthermore Arc-GIS 10.5 is an open-source software product, produced by ESRI company. By using GIS, we can collect, produce, share and manage the data in an easy way for our projects and use them for editing the maps for research purposes or projects whenever wherever we want. In general, Arc-GIS Desktop application suite includes: Arc-Map, ArcCatalog, Arc-Scene, Arc-Globe, and other components include Arc-Toolbox and Model-Builder, Arc-GIS Administrator. Further Arc-Map version 10.5 was used for the present work. The elements of GIS include people, software, hardware, method and data.

4.2.3.2. ENVI Software Version 5.3 + IDL 8.5 (64-bit)

The software of ENVI 5.3+IDL8.5 (64-bit) was used in present research work for image processing. ENVI is another software which we use for analyzing and processing of geospatial imagery. With ENVI software, we can handle LiDAR, hyperspectral, and other datasets of remote-sensing quickly with both allowing users and wizard-based approaches to program operation. The major advantage of ENVI is in the visualization and analysis of the hyperspectral and spectral data. ENVI 5.3 is the new version that has new functionality and features of the ENVI, which helps us in analyzing geospatial imagery.

4.2.3.3. ERDAS IMAGINE 2015 Software

The software of ERDAS IMAGINE 2015 Version 15 was used in this present research work for image processing. ERDAS IMAGINE is the other software which we used for image processing. Via this software package, we can process geospatial imagery and vector data. In addition, EARDAS software can handle LiDAR and hyperspectral from different sensors. EARDAS software has the ability for modelling to offer a vector module and a 3D viewing module. The programing language of ERDAS is EML (Erdas Macro Language).

The second section includes the hardware's used in this research explained in the list below:

- 1.Canon SX 610 HS 20.2 Megapixel PowerShot Camera.
- 2.HP ENVY Travel 6SP25AA Bluetooth Mouse.
- 3.HP K4000 Bluetooth Keyboard.

4.HP ENVY x360 Convertible 15-cn1xxx Laptop, Microsoft Windows 10 Pro, Intel(R) Core (TM) i7-8565U CPU @ 1.80 GHz, 1992 MHz, 4C, 16GB RAM, 8GB Graphic Nvidia, 256 GB SSD+1028GB Hard disk.

4.3. Methodology

In this section it gives an overview of the methodology that is used for the present research.

4.3.1. Determination of the Kabul City flooded area via Application of Geospatial Technology

Kabul city is suffering flood event from many years ago tell present and widely affected this city, it's environment and people, so this event viewed by many satellites' imagery. The current research work about Kabul city flood is a result of the analysis of open-source satellite imagery taken before the Flood, during the Flood, and after the Flood for the city of Kabul between 2014 and 2019. For the present research, the method that has used to find flooded areas in the scope of the study area and the analyzing, process, and evaluation of the satellite imagery data and hydrometeorological station base data via application of geospatial technology such as EARDAS IMAGINE, ENVI, Arc-GIS.

The cause of flood events in Kabul city is the result of climate change and geographical location of the town; in addition, weak management plans of the flood-prone area in the city with the high level of the build-up of the building and homes in the flood-prone area in the city, especially at these present decade. The Flood occurring damage in Kabul is high for the city and citizens of Kabul. So, for the determination of damage risk of the Flood in Kabul city, it is necessary to precisely determine the flood prone areas in the town and this stage would be useful to make an efficient decision for the future because the flood areas are correctly specified.

Fortunately, today we can freely access and download the satellite imagery from many open-sources satellites with high spatial resolutions. In the present decades, different satellite imagery sources used for the determination of the flooded area, such as; optical imagery, Radar imager, etc. Within the scope of the present thesis, optical imagery such as Landsat 8 OLI, Planet-scope, and DEM were used to determine the flooded area in Kabul city. So, for the determination of the flooded area, the exact dates of flood occurrence are so essential to download the precise imagery for the flooded area. Furthermore, we got to access the accurate date of the flood event in Kabul city between 2014 and 2019, which offered by the Afghanistan National Disaster Management Authority (ANDMA). According to the times of the flood event in Kabul city, the open-source satellite imagery has downloaded which these imageries captured the flooded area in Kabul city. Then via geospatial technology tools, this event has been analyzed and evaluated.

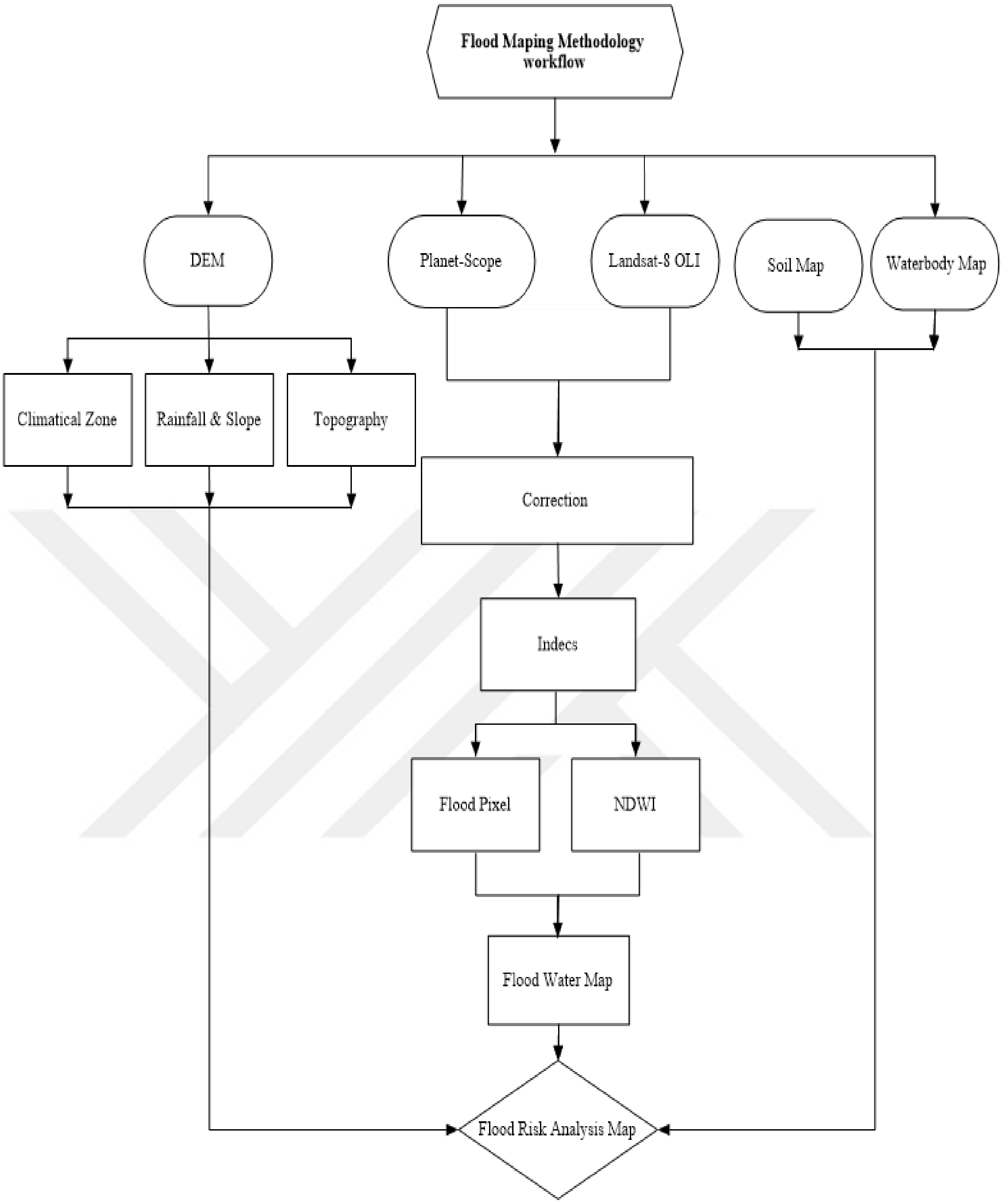

Figure 4.12. *The theses methodology workflow chart.*

4.3.2. Image Processing and steps

The visual enhancement of the image makes it able to detect the flood area boundaries, further that the spectral band is the primary reflects to dedicate the flood prone area. Within the scope of the present thesis, all the applications of the spectral bands were investigated, that determine the flooded area. All the forms and practical work, steps, and processes has been explained in bellow for Landsat-8 OLI:

4.3.2.1. Radiometric Calibration

The first pre-processing step for analyzing of Landsat-8 OLI imagery is Radiometric calibration. Radiometric calibration has used to calibrate images into Atmosphere reflectance, radiance, and temperature brightness. So, via this process, we can remove the grey value of the imagery and the imagery becomes bright, and as a result, the objects have been clearly visible. Furthermore, the aim of Radiometric calibration process is removing of the atmospheric effects of the images. So, for this reason, via using of ENVI software we calibrate the image to radiance and surface reflectance [65].

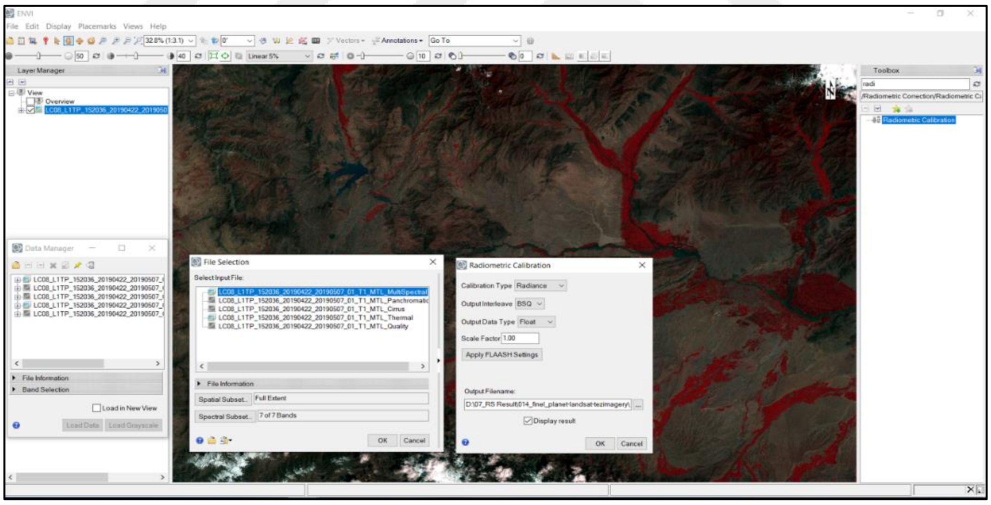

Figure 4.13. *Quick Radiometric calibration process of Landsat-8 OLI images.*

4.3.2.2. Quick Atmospheric Correction (QUAC)

The second pre-processing step for analyzing of Landsat-8 OLI imagery is Quick atmospheric correction. The quick atmospheric correction procedure is for hyperspectral and multispectral imagery. For this process, the input Landsat-8 image must be in radiance. This process can remove the absorption and scattering effect of satellite imagery. For this process of the image, we used ENVI software [66].

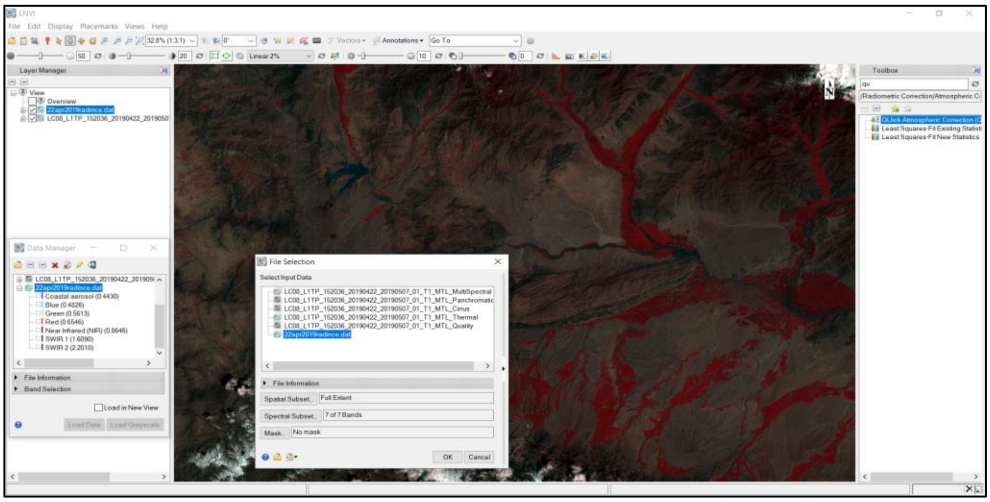

Figure 4.14. *Quick atmospheric correction process of Landsat-8 OLI images.*

4.3.2.3. Pan-Sharping and Subset

The third step of Landsat imagery is pan-sharpening, and we Used Gram-Schmidt Pan Sharpening algorithms. So, one of the most popular methods of pan-sharpening is Gram-Schmidt pan-sharpen algorithm. Via Gram Schmidt Pan-Sharpening algorithms merge low resolution into high resolution so, the resolution of the Landsat-8 images are converted from 30 meters into 15 meters by using ENVI software [67]. Also, in the same processes, the images Subset process was done according to the shapefile of the study area.

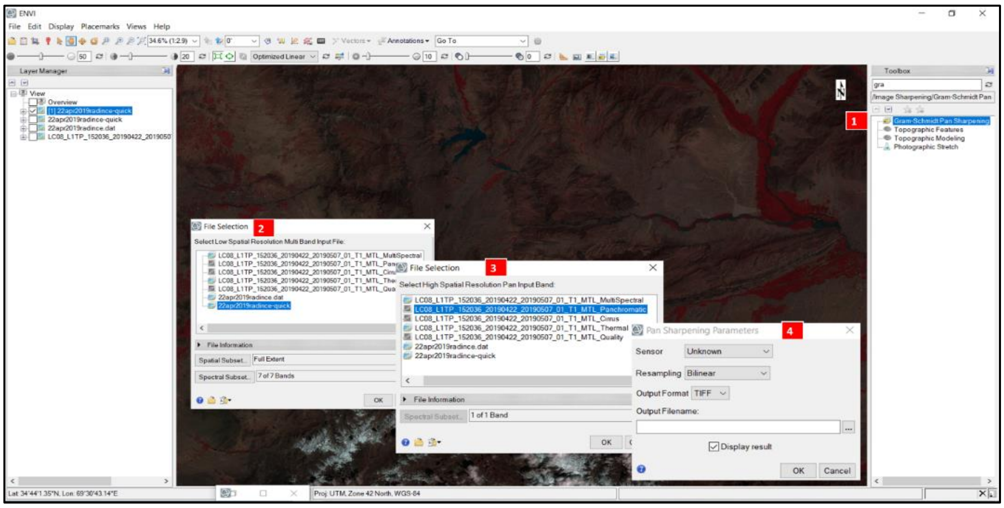

Figure 4.15. *Pan sharpening process of Landsat-8 OLI images.*

4.3.2.4. Rescale

The next steps for the image process after the process of pan-sharping is the Rescaling process. Rescale algorithm is one of the other essential steps which we are doing it for the values of the reflectance images in the range of (0 - 1) for Landsat-8 in ENVI. So, in this process for the of minimum and maximum value of reflectance image, in the Band math, we use the bellow formula: (b1 le 0) *0+(b1 ge 10000) *1+(b1 gt 0 and b1 lt 10000) *float(b1)/10000. We used this formula for all reflectance imagery, and b1 is a channel. After applying the above method for scaling the imagery, we will be able to see the minimum and maximum values of reflectance between zero and one (0-1) in Landsat-8 product. For this image process, we used ENVI software [68].

Note: the above image process is done just for Landsat-8 imagery, but for Planet-scope imagery, only the rescaling has been done because the planet-scope imagery does not need radiometric collaboration, and quick atmospheric correction.

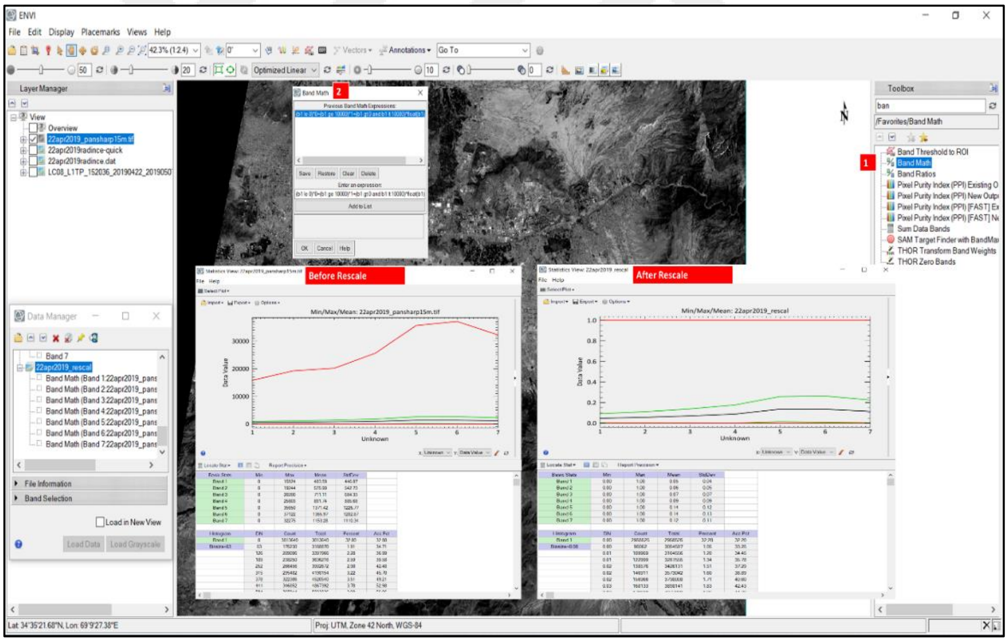

Figure 4.16. *Rescale process of Landsat-8 OLI images.*

4.3.2.5. Mosaicking of the Satellite Imagery

Satellite imagery mosaicking is one of the image processing techniques. For the present research beside of the Landsat-8 OLI imagery, the Planet-scope imagery was used. So, the plane produces imagery as multi-images for the specific area; in this case, the images need to combine in the particular study area. Further, for the combinations of the two images or more than two images as a unique image, we have applied the mosaic pro algorithm to create a single image as a perfect form. For this image process, we used ERDAS IMAGIN software [69].

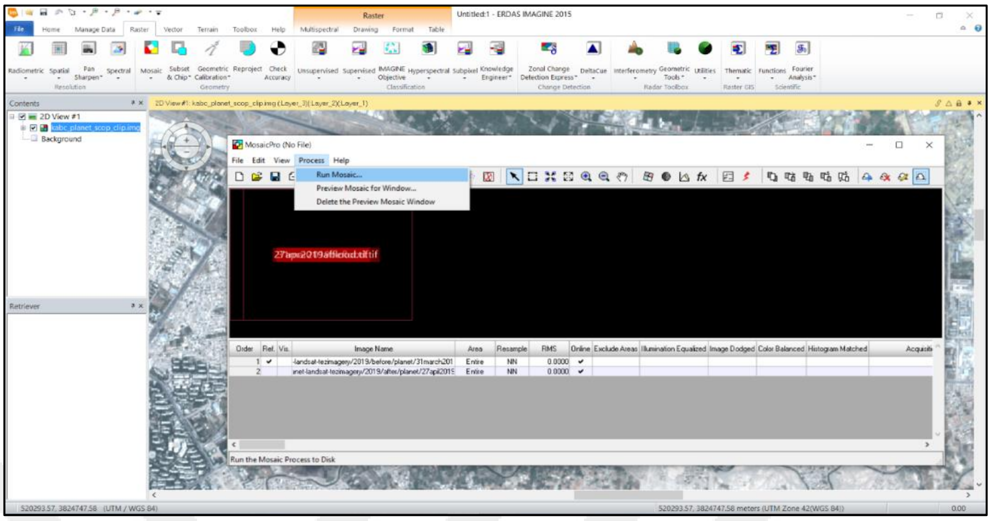

Figure 4.17. *Mosaicking process of 5 images for the research area.*

4.3.2.6. Index Calculation for Satellite Imagery

The next image process after the Rescaling process is the index calculation. The index algorithm calculation is essential steps in which the processes is done for NDWI and Flood Pixel according to the range of the values between -1 and +1 for both Landsat-8 OLI and Planet-scope imagery, and we used the bellow formula: INDWI = (Green - NIR)/ (Green + NIR). B is used as the name of the band, for example, b1 is ban1(Green), and b2 is band2 (NIR).

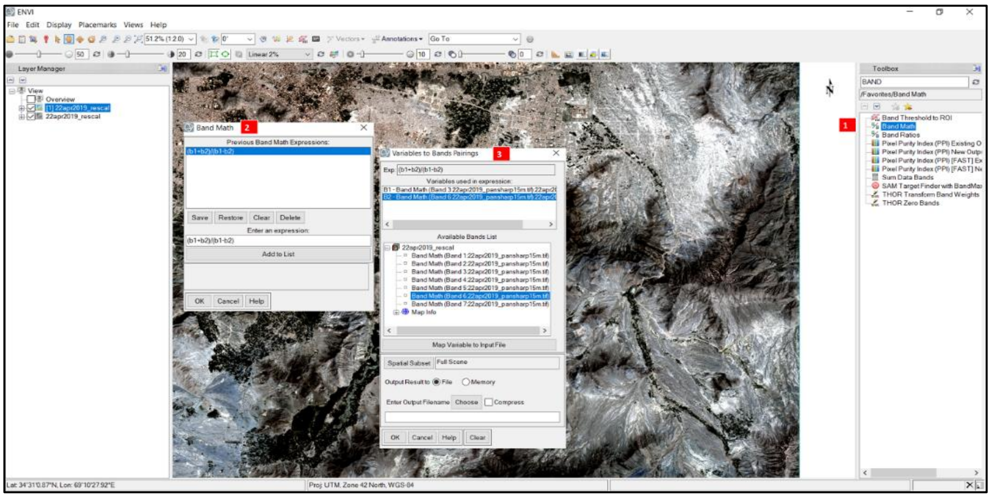

Figure 4.18. *Index calculation process of Lansat-8 OLI images.*

4.3.2.7. Band Threshold to ROI and Determination of the flood area

One of the essential image processing operations is Thresholding algorithm. Images by Thresholding algorithm divided into two classes, such as background and foreground. Via applying Thresholding algorithm, we have the option to choose the threshold value, or it is possible to use an algorithm for calculation of threshold value [45]. For this image process ENVI software have been used. Threshold to ROI for the detection of the flooded area showed the bellow figure 4.19.

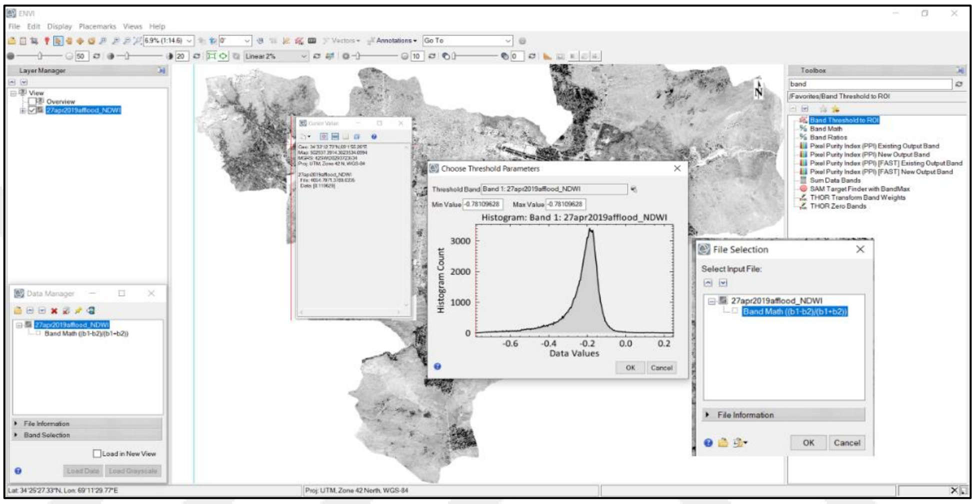

Figure 4.19. *Band Threshold to ROI and Determination of the flooded.*

4.3.3. Spectral Band Combination

For the present work, the band combination process of the satellite images was done by ENVI software to create multi-band images for the next process of the image processing. The band combination processes have carried out with the Layer Stacking command. So, this band combination for planet-scope imagery is Green band from non-flood (b2), and NIR band from flooded (b4) and these bands were combined to find the flood pixel. In addition, these band combinations for Landsat-8 OLI are the band Green from non-flood (b3), and the band of NIR or SWIR from flooded (b5, b6) were combined to find the flood pixel. In the bellow figure, bands Layer Stacking is showed.

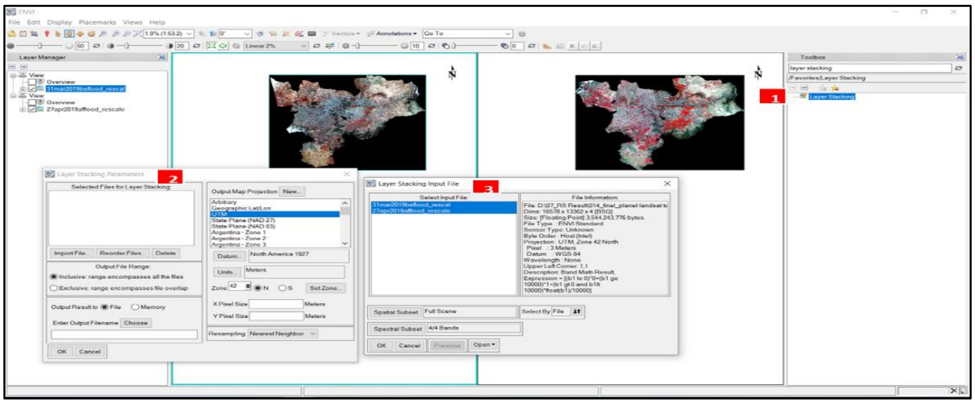

Figure 4.20. *Imagery bands combination via layer staking command.*

4.3.4. Flood area Image Improvement

From the earth, reflected energy via every spectral band record the different wavelengths. In this case, all the imagery is not the same; it is different from each other. In this case, Landsat-8 OLI and the planet-scope imagery bands have been combined to display the flooded area. For detecting a flood with high accuracy, the different formula has been developed through different research by the researchers. For Flood detection some formulas are described in bellow.

The first NDWI (Normalized Difference Water Index) formula has used for normal waters (continuous water) detection. The second NDWI (Normalized Difference Water İndex) formula has used for change detection of floodwater. B is an abbreviation of the band.

$$\boldsymbol{NDWI = \frac{B4\ (NIR) - B5\ (SWIR)}{B4\ (NIR) + B5\ (SWIR)}} \qquad (2)$$

$$\boldsymbol{NDWI = \frac{B3\ (Green) - B4(NIR)}{B3\ (Green) + B4(NIR)}} \qquad (3)$$

In 1981 the research which was done to determine the flooded water of the Black River in northern New York in the USA, and that researcher had used the Landsat MSS (Landsat-1) images, band seven [70]. A combination of two bands has been done, such as; Band 7 (flood) with 0.8 – 1.1 mm wavelengths with band4 (non-flood) with 0.5 – 0.6 mm wavelengths [71]. The below formula had been used to determine the flooded area.

$$\boldsymbol{Flood\ pixel = \frac{B4(Green) - B7(NIR)}{B4(Green)}} \qquad (4)$$

Furthermore, the next researcher in 2000 which had done the research for a City of Wagga in Austra, to determine the flooded water and he had used the band 5 (flood) with 1.55-1.75 micrometers wavelength and band1(non-flood) with 0.45-0.52 micrometers wavelength of Landsat-5 TM [72]. The below formula had been used to determine the flooded area.

$$\boldsymbol{Flood\ pixel} = \frac{\boldsymbol{B1(Blue)-B5(SWIR)}}{\boldsymbol{B1(Blue)}} \tag{5}$$

$$\boldsymbol{Flood\ pixel} = \frac{\boldsymbol{B2(Green)-B5(SWIR)}}{\boldsymbol{B2(Green)}} \tag{6}$$

So, the use of the SWIR band increases the accuracy of the result and image classification, in this case instead of the NIR band the SWIR band is used, that time the SWIR band was not launched, and for the first time in 1982 the SWIR band was started in Landsat-4 imagery.

Figure 4.21. *The above band SWIR (band6) present the flooded area for the year of 20119, Landsat-8 OLI.*

Also, in 1987 the research which was done for the Flood of Severn River in England, used the Multispectral Scanner Data. Landsat-7 MSS bands such as band-7 (NIR) with 0.7-1.1 micrometers wavelength, band-5(Red) with 0.06-0.7 micrometers, and band-4(Green) with 0.5-0.6 micrometers wavelength had been used to determine the flooded prone area [73]. The below formula had been used to determine the flooded area.

$$\boldsymbol{Flood\ pixel} = \frac{\boldsymbol{B4(Green)-B7(NIR)}}{\boldsymbol{B4(Green)}} \tag{7}$$

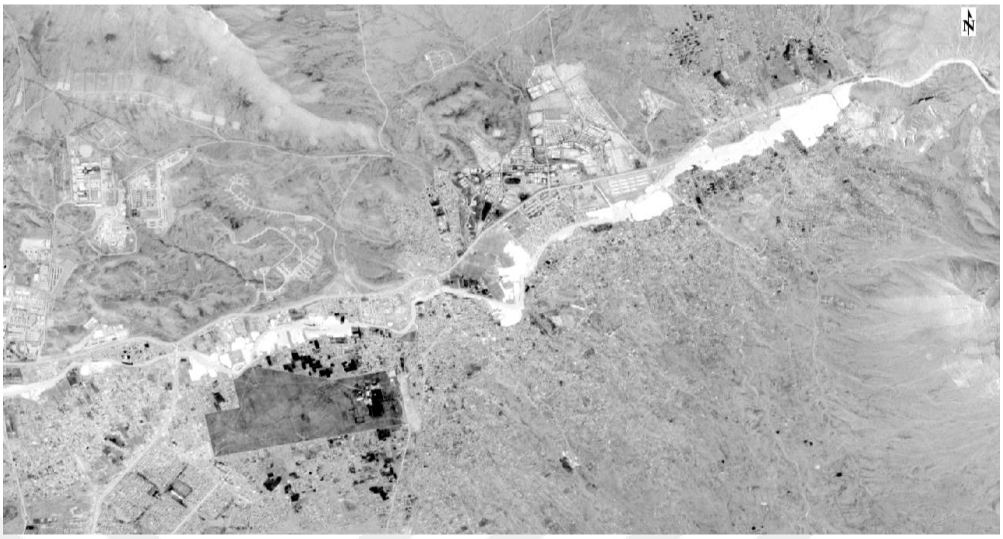

Figure 4.22. *The above flood pixel formula applied for the Kabul city Flood year of 20119, Landsat-8 OLI.*

For the first time in 1996 by Gao, the index of NDWI (Normalized Difference Water Index) was introduced [74]. So, Gao used the bands of $\boldsymbol{NIR}(\mathbf{0.86\ \mu m})$ and $\boldsymbol{SWIR}(\mathbf{1.24\ \mu m})$in the below formula for calculation of the NDWI index which applied with Landsat MSS image data.

$$\boldsymbol{NDWI} = \frac{\boldsymbol{B}\mathbf{4}\ (\mathbf{NIR}) - \boldsymbol{B}\mathbf{5}\ (\mathbf{SWIR})}{\boldsymbol{B}\mathbf{4}\ (\mathbf{NIR}) + \boldsymbol{B}\mathbf{5}\ (\mathbf{SWIR})} \tag{8}$$

Furthermore, the index of NDWI (normalized Difference water index) was proposed for the first time in 1996 by McFeeters for the determination of the surface water (to delineate the open waters) of the non-urban area [75]. So, McFeeters used the Green and NIR bands of Landsat MSS image data into the bellow formula for calculation of the INDWI index.

$$\boldsymbol{NDWI} = \frac{\boldsymbol{Band}\mathbf{2}\ (\mathbf{Green}) - \boldsymbol{Band}\mathbf{4}(\mathbf{NIR})}{\boldsymbol{B}\mathbf{and2}\ (\mathbf{Green}) + \boldsymbol{B}\mathbf{and4}\ (\mathbf{NIR})} \tag{9}$$

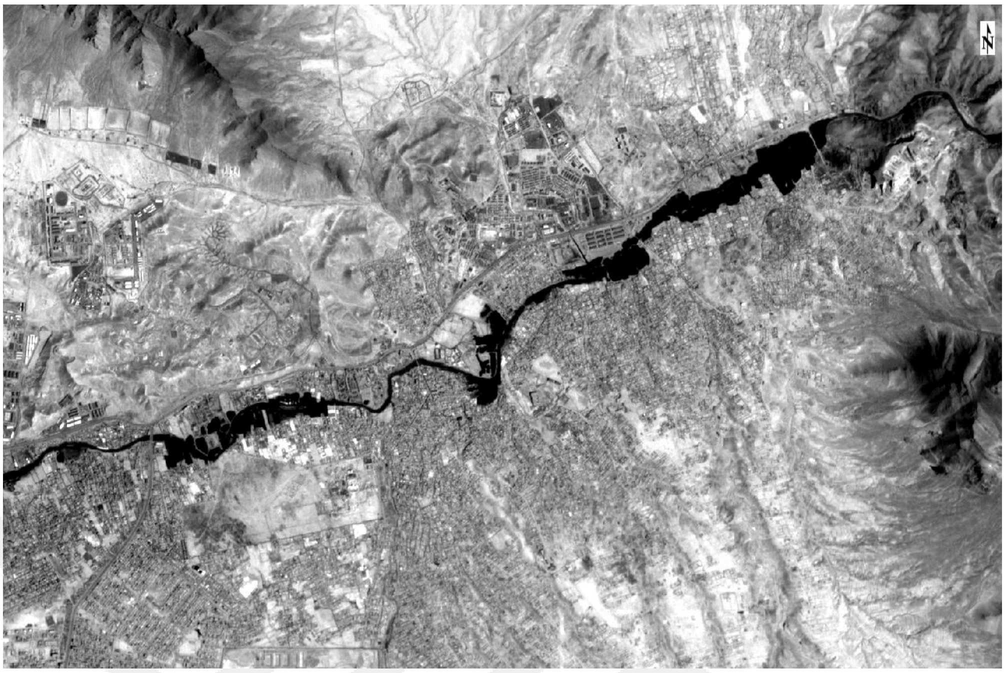

Figure 4.23. *The above band NIR (band4) detect the flooded area for the year of 20119, Planet-scope imagery.*

In 2002 research was done by Xiao for the determination flooding & the paddy fields and used NIR and SWIR bands to calculate the INDWI (Normalized Difference Water Index) index [76]. So, Xiao used NIR(0.78 -0.89 **μm**) and SWIR(1.58-1.75 **μm**) bands.

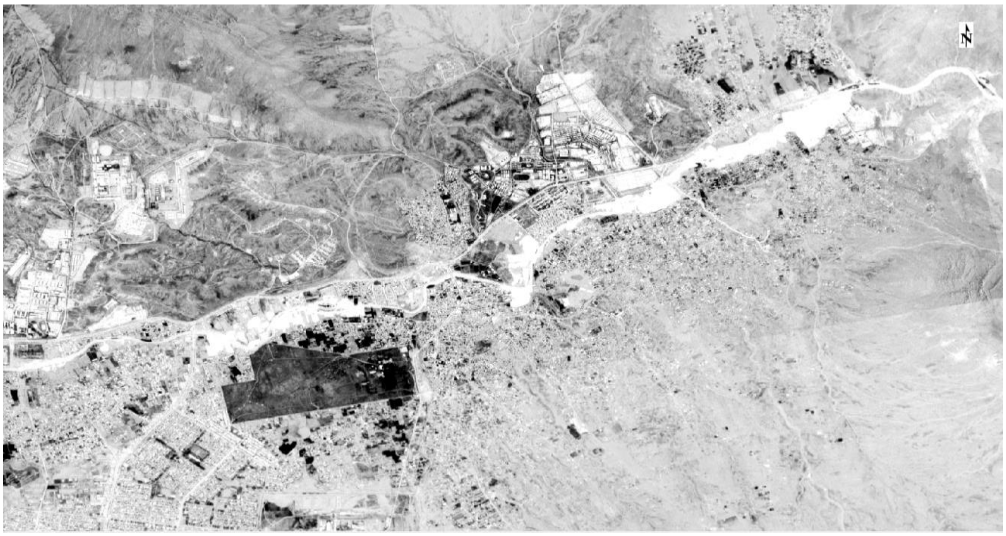

Figure 4.24. *Determination of flooded area via NDWI formula for the Kabul city Flood 2019, Landsat-8 OLI.*

4.3.5. Extraction of the Study area Landsat and Planet-Scope Image

The planet-scope imagery and Landsat-8 imagery downloaded for the present study was vast. Still, the study area had extracted according to shapefile, which has been created before for the study area, so the extraction process was applied via the ENVI software according to shapefile. The images extraction steps are including; Createing shapefile for the study area, Entering the created shapefile into the ENVI program, from the toolbox of the ENVI software then click on subset command. In the bellow figure, the image extraction was viewed.

4.3.6. Detection and Evaluation of flood in Kabul City via using of Satellite Imagery

Kabul city is one of the urban areas in south-Asian regions in which the mountains and hills cover the closest area of this city, and almost half of the residential area of the city is in the mountainous or hilly areas. So, this complex structure and un-planned build-up of homes affect citizen's daily life and made it difficult to detect and evaluate the flooded areas of the city. In this case, in the present work, we attempted to identify and assess flooded prone areas via using the satellite imagery between 2014 - 2019. So, From 2014 till 2019, the satellite images such as lansat-8 OLI satellite image, which has a 16-day repeat cycle and Planet-scope image which has daily (early 2017) revisit time, were accused to process and evaluated the flood event in Kabul city. These satellite imageries were captured during the flood event and after the flood event. Within the scope of the present thesis, satellite imagery has been examined and evaluated to find the flooded area. So, evaluation of the satellite imagery via image processing for the affected and non-affected areas of Flood has given in the below:

4.3.6.1. Kabul City - Flood 22Dec - 2014

Landsat-8 OLI images, which have taken for the dates of 8th October 2014 (before flood event) and 27th December (after flood event), were downloaded and processed to detect the flood event which took place on 22nd December 2014 in Kabul city. In this case, to identify the floodwater, we combined band 3 (Green) and band 6 (SWIR) for Landsat-8 OLI Imagery and the combination of band 2 (Green) and band 4 (NIR) have been used for Planet-scope imagery. Furthermore, we calculated the water level before the Flood and after the Flood in the same area in which Flood took place. In addition, some times, the same area has different colors in the image; the reason is the effect of the different seasons in which the image was captured. The pre-flood and post-flood area showed in the bellow figure 4.25 for the year 2014.

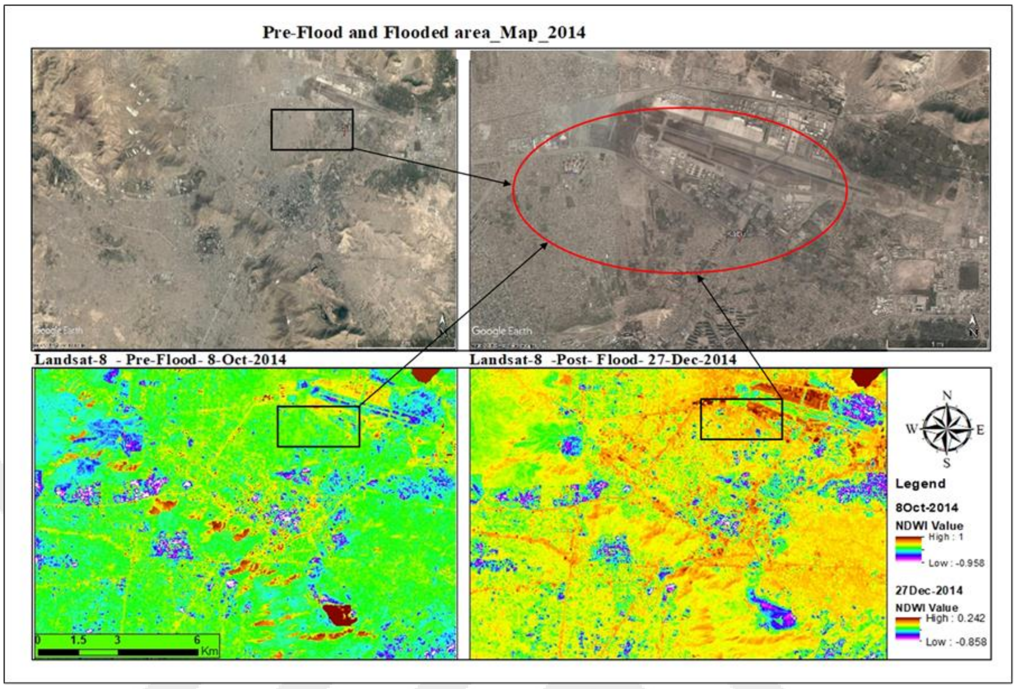

Figure 4.25. *The flooded area of Kabul city which took place on 22 December 2014 and the event detected via satellite images.*

The flooded area, according to the calculation of the flood pixel for the flooded area, has been equaled to 1517175 m^2 ($\cong$1.5171km^2) or according to the hectare, it is equal to ($\cong$151.71h). So, this area is including to the 1st 2nd and 8th district of Kabul city. In addition, on the same date, according to Hydrometeorological station base data, the amount of percepatation of the Kabul city is high, and these variable values are showen in the bellow Figure 4.26.

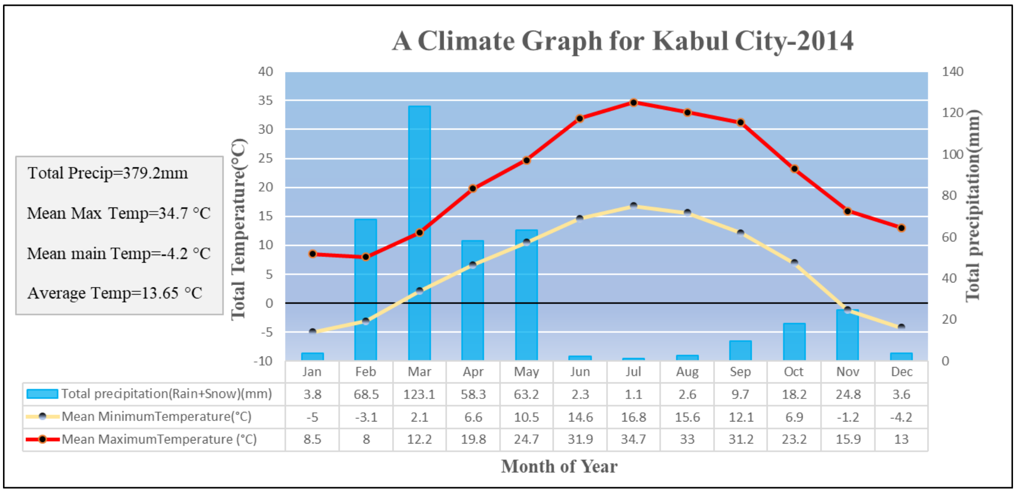

Figure 4.26. *Monthly Total Temperature and total Precipitation for the Kabul city in 2014.*

4.3.6.2. Kabul City - Flood 28July - 2015

Landsat-8 OLI images, which were taken for the dates of 13th February 2015 (before flood event) and 8 Agust (after flood event), were downloaded and processed to detect the flood event which took place on 28th July 2015 in Kabul city. In this case, to detect the floodwater, we combined the band 3 (Green) and band 6 (SWIR). Furthermore, we calculated the water level before the Flood and after the Flood in the same are which Flood took place. In addition, some times, the same area has different colors in the image, and the reason is the effect of the different seasons in which the image was captured. The pre-flood and post-flood area showed in the bellow figure 4.27 for the year of 2015.

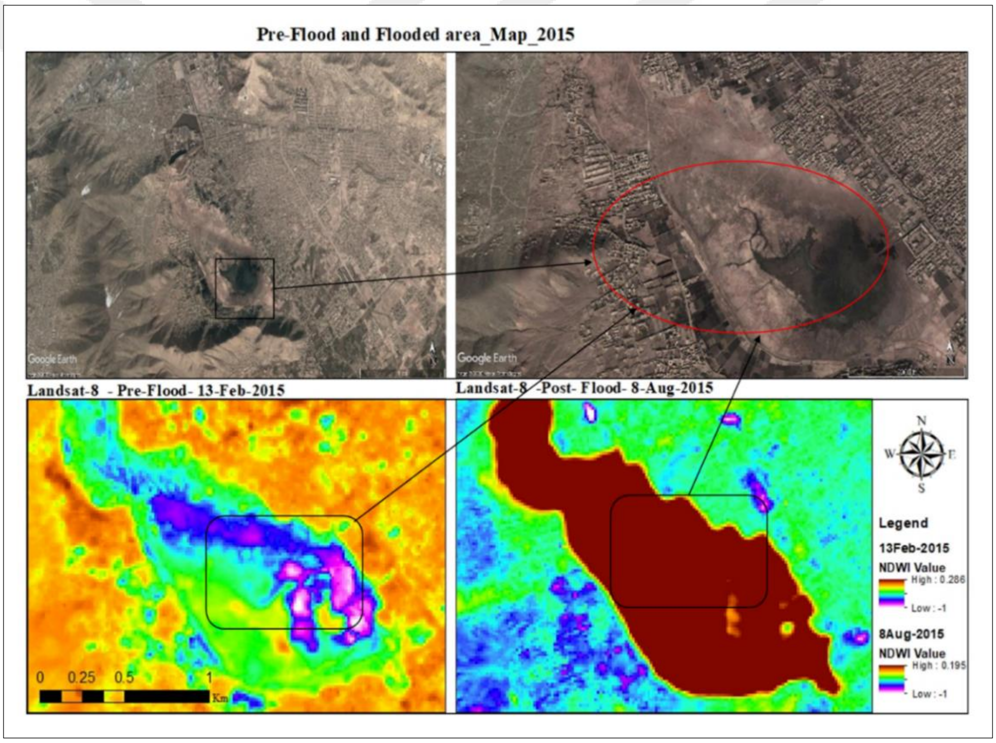

Figure 4.27. *The flooded area of Kabul city took place on 28 July 2015 and the event detected via satellite images.*

The flooded area according to the calculation of the flood pixel for the flooded area is equal to 2169720 m^2(≅2.169 km^2) or according to hectare it is equal to (≅216.9 ha). So, this area is including the 7th and 8th district of the Kabul city. In addition, on the same date, according to Hydrometeorological station base data, the amount of precipitation and temperature of the Kabul city variable values are shown in the bellow Figure 4.28.

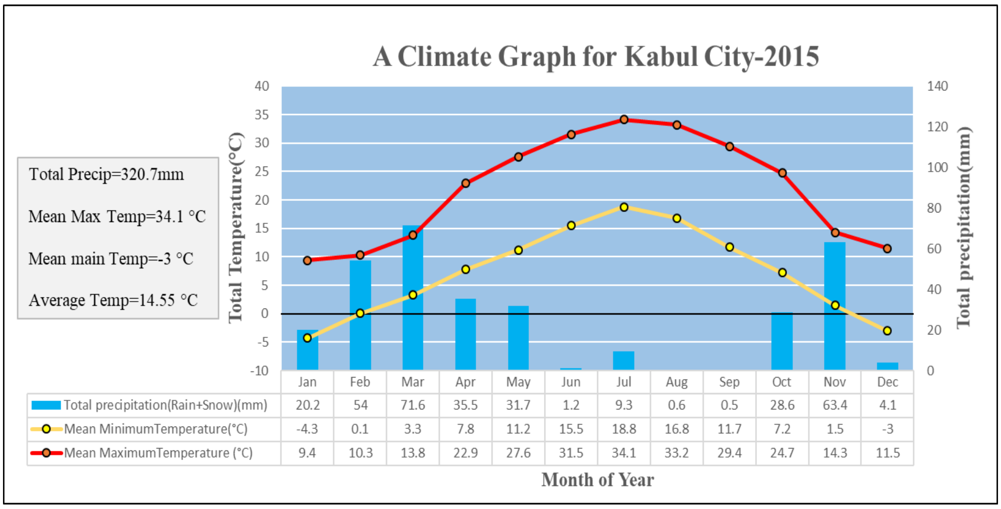

Figure 4.28. *Monthly Total Temperature and total Precipitation for the Kabul city in 2015.*

4.3.6.3. Kabul City-Flood 4April – 2016

Landsat-8 OLI images, which were taken for the dates of 18th February 2016 (before flood event) and 4th April 2016 (after flood event) were downloaded and processed to detect the flood event which took place on 30, 31st March 2016 in Kabul city. In this case, to detect the floodwater, we combined the band 3 (Green) and band 6 (SWIR). Furthermore, we calculated the water level before the Flood and after the Flood in the same are which Flood took place. In addition, some times, the same area has different colors in the image; the reason is the effect of the different seasons in which the image was captured. The pre-flood and post-flood area showed in the bellow figure 4.29 for the year of 2016.

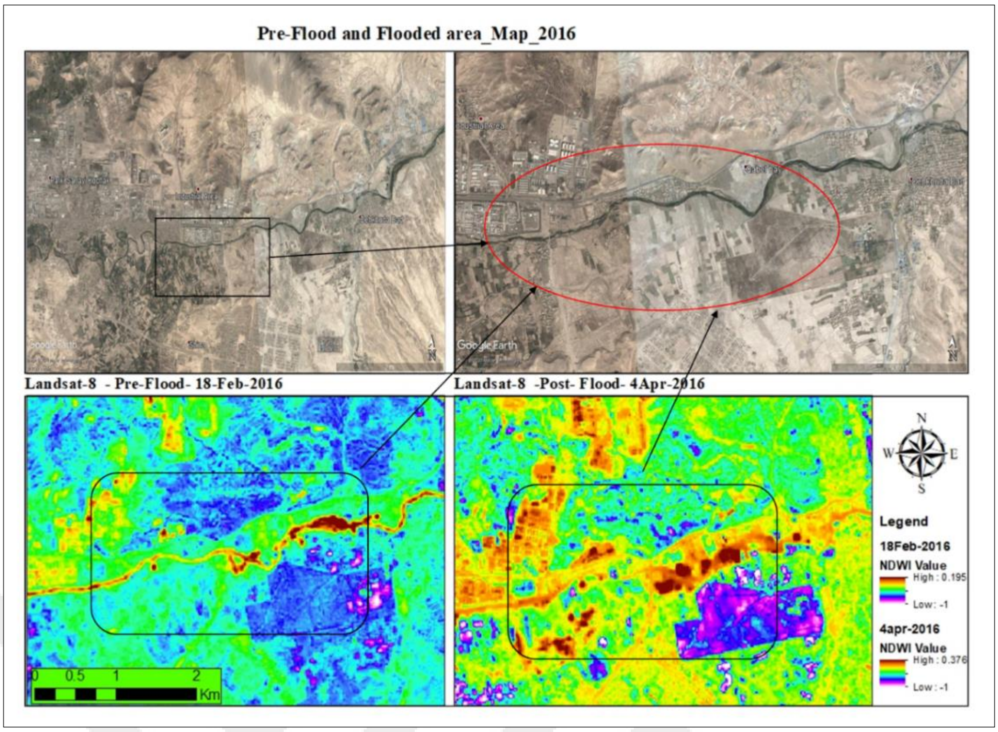

Figure 4.29. *The flooded area of Kabul city which took place on 30, 31 March 2016 and the event detected via satellite images.*

The flooded area according to the calculation of the flood pixel for the flooded area is equal to 2400015 m^2($\cong$2.40 km^2) or according to hectare it is equal to ($\cong$240 ha). So, this area is including the city center and the 7th district of Kabul city. In addition, on the same date, according to Hydrometeorological station base data, the amount of precipitation of the Kabul city is so high on march month, and these variable values are shown in the bellow Figure 4.30.

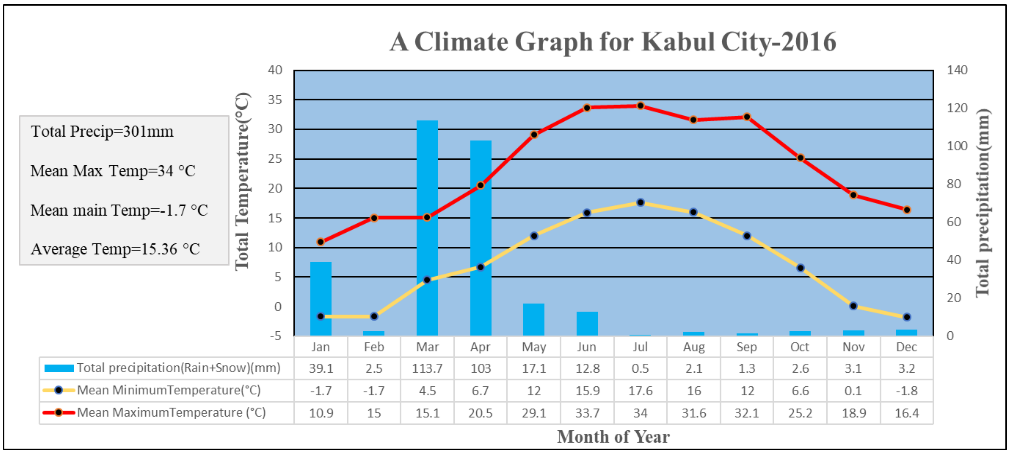

Figure 4.30. *The monthly Total Temperature and total Precipitation for the Kabul city in 2016.*

4.3.6.4. Kabul City - Flood 22Dec – 2017

Landsat-8 OLI images which were taken for the dates of 6th March 2017 (before flood event) and 31st March 2017 (after flood event) were downloaded and processed to detect the flood event which took place on 21st March 2017 in Kabul city. in this case, to detect the flood water we combined the band 3 (Green) and band 6 (SWIR) furthermore we calculated the water level before the Flood and after the Flood in the same are which Flood took place. In addition, some times, the same area has different colors in the image, and the reason is the effect of the different seasons in which the image was captured. The pre-flood and post-flood area showed in the bellow figure 4.31for the year of 2017.

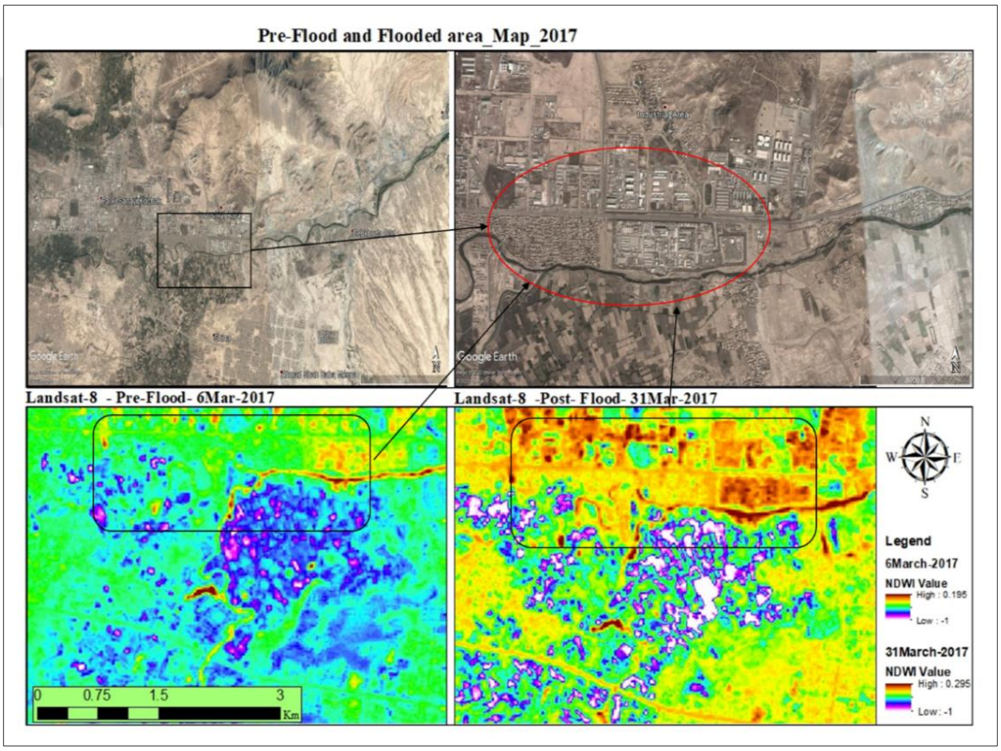

Figure 4.31. *The flooded area of Kabul city which took place on 21 March 2017 and the event detected via satellite images.*

The flooded area according to the calculation of the flood pixel for the flooded area is equal to 9764325 m^2(≅9.76 km^2) or according to hectare it is equal to (≅976.43 ha). So, this area is including in the city center and 7th district of Kabul city. In addition, on the same date, according to Hydrometeorological station base data, the amount of precipitation of the Kabul city is so high on march month, and these variable values are showen in the bellow Figure 4.32.

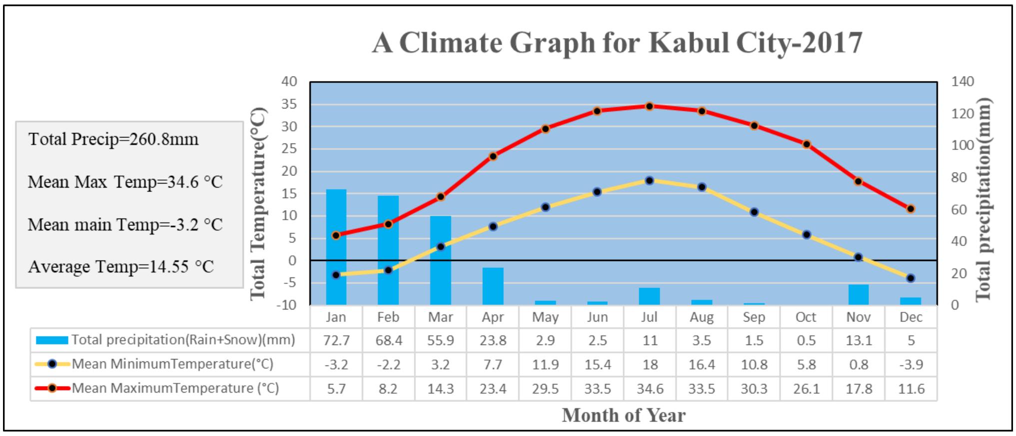

Figure 4.32. *The monthly Total Temperature and total Precipitation for the Kabul city in 2017.*

4.3.6.5. Kabul City - Flood 22Dec – 2018

Planet-scope images that were taken for the dates of 5th January 2018 (before flood event) and 21st April 2018 (after flood event) were downloaded and processed to detect the flood event which took place on 21st April 2018 in Kabul city. In this case, to detect the floodwater, we combined the band 2 (Green) and band 4 (NIR). Furthermore, we calculated the water level before the Flood and after the Flood in the same are which Flood took place. In addition, some times, the same area has different colors in the image, and the reason is the effect of the different seasons in which the image was captured. The pre-flood and post-flood area showed in the bellow figure 4.33 for the year of 2018.

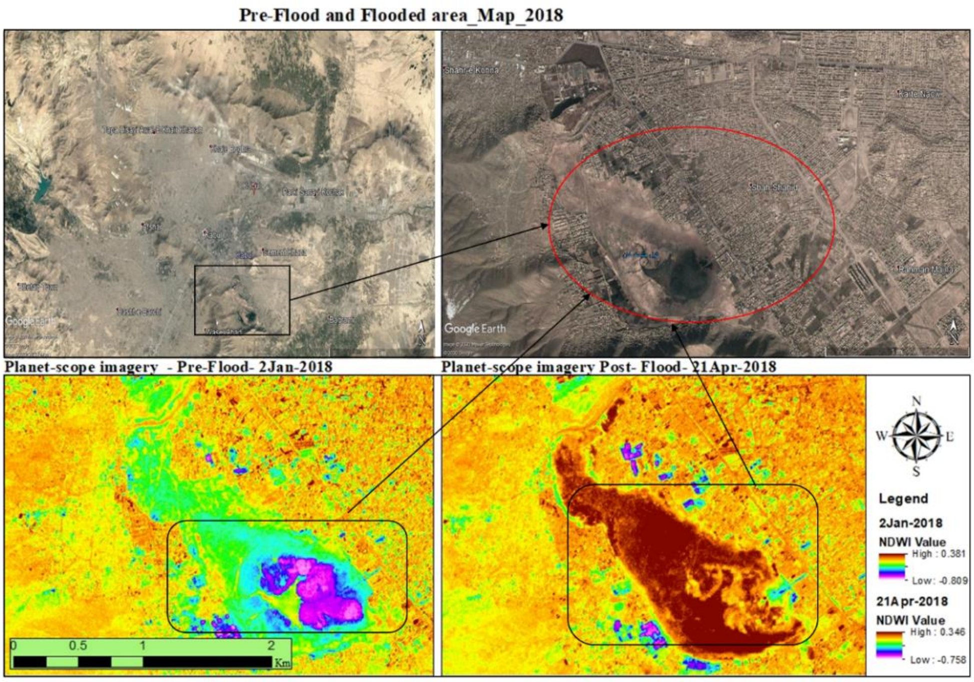

Figure 4.33. *The flooded area of Kabul city which took place on 21 April 2018 and the event detected via satellite images.*

The flooded area according to the calculation of the flood pixel for the flooded area is equal to 815868 m^2(≅0.81km^2) or according to hectare it is equal to (≅81.58 ha). So, this event took place in the 16th district (Bagrami) and the 8th district of Kabul city. In addition, on the same date, according to Hydrometeorological station base data, the amount of precipitation of the Kabul city is so high on march month, and these variable values are showen in the bellow Figure 4.34.

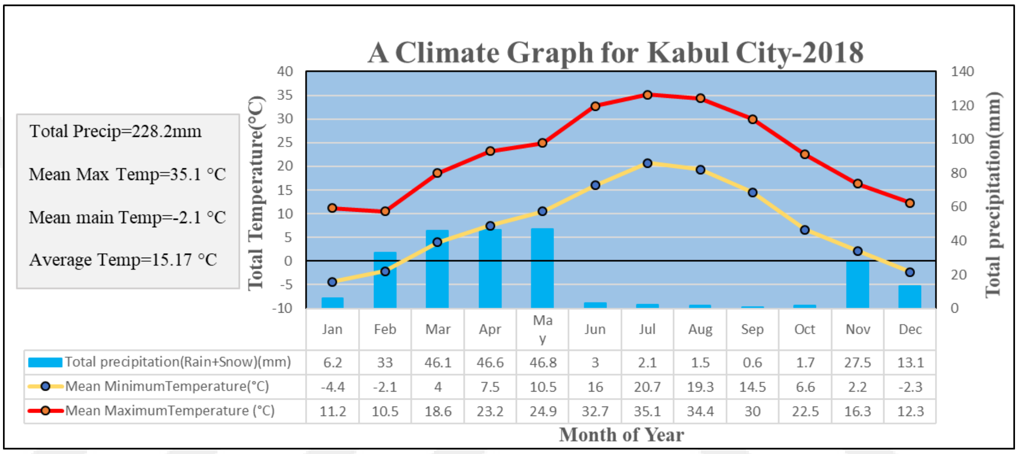

Figure 4.34. *The monthly Total Temperature and total Precipitation for the Kabul city in 2018.*

4.3.6.6. Kabul City - Flood 22Dec – 2019

Planet-scope images that were taken for the dates of 31st March 2019 (before flood event) and 27th April 2019 (after flood event) were downloaded and processed to detect the flood event which took place on 14,16,18,27 April 2019 in Kabul city. In this case, to detect the floodwater, we combined the band 2 (Green) and band 4 (NIR). Furthermore, we calculated the water level before the Flood and after the Flood in the same are which Flood took place. In addition, some times, the same area has different colors in the image, and the reason is the effect of the different seasons in which the image was captured. The pre-flood and post-flooded area showed in the bellow figure 4.35 for the year of 2019.

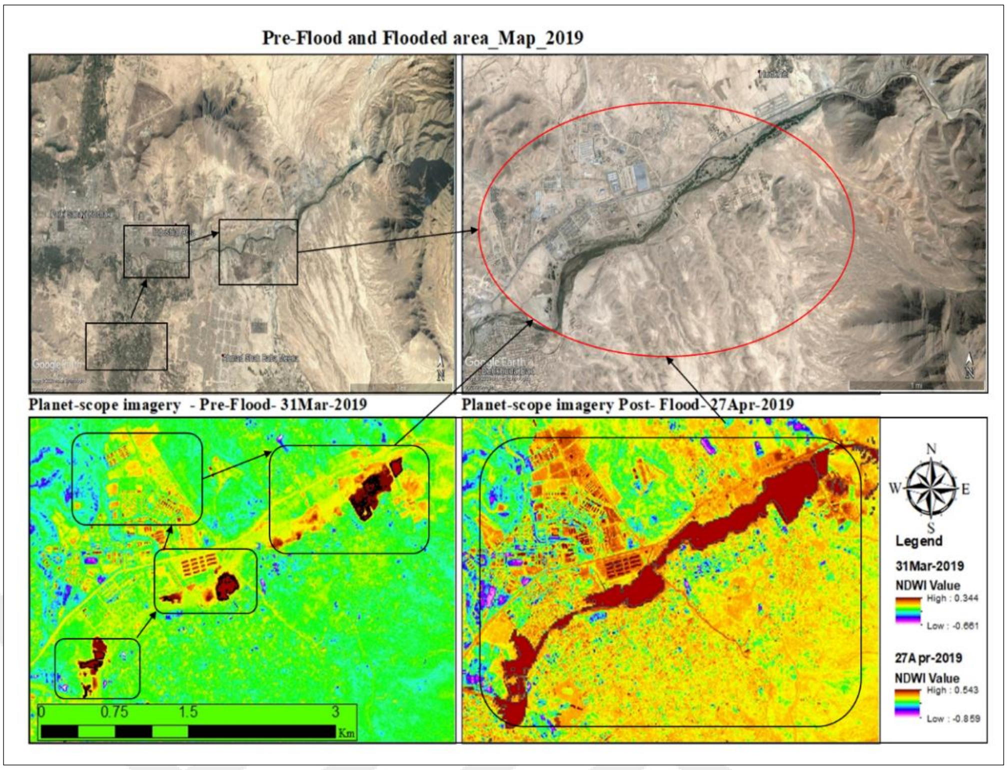

Figure 4.35. *The flooded area of Kabul city which took place on 21 April 2018 and the event detected via satellite images.*

The flooded area according to the calculation of the flood pixel for the flooded area is equal to 8824437 m^2(≅8.82 km^2) or according to hectare it is equal to (≅882.4 ha). So, this event took place in the city center, 5th,6th, 9th, 13th, 15th, 16th(Bagrami) districts of Kabul city. In addition, on the same date, according to Hydrometeorological station base data, the amount of precipitation of the Kabul city is so high on march month, and these variable values are showen in the bellow Figure 4.36.

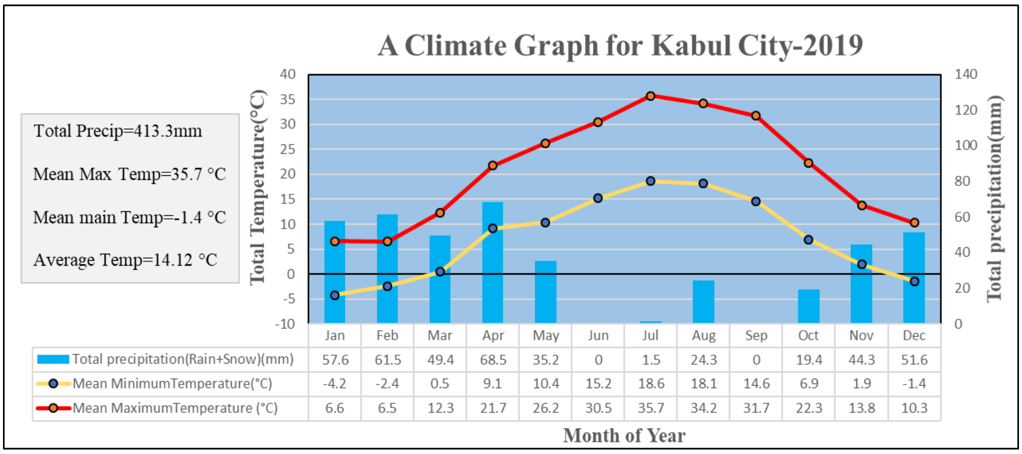

Figure 4.36. *The monthly Total Temperature and total Precipitation for the Kabul city in 2019.*

For the calculation of flood pixel formula for the Landsat-8 OLI imagery, we combined the band 3 (Green, before the Flood) and the band 6 (SWIR, after the Flood). In addition, for the calculation of flood pixel formula for the planet-scope imagery, we combined the Green (band 2- before the Flood) and NIR bands (band 4- after the Flood). Flooded prone area showed in the bellow figure 4.37 for the year of 2019.

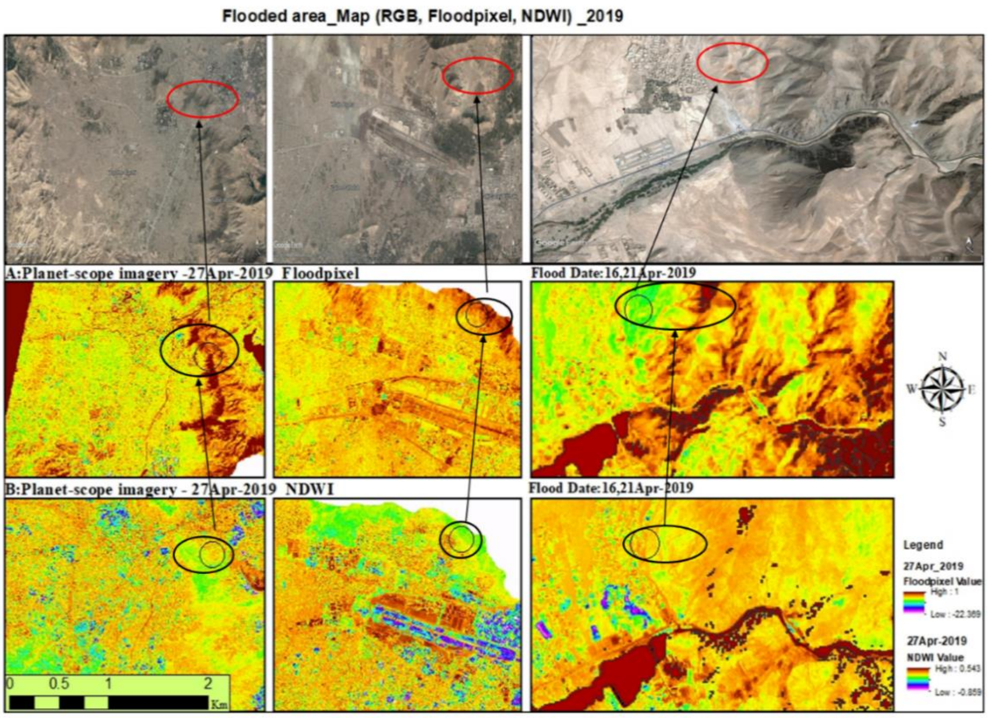

Figure 4.37. *The RGB colors, Flood-pixel and NDWI formula for flooded area of Kabul city which took place on 16,21 April 2019 and the event detected via satellite images.*

In this case, the flood pixel formula has not proved the floodwater of the present study area. So, the two different images (before and after the Flood) band combination was not proved the flooded area because it was mixed the non-flooded area with the flooded area and we could not find differences between them, such as the top areas of the mountains and the top areas of hills. It means it did not make the floodwater as a clear, and determining the flood areas was with a lot of errors, especially for the present study area. So, the best method to detect the flooded area according to calculation and high accuracy assessment was the NDWI formula for the current study area than others.

4.3.7. Kabul City Runoff and Rainfall comparison

The comprehensive reaction of runoff and rainfall, according to Hydrometrological Station data, is a crucial point for water management. The interaction between flow and rain is significant in hydro-metrological science, such as of the analysis of climatical events like drought and Flood. In the present work, we compared the total precipitation and water flow of the Kabul river as a monthly and annually for better understanding the reaction of the precipitation and runoff in Kabul city. Usually, in Kabul city, during the spring season in April and May, the precipitation is as rain form and during the winter season in December, January, February, March as snow form. So, mostly the spring season rains cause Flood event in the city. Besides, on the same date of flood event according to Hydrometeorological station base data, the peak discharge for the Kabul River, which crosses among the Kabul city, has bee explained for the present research. So, the floods peak discharge value according to Hydrological station base data, which recorded between the year 2009-2019 for the Kabul city showed in the below graph as separately for each station. Each of the stations showed in the bellow figure 4.38.

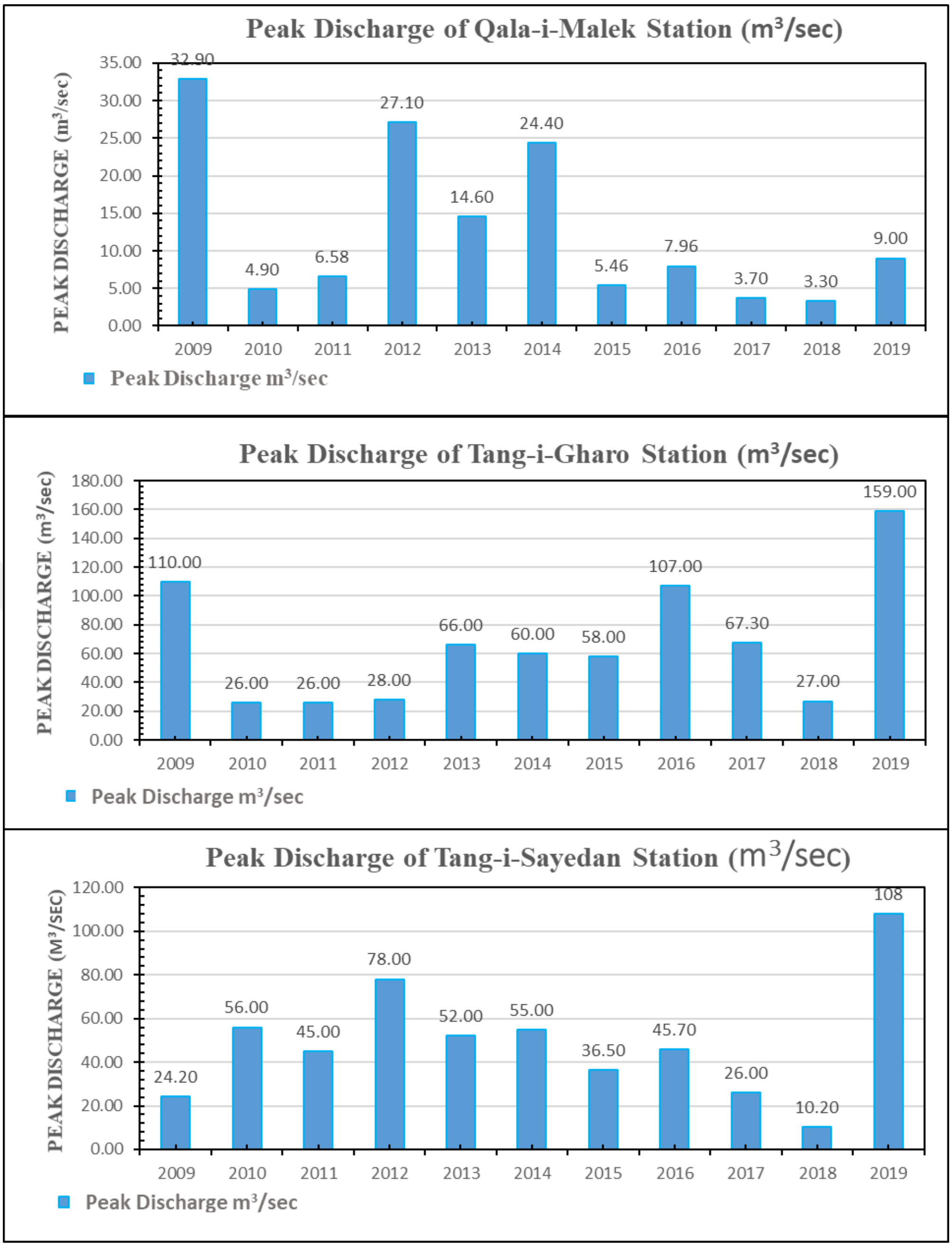

Figure 4.38. *Peak discharge for the Kabul city via three different Hydrological stations base data between 2009-2019.*

The Comparison of precipitation and flooding peak in three different hydrometeorological stations in Kabul city which, based on observational figured of precipitation and water flow for the elven year between 2009 to 2019. So, the annual flood peak rate is at the Qala-i-Malek station is 9m^3/sec, annual flood peak at Tang-i-Gharo station is 159 m^3/sec, and yearly flood peak at the Tang-i-Sayedan is 108m^3/sec. The below graph showed the Comparison between total precipitation and discharge in the year

2019 for Kabul city, which recorded by the hydrometeorological station in Kabul city. Each of the stations showed in bellow figure 4.39.

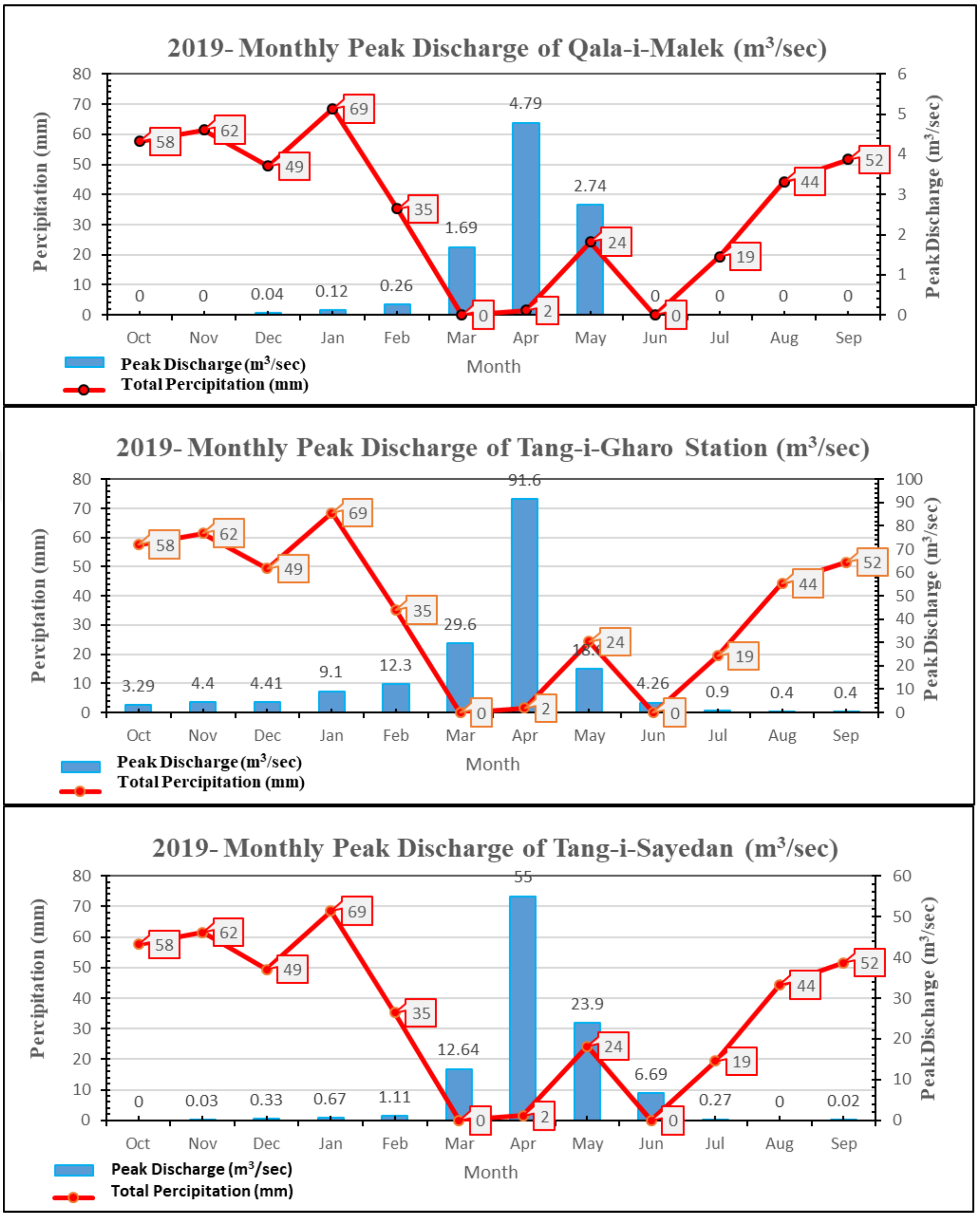

Figure 4.39. *The Comparison of precipitation and flooding peak in the Kabul city by three different hydrometeorological stations base data in 2019.*

As conclusion, the above figures shows that in Tang-i-Seydan and Tang-i- Gharo station the highest water flow peak in 2019 and was recorded at 108 cubic meters per second and 159 cubic meters per second for both stations, in this case, the heavy rainfall in April of 2019 caused the flood phenomena in the city and this high flood peak has broken the historical record and shows the highest figures in the last few decades in Kabul city.

4.3.8. Evaluation of the present Research work and finding

For the evaluation of the flood event, the historical flood event data has an essential role because of the area which affected via flood event in the past, and this recorded data it helps us for future planning. It will be easy to make a definite plan with high proficiency and low economic coast for the future flood event, which is going to take place in the same area annually. A necessary measure applied according to flood history data will be essential steps and help us to protect the environmental process, in addition in the same affected area, the environmental degradation will be at a low level in the future.

In Afghanistan, unfortunately, we do not have the complete recorded data of the past flood disasters. But we have a few year records of the flood disasters which are recorded by the government after the disaster in the area. So, Historic floods are essential steps and one of the pre-flood assessment methods. Besides, a record of the flooded area is the main point to identify the dangerous places correctly. Thus, the history of the flood vulnerable areas assists us in making a more efficient plan. These steps do not entirely express the spread area of the Flood. In this case, to increase the accuracy in the determination of the spreading area of Flood and vulnerable areas, it will be perfect and useful to use geospatial technology, especially remote sensing systems. If we can record the Flood along with the places where it spreads, the vulnerable and dangerous area can be correctly identified. For a safe and clean environment with a standard environmental process in our country, especially in the large cities, the flood event must be recorded along with their spreads areas. Via methods of remote sensing technology, the floodwater area map, which descript the vulnerable area, it will be easy to detect with high accuracy the flood zones, and flood-prone area figured in the bellow figure 4.40.

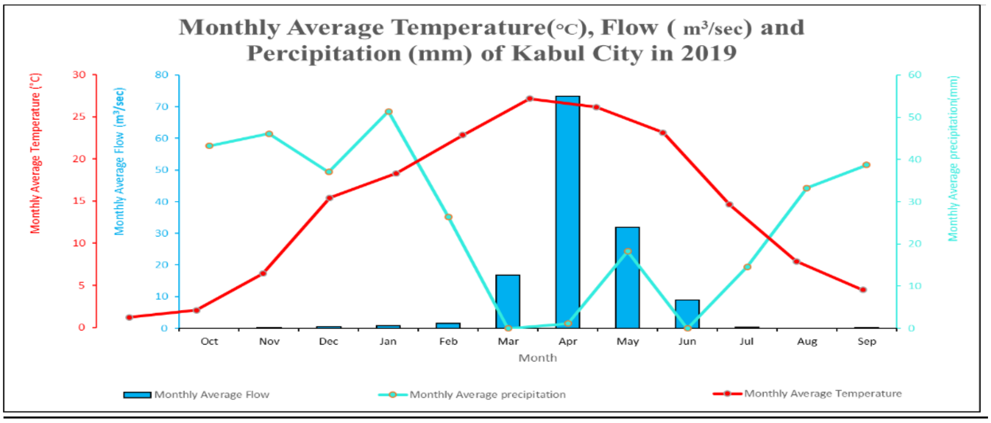

Figure 4.40. *Compression of monthly average Temperature, monthly average flow and monthly average Precipitation for Kabul city in 2019.*

From 2009 till 2019, we have a variable climate element for Kabul city, which in figure 4.41 showed in the bellow.

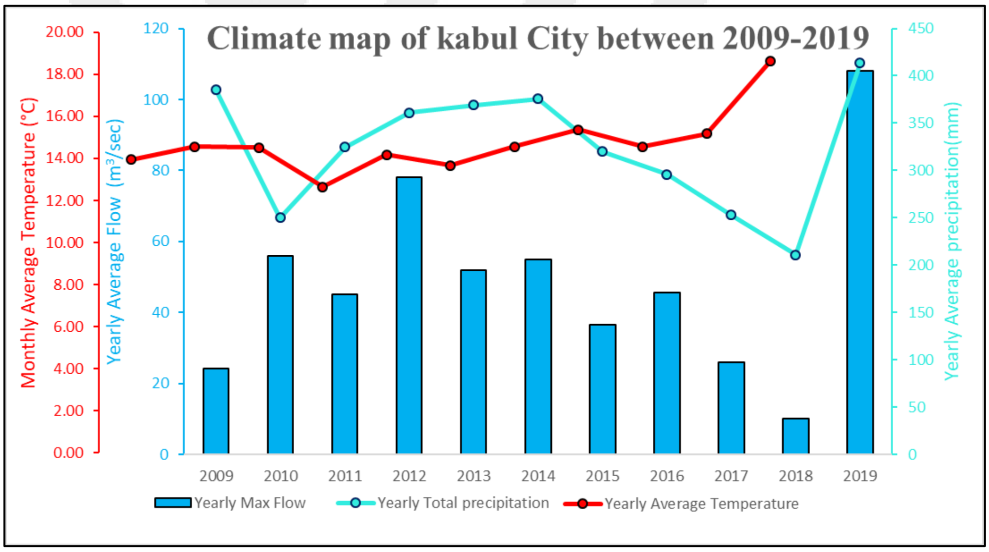

Figure 4.41. *Compression of Yearly average Temperature, Yearly Max flood peak and Yearly average Precipitation for Kabul city between 2009 - 2019.*

In different parts of Kabul City, some close sides of the Kabul river, even riverside are illegally expropriated for settlement by people, especially this expropriation action in the two past decades was as high level. Comparison of the riverside and close area to the Kabul City river between 2008 and 2016, which has been used for habitation, showed in the bellow 4.42.

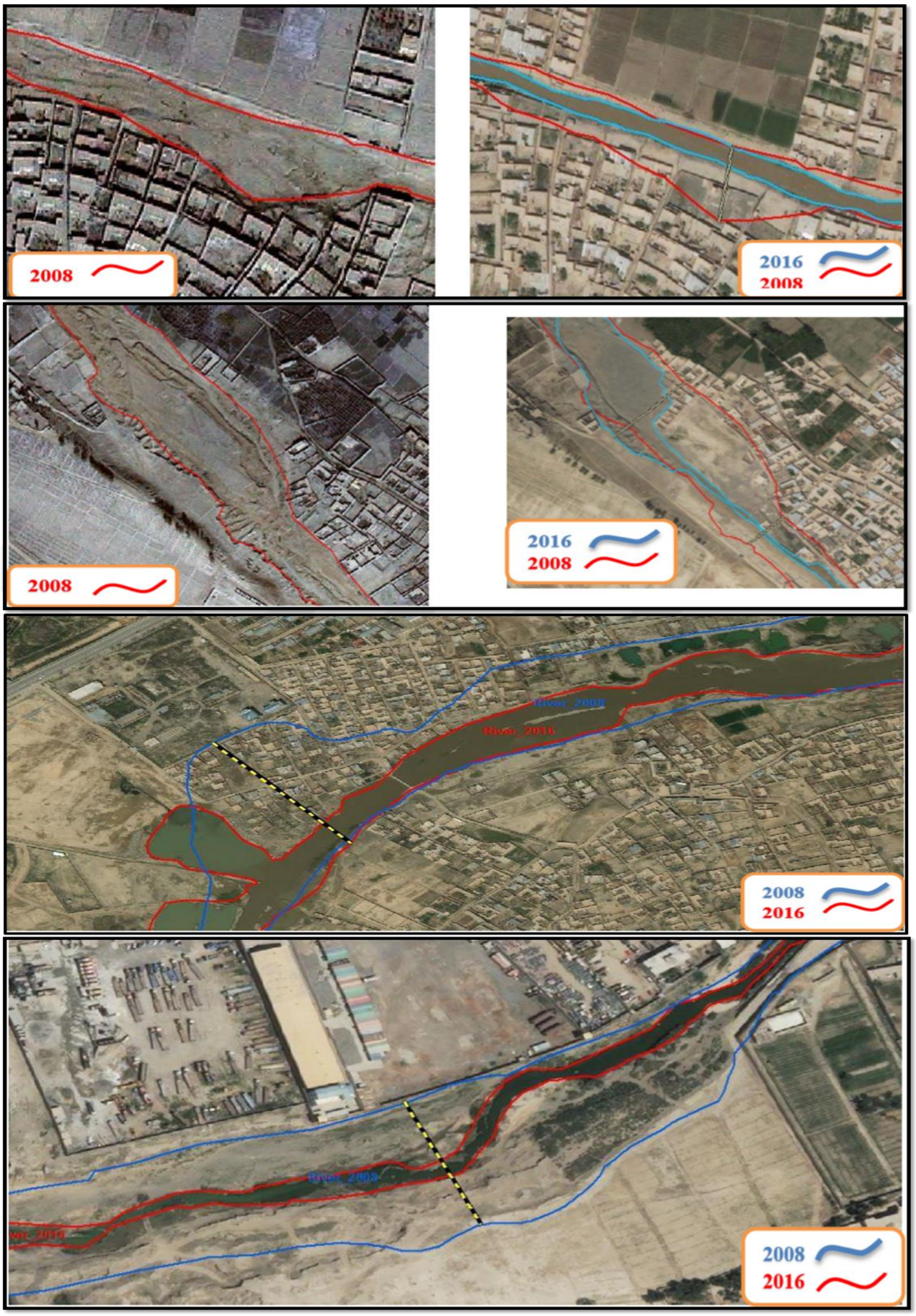

Figure 4.42. *Compression of Yearly average Temperature, Yearly Max flood peak and Yearly average Precipitation for Kabul city between 2009 - 2019.*

In the bellow flood, an aerial photograph showed the affected area of Flood, and the pictures were taken during a survey of the Kabul riverside and Qargha Dam in Kabul city in 2019, after flood event and showed in bellow figure 4.43.

Image 4.1. *Survey of Kabul city riverside which affected by Flood event, 2019.*

In the bellow flood, an aerial photograph showed the Flooded prone area in Kabul City and the photographs were taken during and after the Flood event in Kabul city, and max flood flow in River and closet area which neighbored with riverside in Kabul city, in 2019 and the affected area showed in bellow figure 4.44.

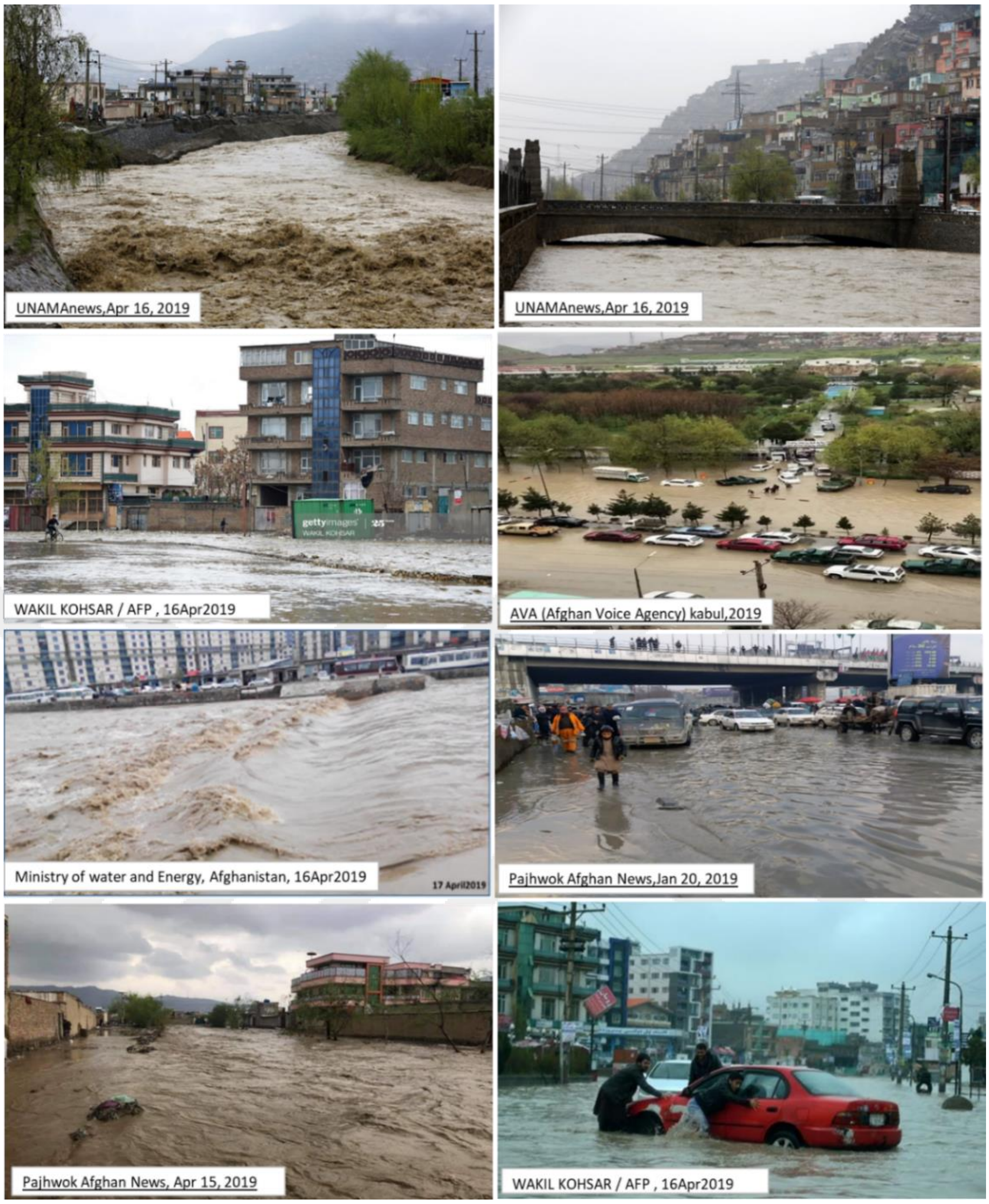

Image 4.2. *Kabul city affected by Flood event, 2019.*

5. CONCLUSION AND RECOMMENDATION

This chapter focuses on explaining the conclusion I reached to by doing this research work and related recommendation.

5.1. Conclusion

According to the report of UNEP (United Nations Environment Program) and WMO (World Meteorological Organization) organization in the past hundred years, the earth's surface climate change is so high, and this issue affects the amount of precipitation and environmental degradation. The reason for this phenomenon is human and natural activities. Economic and social activities of humans, specially the consumption of fossil fuels, are among the most essential factors affecting earth’s atmosphere negatively and causing climate change. If the current trend continues, severe climate change will occur in the coming decades. And that's a significant threat to environmental processes. According to studies, Afghanistan is one of the countries facing rising temperatures, declining rainfall, frequent floods and droughts in recent decades as a result of massive human activities and consumption of fuels in large cities, especially in Kabul. The reason for over-vulnerability of Kabul city against the threat of climate change is the uneven and complex topographic structure of Kabul city which increases the level of environmental threat, namely, pollution and ecosystem degradation. The findings of this study show that; in Kabul city especially in recent years, the rising temperatures have been reducing the amount of precipitation and resulting in less-watery years. For example, the years 2009, 2015, 2017 and 2018 are the times when the amount of precipitation in the city has been low, but the temperature has been high, and the flow rate has also been low.

Analysis of the climate graph (Precipitation graphs, temperature and flood peaks) in Kabul between 2009 and 2019 shows that the highest rainfalls happen in February, March, and April, while the highest temperatures are recorded in June and July. Most of the significant flood peaks were recorded in April month. Therefore, climate change has increased the temperature, reduced the amount of rainfall and flow. These changes indicate that the peak of rainfall does not correspond to the peak of floods. They have affected environmental processes and the flood risk level is increased, Also we are witnessing environmental degradation in Kabul city, and is increasing day by day. Kabul's riverside areas in Kabul city have been occupied by citizens who have built their homes and buildings without standard canalization systems for managing water and sewage.

Without observing the government construction law, this kind of construction built-up close to the riverside has caused the river area to shrink, which can be especially observed in the center of the city. This kind of arbitrary actions has played a significant role in increasing the risk level in the urban areas like Kabul city which is affected by the floods event almost every year.

According to the Flood pixel formula and NDWI index calculation, flooded areas in Kabul city in the year 2014 were equal to 151.71 hectares (figure 4.28), in 2015 it rose up to 216.97 hectares (figure 4.30), in 2016 to 240 hectares (figure 4.32), in 2017 to 976.4 hectares (figure 4.34), in 2018 to 81.6 hectares (figure 4.36) and in the year 2019 it demonstrated a value of 882.4 hectares (figure 4.38). Most flooded areas occurred inside the city. The present work's results showed that the water bodies' like Qargha-Dam were increased after as a result of Floods. The new finding in this present study is the useful usage of Geographical information system and Remote sensing technology for the assessment of climate change impact on environmental processes. We should use this valuable tool in our country, like a developed country for climate change analysis, such as the monitoring of Flood, water resource management and environmental risk reduction. For example, offering the information via satellite imagery in which the human reach or accessibility is not possible, or we only have very low access to them. Especially in the present study for calculation of Flood pixel and NDWI index Planet-scope imagery, it has more sensitivity than Landsat-8 OLI imagery because it's of high resolution.

Flood pixel formula and NDWI formula is a new method developed for the detection of open water and floodwater. In the present work, it has been proved that the NDWI index has been more accurate and sensitive than flood pixels formula for the detection of the urban area flood, which is shown in (figure 4.40). One of the reasons why Flood-pixel formula was not suitable for present work is the complex topographic structure of Kabul city.

5.2. Recommendation

- Preventing and prohibiting the dumping of garbage and waste at the riverside to prevent the riverbed from rising and filling during the floods and the risk level is not much at that time.
- Preventing and banning the construction of buildings and houses close to the riverside.
- Preventing and banning the flow of sewage, wastewater and factory waste into water sources.
- Creating of Geodatabase system for recording flood events' date and time in the city with their specific geographic coordination's. Furthermore, geospatial technology should be used for the impacted assessment of climate change on the environmental processes, monitoring and decreasing the risk level in the future.
- Management and monitoring of the flood risk in the urban areas are so expensive. For Afghanistan, especially for Kabul city, I recommend the use of cheapest and effective ways like using remote-sensing data for monitoring and management of the flood event.
- Creating the database system to provide the updated information for public people and researchers in cases of flooding event by providing the online service accessibility.
- In the vulnerable areas, relatively accurate statistics should be prepared from the houses, and the number of people threatened by flood events.
- In the middle Kabul river basin, there are not enough active meteorological stations for the recording of precipitation where rainfall is one of the most and essential elements in flood forecasting. Also, it can be caused to decrease the risk level of environment.
- The approval of the riverside regulation, ecosystem areas for Kabul city, and the renewal of the urban master-plan, taking into observing the environmental laws and regulations that are considered a major necessity for Kabul city today, should be implemented and is recommended to be continuous.

In Kabul city, serious attention should be paid to the ecosystem, Forest and Greenland areas because at present, we are witnessing the terrible situation of the city and by every day passed, the city faces a different environmental problem, mainly, pollution and ecosystem degradation.

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