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The contribution of geomatics to the development of a natural risk prevention plan, case study El Guerrara

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DEDICATION

I dedicate this master's thesis to all those who have supported and inspired me throughout this journey.

To my family, whose unwavering love and encouragement have been my anchor, thank you for always believing in me and providing the support I needed to pursue my academic goals.

To my friends and classmates, thank you for the countless hours of study sessions, discussions, and encouragement. Your camaraderie and shared experiences have made this academic pursuit all the more meaningful.

This thesis is dedicated to all of you, as a token of my appreciation and gratitude. May our collective efforts contribute to the betterment of society and the advancement of knowledge in our chosen field

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ABSTRACT

Abstract:

The integration of the Geomatics that holds the GIS, and other geospatial technologies with modern tools of measurements provides a powerful platform for monitoring and managing natural risks, including identifying vulnerable areas, assessing potential impacts, and developing effective strategies for disaster preparedness and response.

The study was done using Geospatial data from the open sources like Landsat 8-9 Products of imagery images, Sentinel-1 and Shuttle Radar Topography Mission data that are presented as digital elevation models (DEM)s for better insight about the natural risk, and by determining all the factors and causes that could led to any further potential risk of flooding in the study area; El Guerrara.

Keyword: Geomatics, Flood Risk, Prevention Plan, El Guerrara.

Résumé :

L'intégration de la géomatique qui contient le SIG et d'autres technologies géospatiales avec des outils de mesure modernes fournit une plate-forme puissante pour surveiller et gérer les risques naturels, y compris l'identification des zones vulnérables, l'évaluation des impacts potentiels et l'élaboration de stratégies efficaces pour la préparation et la réponse aux catastrophes.

L'étude a été réalisée à l'aide de données géospatiales provenant de sources ouvertes telles que Landsat 8-9 Produits d'images d'imagerie, les données Sentinel 1 et Shuttle Radar Topographie Mission qui sont présentées sous forme de modèles numériques d'élévation (DEM) pour une meilleure compréhension du risque naturel, et par déterminer tous les facteurs et causes qui pourraient entraîner tout autre risque potentiel d'inondation dans la zone d'étude ; EL Guerrara.

Mot clé : Géomatique, Risque Inondation, Plan de Prévention, El Guerrara.

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Preface:

Natural disasters, such as earthquakes, floods, landslides, and wildfires, have been causing significant damage and loss of life around the world for centuries. The increasing frequency and severity of these events have led to the realization that traditional approaches to disaster management are no longer sufficient. Instead, a more proactive and preventative approach is required, which can help mitigate the risks associated with natural disasters.

This thesis explores the role of geomatics in developing a prevention plan against natural risks. Geomatics is an interdisciplinary field that incorporates various technologies, including Geographic Information Systems (GIS), Global Positioning Systems (GPS), remote sensing, and other data acquisition and analysis tools, to support effective decision-making in disaster management. The thesis investigates how these technologies can be utilized to create a comprehensive prevention plan that incorporates risk assessment, hazard mapping, and emergency response planning.

The research presented in this thesis draws upon case studies from different parts of the world to highlight the potential of geomatics in disaster management. It also evaluates the limitations and challenges associated with the application of geomatics in prevention planning, including data accuracy, availability, and accessibility.

This thesis is intended to provide insights into the use of geomatics in disaster management and to contribute to the ongoing efforts to develop effective prevention plans against natural risks. It is hoped that the research presented in this thesis will help decision-makers and planners to make informed choices and create more resilient communities in the face of natural disasters.

PREFACE

Problematic:

Despite the potential of geomatics technologies in developing a prevention plan against natural risks, their application remains limited in many parts of the world. This raises questions about the reasons for this limitation and the barriers that prevent the widespread use of geomatics in disaster management. Moreover, there are concerns about the effectiveness of geomatics-based prevention plans, and whether they adequately address the complex and dynamic nature of natural risks. Therefore, this thesis aims to explore the limitations and challenges associated with the application of geomatics in disaster management, and to assess the effectiveness of geomatics-based prevention plans in mitigating natural risks. By addressing these issues, this thesis seeks to provide insights into how geomatics can be effectively used in developing prevention plans that can create more resilient communities in the face of natural disasters.

- How can geomatics be used to mitigate the risks associated with natural disasters such as floods in the city, and what are the ways of the geomatics contribution in developing a prevention plan for the natural risks?
- How can we defining the source of natural risk of flood; if its internal or from outside the city?

Hypotheses:

Through the questions that we had in the problematic, we were able to make hypotheses for our research;

- The geomatics may help, through implementing its tools and technology in the analysis of all aspect and factors of the natural risk, leading to defined the red zones in order to reduce its impacts as much as we can.

- The sources of flooding could be external due to the low annual precipitation in the city.

PREFACE

Research objectives:

- Define the flood risk zone using Geomatics technology, and GIS Data.
- Investigation about future floods of 10 and 20 years, depending on the intensity of the rainfall.

Part I: Theoretical Framework

Chapter 1. Natural risk terms & definitions

I.1.1 Introduction:

Climate change causes a significant increase in the amount of natural disasters. Besides the frequency of natural disasters, the intensity and the economic damage of natural disasters are increasing. The severe effects of natural disasters are not to be underestimated with damages worldwide surpassing 100 billion US dollars in 2018. (Schipper, 2020)

A disaster is stated to occur when a society is unable to cope with the impact of an event, giving rise to humanitarian crises where people's safety, livelihoods and health become threatened. However, the severity of a disaster is not solely determined by the force of the hazard but also by the exposure and vulnerability towards them, which vary to a drastic extent depending on the amount of resources people and societies obtain. This interpretation of a disaster implies that societies have specific capacities to either maintain or lose control over the impacts from hazards. (Lindberg, 2022)

I.1.2 Definitions:

I.1.2.1 Risk:

It is accepted to define risk as the product of intensity and the probability of occurrence of a naturally occurring event. The intensity of an event can be related to the volumes of materials mobilized, as well as to the dynamics of the phenomenon. (François, 2019)

I.1.2.2 Exposure:

The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas.

Annotation: Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability and capacity of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest. (UNDRR, n.d.)

I.1.2.3 Hazard:

In the context of occupational health and safety, a hazard is any object, situation, or behavior that has the potential to cause injury, illness, damage to property, or harm to the environment. (Mishra, 2019)

In this more Cartesian context, danger is the intrinsic characteristic of an object or an activity, likely to materialize in an undesired event that will cause damage (ultimate consequences) that can go as far as the death of living beings. and total destruction of objects. (Wikipedia, 2021)

I.1.2.4 Vulnerability:

Vulnerability refers to the potential for casualty, destruction, damage, disruption or other form of loss in a particular element: risk combines this with the probable level of loss to be expected from a predictable magnitude of hazard (which can be considered as the manifestation of the agent that produces the loss). (Nguyen-Trung, 2019)

Hazards do not impact everyone equally. Some people and communities are more vulnerable to hazard impacts than others. People can be vulnerable if:

- They don’t understand the local hazards or the impacts they can have.
- They have no access to information about how to protect themselves or their property.
- They don’t have the resources they need to take action to protect themselves and their property. (Resilience, n.d.)

I.1.2.5 Disaster:

Is defined as any natural or human-generated calamitous event that produces great loss of human life or destruction of the natural environment, private property, or public infrastructure. A disaster may be relatively sudden, such as an earthquake or an oil spill, or it may unfold over a longer period, such as the effects of an ongoing pandemic or climatic disruption. (Rafferty, 2022)

Second definition of the disaster:

A disaster is a serious problem occurring over a short or long period of time that causes widespread human, material, economic or environmental loss which exceeds the ability of the affected community or society to cope using its own resources.

Disasters are routinely divided into either "natural disasters" caused by natural hazards or "human-instigated disasters" caused from anthropogenic hazards. (Wikipédia, 2023)

A disaster only occurs when a natural hazard impacts upon a vulnerable community. This can be represented in a disaster as follows:

Natural Hazard + Vulnerable Community = Disaster

But the risk in other hand can be described as follows:

Hazard + Exposure + Vulnerability = Risk (Monrat, 2018)

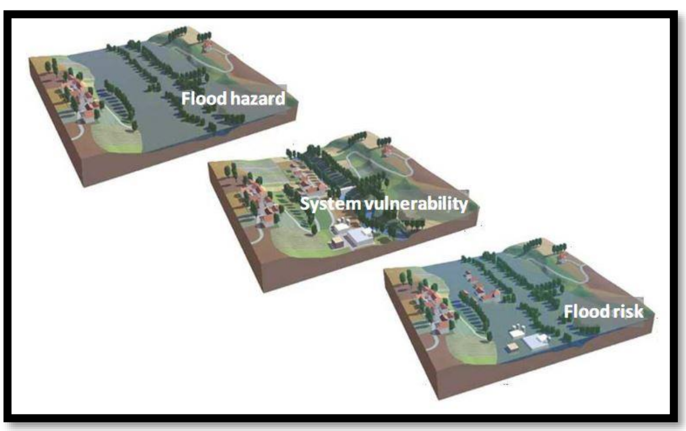


Figure I.1. Flood risk as the conjunction of hazard and vulnerability (ELEUTÉRIO, 2012)

I.1.3 The natural disaster classification:[1]

Biological	Geophysical	Hydrological	Metrological	Climatological
• Epidemic • Insect infestation • Animal stampede	• Earthquake • Volcano	• Flood	• Sandstorm	• Extreme temperature • Drought • Wildfire

I.1.4 The type of Natural Risk studied (Floods):

I.1.4.1 Definition:

Flooding is a natural process that occurs when the level of a body of water rises until it overflows its natural banks or artificial levees and submerges areas that were usually dry. Along a watercourse, a flood can manifest itself annually. Usually, highwater flow is contained between the natural banks or artificial levees, but when the volume of the flood waters can no longer be contained within those natural or artificial confines, waters expand into the surrounding areas. The flood extent follows adynamic propagation that depends essentially on the amount of water that overflows, the speed of the water flow, and the morphology of the surrounding areas. (Luino, 2016)

I.1.4.2 Flood Types:

I.1.4.2.1 River Floods:

A river flood occurs when a river overspills its banks; that is, when its flow can no longer be contained within its channel. Flooding is a natural and regular reality for many rivers. (Shaw, 2019)

I.1.4.2.2 Coastal Floods:

Coastal flooding is a sudden and abrupt inundation of a coastal environment caused by a short-term increase in water level due to a storm surge and extreme tides. The magnitude and

[1] https://www.researchgate.net/figure/Classification-of-natural-disasters-16_fig1_330400757

extension depend on the coastal topography, storm surge conditions and broader bathymetry of the coastal area.

Coastal flooding is generally a natural process and constitutes an important part of the natural coastal dynamics, especially for salt marshes and mangrove forests. In areas with human activities, however, it can constitute a major challenge and lead to loss of property and lives. (Wheel, n.d.)

I.1.4.2.3 Flash Flood:

A flash flood is a rapid rise of water along a stream or low-lying urban area. Flash flooding occurs within six hours of a significant rain event and is usually caused by intense storms that produce heavy rainfall in a short amount of time. (Measurement, n.d.)

I.1.4.2.4 Storm Surge:

Is the abnormal rise in seawater level during a storm, measured as the height of the water above the normal predicted astronomical tide. The surge is caused primarily by a storm's winds pushing water onshore. The amplitude of the storm surge at any given location depends on the orientation of the coast line with the storm track; the intensity, size, and speed of the storm; and the local bathymetry. (sevice, n.d.)

I.1.4.2.5 Urban Flooding:

Urban flooding is the accumulation of floodwaters that result when the inflow of storm water exceeds the capacity of a drainage system to infiltrate water into the soil or to carry it away. When a natural landscape is transformed by urban development, its drainage pattern is disturbed. (Sciences, 2019)

In many cases the so called floods are not caused by rivers overflowing but are caused by the inadequate drainage facilities. In urban areas this phenomenon occurs due to haphazard construction with poor planning which does not allow sufficient retention and percolation areas. In some cases people encroach drainage areas, even obstructing drainage paths and disrupting natural drainage patterns. (German Development Cooperation, 2008)

I.1.4.3 Factors of flood risk perception:

Tobin and Montz (1997) divide factors influencing the perception of risk and its main elements (awareness, worry, preparedness) into two groups: situational and cognitive ones. The former include:

- The physical location reflecting proximity to a hazard (the probability of the occurrence of flood);
- The nature of the flood (since a violent mountain flood is perceived differently to a lowland flood that is long-term in nature and can be predicted beforehand);
- The extent of the effects;
- The experience;
- The level of hazard awareness and the degree of its uncertainty;
- Socio-economic and demographic factors of the population (gender, age, education, income, number of children);
- The residence characteristics (owning a house, type of a building, presence of a ground floor, cellar);
- The cultural-historical context;
- Voluntary/involuntary nature;
- The group of people influenced by the flood (individuals can perceive a risk differently, depending on whether they are directly influenced themselves, their families are influenced or it regards people they are not connected to emotionally). (Lechowska, 2018)

I.1.4.4 Causes of flooding:

- Prolonged rainfall - if it rains for a long time, the land around a river can become saturated (it's holding as much water or moisture as can be absorbed). If there is more rainfall it cannot be soaked up, so it runs along the surface - this is known as surface run-off.

- Heavy rainfall - if there is heavy rainfall there is less chance of it being soaked up by the soil (infiltration) so it runs off into the river. The faster the water reaches the river, the more likely it will flood.

- Relief - a steep valley is more likely to flood than a flatter valley because the rainfall will run off into the river more quickly.

- Geology - permeable rocks allow water to pass through pores and cracks, whereas impermeable rocks do not. If a valley is made up of impermeable rocks, there is a higher chance of flooding as there is an increase in surface run-off.

- Vegetation - trees and plants absorb water, this is known as interception. Lots of vegetation reduces flood risk. Sometimes people cut down trees (deforestation). This will increase the flood risk, as the water will not be intercepted and flow into the river.

- Urban land use - when an area surrounding a river is built on, there is an increase in the amount of tarmac and concrete, which are impermeable surfaces. Drains and sewers take water directly to the river which increases flood risk. (BITESIZE, 2023)

I.1.5 Conclusion:

This chapter, we explored the concept of natural risk and its significance in the context of disaster management. We discussed various definitions and classifications of natural hazards, emphasizing their unpredictable and potentially destructive nature. Furthermore, we examined the distinction between natural hazards and natural disasters, emphasizing the role of vulnerability and exposure in transforming hazards into disasters.

Chapter 2. Natural disaster management and its policy

I.2.1 Introduction:

Natural disasters are sudden and unexpected events that can cause massive destruction, loss of life, and damage to property and infrastructure. Managing natural disasters is crucial in minimizing their impact and helping communities recover.

Natural disaster management involves a range of activities and processes that aim to reduce the risk of disasters and their impacts, prepare communities for disasters, respond to disasters, and facilitate recovery efforts. These activities are typically carried out by government agencies, non-governmental organizations (NGOs), and other stakeholders in the community.

I.2.2 Disaster management definition:

Disaster management is a process of effectively preparing for and responding to disasters. It involves strategically organizing resources to lessen the harm that disasters cause. It also involves a systematic approach to managing the responsibilities of disaster prevention, preparedness, response, and recovery. (Talane University, 2021)

I.2.3 The processes of the natural disaster management:

I.2.3.1 Prevention:

Actions taken to avoid an incident. Stopping an incident from occurring. Deterrence operations and surveillance.

I.2.3.2 Mitigation:

Refers to measures that prevent an emergency, reduce the chance of an emergency happening, or reduce the damaging effects of unavoidable emergencies. Typical mitigation measures include establishing building codes and zoning requirements, installing shutters, and constructing barriers such as levees.

I.2.3.3 Preparedness:

Activities increase a community's ability to respond when a disaster occurs. Typical preparedness measures include developing mutual aid agreements and memorandums of understanding, training for both response personnel and concerned citizens, conducting disaster exercises to reinforce training and test capabilities, and presenting all-hazards education campaigns.

I.2.3.4 Response:

Actions carried out immediately before, during, and immediately after a hazard impact, which are aimed at saving lives, reducing economic losses, and alleviating suffering. Response actions may include activating the emergency operations center, evacuating threatened populations, opening shelters and providing mass care, emergency rescue and medical care, fire fighting, and urban search and rescue.

I.2.3.5 Recovery:

Actions taken to return a community to normal or near-normal conditions, including the restoration of basic services and the repair of physical, social and economic damages. Typical recovery actions include debris cleanup, financial assistance to individuals and governments, rebuilding of roads and bridges and key facilities, and sustained mass care for displaced human and animal populations. (Stolouis mo gov)

I.2.4 The legal framework governing natural disasters in Algeria:

The legal framework, according to its level of readiness and alignment with the subject of natural disasters and major hazards, is considered an important mechanism for determining authorities and responsibilities in the event of natural disasters or the presence of potential threats in the form of major risks. This is due to the multiplicity and diversity of the sectors involved and the potential for collaboration among them in field operations, whether in preventive measures or operational interventions, and here is the set of lows and executive decrees; (Gherbi, 2020)

And this is the list of the lows and regulations of natural disaster management in Algeria:

- The Executive Decree 85/231, dated 25 May 1985, relates to the conditions for organizing interventions and aid in the event of accidents.
- The Executive Decree 232/85, dated 25 May 1985, relates to the prevention of major disasters in the short, medium or long term.
- Law 20/01, dated 12 December 2001, relates to sustainable development and planning, Article 4 states: 'Protection of the region and its inhabitants from hazards and natural disasters is necessary for sustainable development.'
- Law 05/04, dated 14 August 2004, relates to the integration of multiple hazards in urban and regional planning schemes.
- The Order, dated 11 January 2004, relates to regulations for seismic safety in Algeria (RDA 1990) as amended in 2003.
- Law 20/04, dated 25 December 2004, relates to prevention against major hazards and disaster management within the framework of sustainable development.
- Recommendation 12/03, dated 26 August 2003, relates to the compulsory insurance against natural disasters and compensation for victims. (Dr.Samir, 2020)

I.2.5 Conclusion:

As a conclusion, there is highly organized steps for managing these natural disasters, each one of those has an impact on the one which comes after, and defines the level of respond and the actions that must be adopted during the crises events through the prevention phase, as the lows and regulations of the Algeria government gives more clarity of how the natural risks could be managed according to the legal framework, that enhance the decision making between the organizations and stakeholders throughout the entire county.

Chapter 3. Geomatics role in natural risk management

I.3.1 Introduction:

The main focus of disaster risk management is often dedicated to monitoring the risk evolution process of objects, areas, regions or even the whole earth with the aim to give early warning of an impending disaster. Disaster reduction measures are based on a continuous assessment of vulnerability, hazard analysis and monitoring.

Geomatics products, whether based on satellite imagery, air photography or ground surveys, are fundamental foundations for disaster mitigation planning efforts. Areas prone to seismic activities resulting from crustal movements or explorations, for example, need to be monitored to minimize the disastrous effects of phenomenon such as earthquakes, volcanoes and landslides. Space geodesy techniques using Very Long Based Interferometry (VLBI), Satellite Laser Ranging (SLR) and Global Positioning System (GPS) are used for taking the precise and repeated measurements of carefully chosen points established in such areas to detect crustal movements that can lead to volcanoes, earthquakes and landslides. (ADELEKE.JIMOH, 2013)

I.3.2 Geomatics definition:

Geomatics is the science of building efficient Earth-related data production workflows. Such workflows go from initial measurements using diverse technologies to the processing and dissemination of these data in various formats: maps, geospatial databases, field coordinates, spatial statistics, aerial images, etc. For example, Google Earth success relies on an efficient workflow to acquire, integrate, process and disseminate satellite images, aerial photographs, 3D digital terrain models, roads maps and GPS positions obtained from heterogeneous sources. Geomatics is thus concerned with the measurement and representation of the Earth, its natural and man-made features, its resources, its use and of the phenomena taking place on it. It is also concerned with the influences of geospatial digital workflows on the Society, organizations and individuals. (Bedard, 2008)

I.3.3 The difference between GIS and Geomatics:

Geographic Information Systems (GIS), and Geomatics are commonly mistaken to mean the same thing, but the two fields are very different.

Geomatics is the discipline of gathering, storing, processing, and delivering spatially referenced information. It encompasses the fields of surveying, mapping, remote sensing (LiDAR or HDS Scanning), photogrammetry, hydrography, global positioning systems (GPS), and geographic information systems (GIS). It is often an umbrella term for every method and tool from data acquisition, to distribution including math, computers, and Earth science.

GIS is composed of a spatial database, a graphic user interface, and a set of tools to manipulate spatial data. It is a framework for gathering, managing, and analyzing. Rooted in the science of geography, GIS integrates many types of data, analyzes spatial location, and organized layers of information into visualizations, using maps and 3D landscapes. It can reveal deeper insights into data, such as patterns, relationships, and situations. Thus, helping clients and users make smarter decisions. (sebagotechnics, 2020)

I.3.4 Geomatic Applications in natural risk management:

1. **Hazard mapping**:

Geomatics technology can be used to create detailed maps of areas at risk of natural hazards such as floods, earthquakes, landslides, and wildfires. These maps can be used to identify high-risk areas and develop effective risk reduction strategies.

2. **Early warning systems:**

Geomatics technology can be used to monitor natural hazards in real-time and provide early warnings to communities at risk. For example, remote sensing technology can be used to monitor weather patterns and predict severe storms or floods.

3. Emergency response:

Geomatics technology can be used to support emergency response efforts during and after a natural disaster. For example, satellite imagery can be used to identify areas of damage and prioritize response efforts.

4. Risk assessment:

Geomatics technology can be used to assess the potential impacts of natural hazards on communities and infrastructure. For example, geographic information systems (GIS) can be used to model flood scenarios and estimate the potential damage to buildings and infrastructure.

5. Land-use planning:

Geomatics technology can be used to inform land-use planning decisions and reduce the risk of natural hazards. For example, hazard maps can be used to identify areas that should be avoided or protected from development. (Heavy.ai, 2022)

I.3.5 Conclusion:

The utilization of geomatics in natural risk management is imperative, particularly given the rapid growth of modern cities. Geomatics provides essential tools and techniques to handle the increasing size and complexity of urban areas. By integrating remote sensing, Geographic Information Systems (GIS), and other geospatial technologies, geomatics enables efficient assessment, mitigation, and response strategies for the expanding urban environment. Its applications make a significant contribution to decision-making, offering a high level of precision and efficiency. Geomatics ensures the safety and resilience of expanding cities, making it an indispensable component of modern natural risk management strategies. Continued investment in geomatics research and technology will further strengthen our ability to mitigate and adapt to natural risks, fostering resilient and sustainable communities.

Part II: Applied Aspect

Chapter 1. The contribution of geomatics in the development of a natural risk prevention plan

II.1.1 Introduction:

El Guerrara city has witnessed to many floods events since the 1900th. The floods on the of the economy or human safety aspect was almost negligible effect that time, but with the expansion of the city, the risk can elevate from small concern to a serious matter, that can be presented as natural disaster, in addition to study is difficulty as the city grow every year, therefor we needed to use the Geomatics which came as a field integrating the use of geographic information, spatial analysis, and technology to solve problems related to the environment, infrastructure, and natural resources.

One of the key applications of geomatics is in natural risk management, where it plays a crucial role in understanding, assessing, and mitigating various natural hazards and disasters. These hazards can range from earthquakes and hurricanes to wildfires and floods, and their impact can be devastating to communities, economies, and the environment.

With the help of geomatics, risk management can be improved by providing accurate and up-to-date information about the location and extent of the hazards, as well as the vulnerability of the population and assets at risk. By combining the power of geographic information systems (GIS), remote sensing, and other geospatial technologies, geomatics provides a comprehensive approach to natural risk management that can help reduce the risks and impacts of these events.

II.1.2 Research Methodology:

In order to understand the analysis method of flood risk, we need to set create a diagram that explains our steps as shown below;

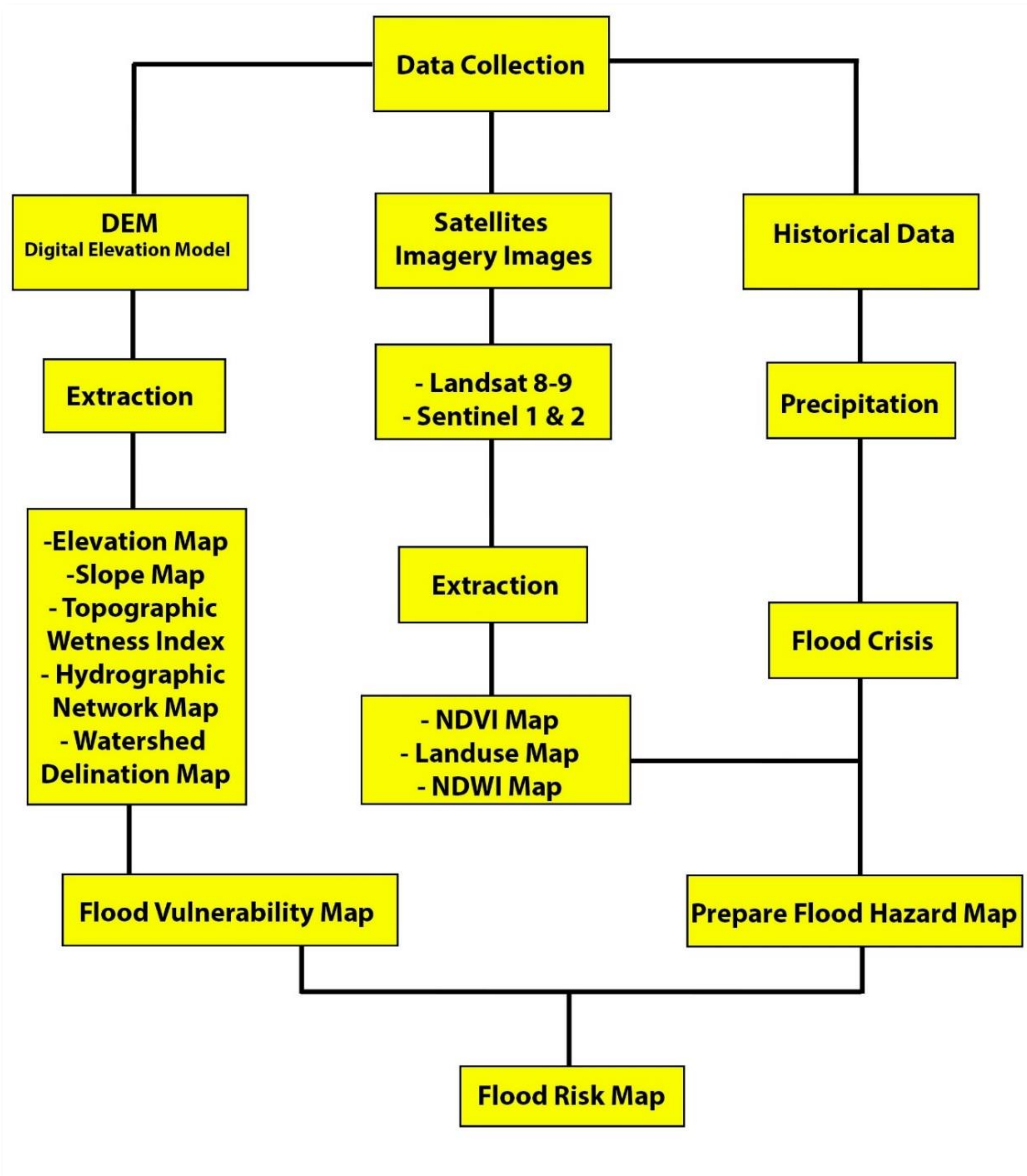


Figure II.1 Research Framework

II.1.3 Presentation of the city (EL GUERRARA):

II.1.3.1 Geographical location:

The state of El Guerrara is Ghardaia, that located in the central part of Algeria, in the M'zab Valley. It covers an area of 21,224.03 km². The State is situated at an elevation of 572 m above sea level. The geographical coordinates of Ghardaia are N 32.5° and E 3.7°. Map of Ghardaia and its surrounding regions (Figure 1) as shows and also its location in Algeria.

- From the north by the wilaya of Laghouat;
- From the northeast by the wilaya of Djelfa;
- From east by the wilaya of Ouargla;
- From the south by the wilaya of El Menia;
- From the west by the wilaya of El Bayadh.

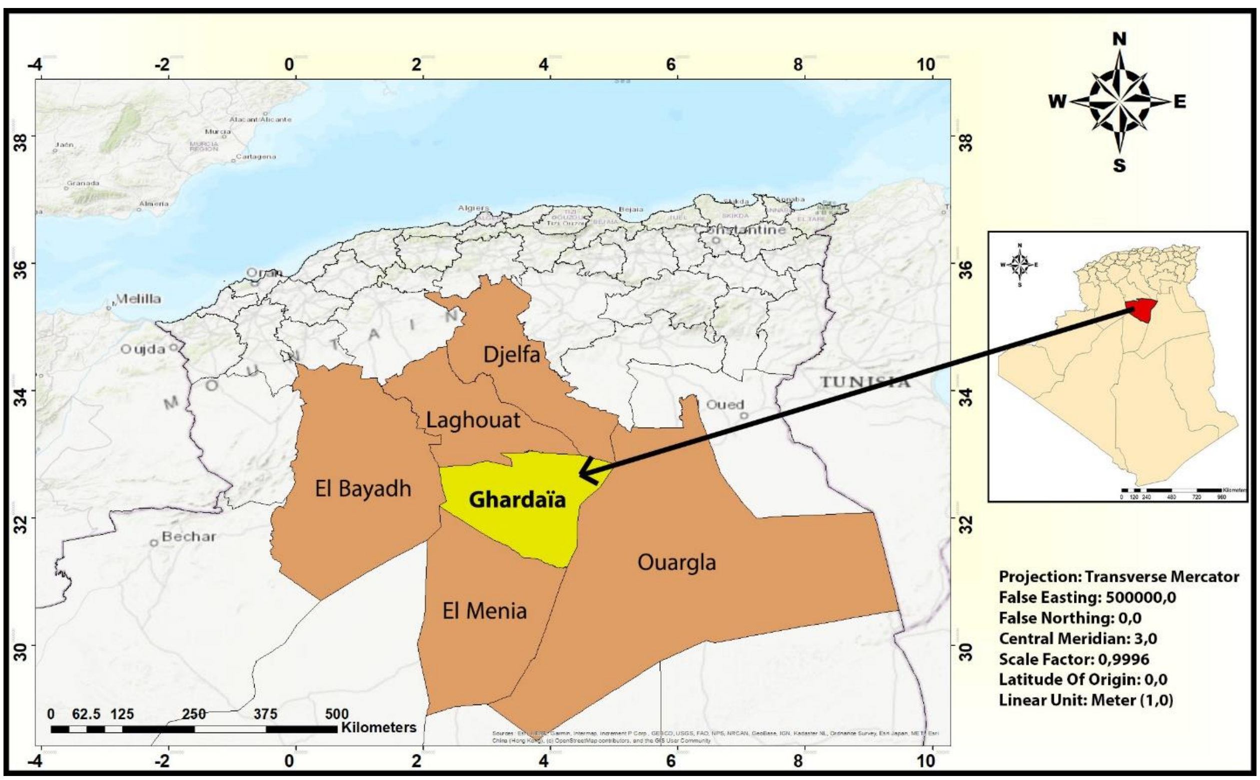


Figure II.2 The Geographical location of Ghardaia State

II.1.3.2 Administrative area:

El Guerrara cover an area of 2900 km2. It's situated at an elevation of 310 m above sea level and has a hot desert climate with average temperatures ranging from 10°C in the winter to 40°C in the summer. The geographical coordinates of El Guerrara are N 32.4° and E 3.8°. As we see in the figure 2 the municipality is at north east of the state.

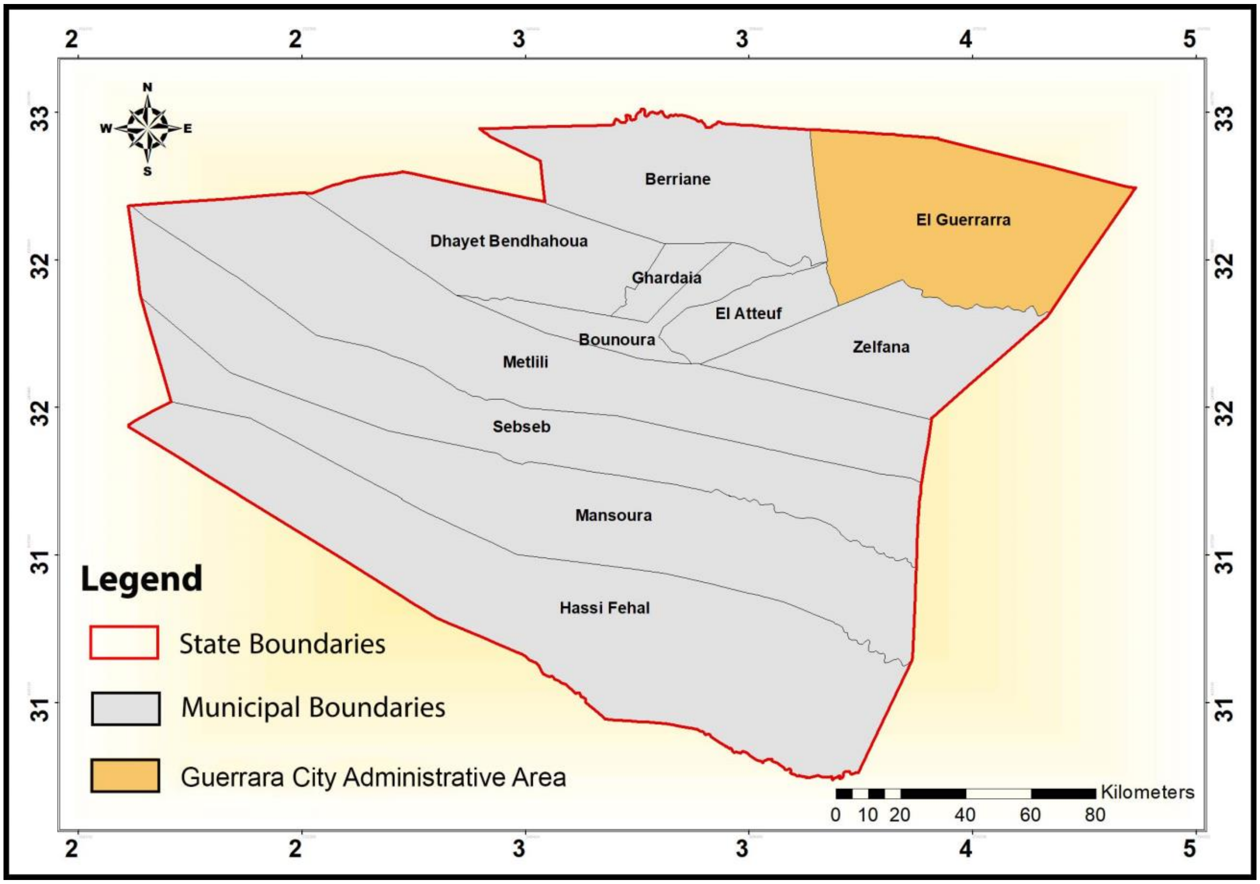


Figure II.3 Gurrara Administration Area Location

II.1.4 Study Area:

Our study area is a part of watershed delineation of that intersect with the municipality of El Guerrara, and has effectiveness and influence of flood on it, due to its location; in minimal altitude inside the watershed.

II.1.4.1 Watershed Definition:

A watershed is the total land and underground area that supplies water, sediment and dissolved materials to a stream. The area of land that water runs off of before it drains into a stream is called a surface watershed, catchment area, drainage basin or basin. (Femmer, 2022)

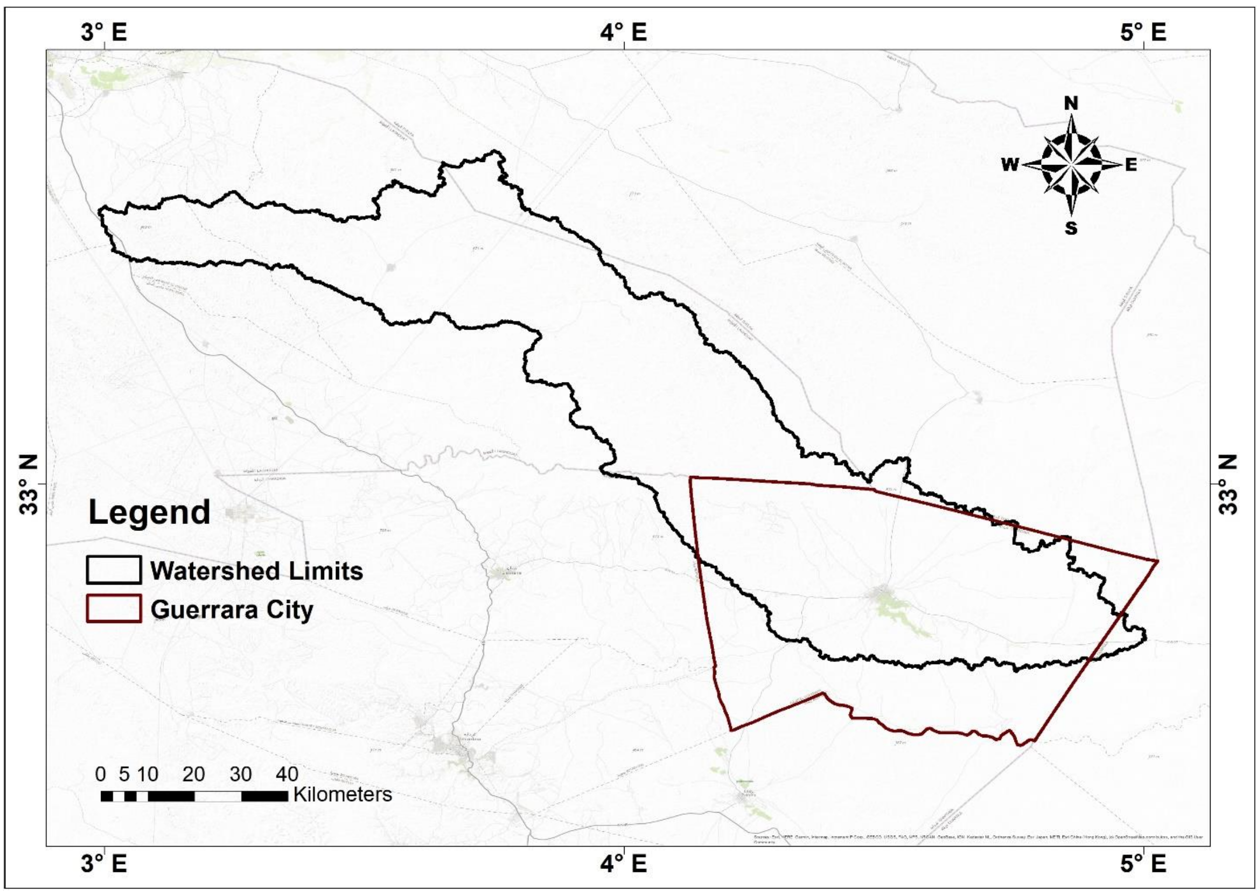


Figure II.4 Watershed As The Study Area

II.1.5 The morphometric Study:

Morphometric analysis is a quantitative measurement and mathematical analysis of landforms. It plays a significant role in understanding the geohydrological characteristics of a drainage basin in relation to the terrain feature and its flow patterns. It also helps to estimate the incidence of infiltration and runoff, and other related hydrological character of a watershed like erosion and sediment transport which has a strong implication for natural resource conservation. (Workineh, 2019)

II.1.5.1 Watershed Spatial Features:

By Using ArcGis Pro program, we were able to calculate and determine the spatial features that provide us with essential information about the physical characteristics and behavior of a watershed.

The perimeter :

763.389753323 km = 763.38 km

The Area :

5456.95270466 km² = 5457 km²

Compactness Index:

The index most commonly referred to is the compactness coefficient proposed by Gravelius. This is the ratio of the perimeter of the watershed to the circumference of a circle whose area is equal to that of the given drainage basin. (HUBERT, 2002)

The compactness coefficient formula given as follows:

$$KG = \frac{P}{2\sqrt{\pi A}} = 0.28 * \frac{P}{\sqrt{A}}$$ (Robert, 2021)

where:

- π: is the ratio of the circumference of a circle to its diameter (appr 3.14159).

- A: is the area of the shape in square units.

- P: Perimeter is the length of the boundary of the shape in linear units.

-K_G: is compactness coefficient.

So, the result of K_G= **2.8935 km**

It means that the watershed has a relatively complex shape, which helps to concentrate water and increase its speed through the hydrographic network, that raises the potential of flood accruing.

Rectangular Parameter:

The length:

$$L = \frac{Kc * \sqrt{A}}{1.12} * \left(1 + \sqrt{1} - \left(\frac{1.12}{Kc}\right)^2\right)$$

L = 366.81 km

The width:

$$W = \frac{Kc * \sqrt{A}}{1.12} * \left(1 - \sqrt{1} - \left(\frac{1.12}{Kc}\right)^2\right)$$

W = 14.87 km

II.1.5.2 Hydrographic features:

II.1.5.2.1 Definition of the hydrographic network:

The hydrographic network is characterized by the ratio density of river, lake, and swamp networks, that is, the relation of the area of the water table of a lake or of the surface of a swamp to the area of a given territory as expressed in percentages. (Encyclopedia, 2010).

It refers to the natural or artificial channels that carry water over the land surface. It plays a key role in determining how water will flow during a flood event.

II.1.5.2.2 Order of streams by: classification de Strahler (Stream order)

In Strahler's classification, any drain that has no tributary is assigned the value 1. Then, the value of each drain is calculated according to the following method: a drain of order n+1 is taken from of the confluence of two drains of order n. The Strahler order or rank of a watershed is the order from the main drain to the outlet. Improvements were made to this method by Shreve and Scheidegger to tune Strahler's order with the magnitude of the flow on the main drain. (wikipedia, n.d.)

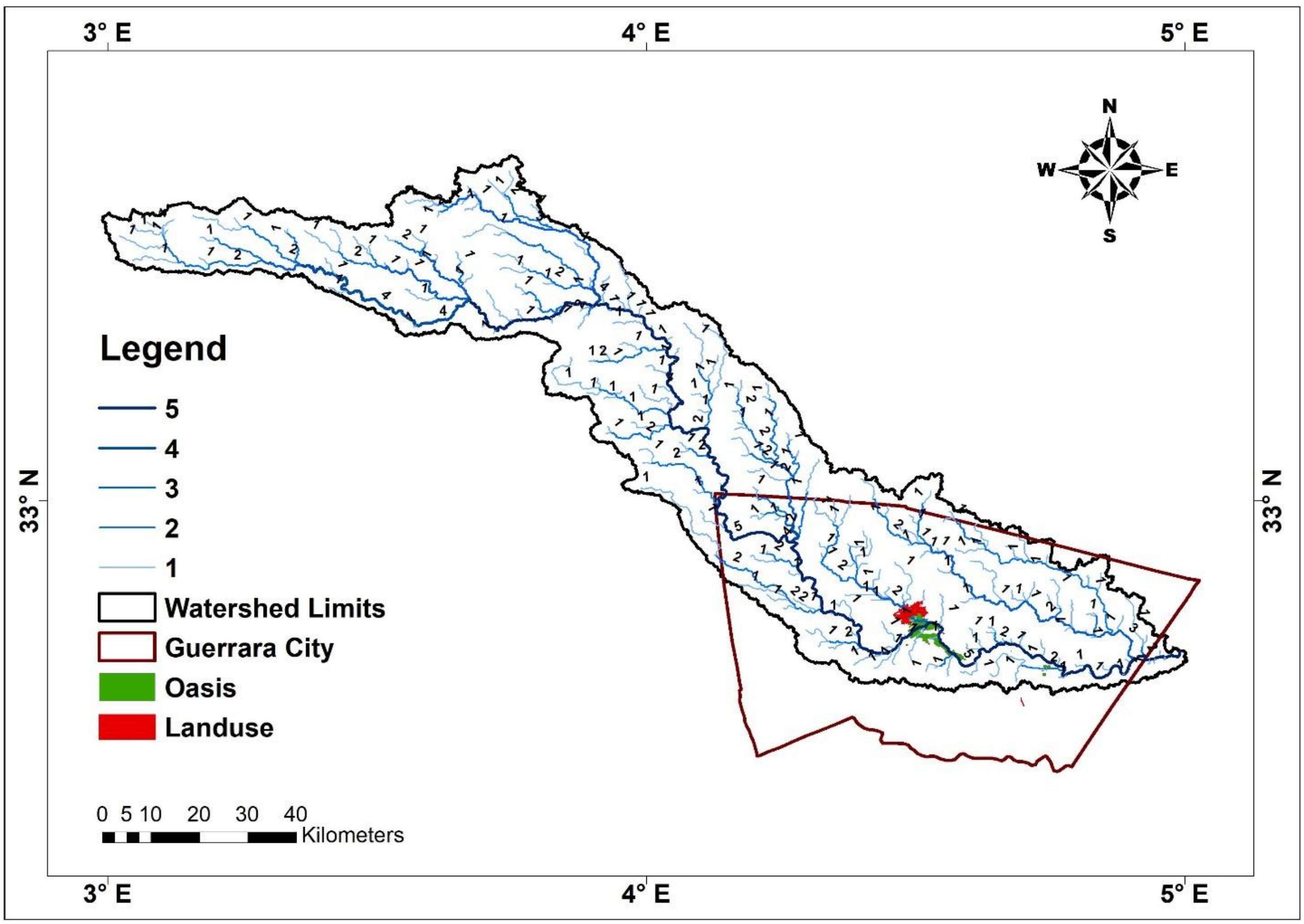


Figure II.5 The streams order within the watershed

We defined 5 stream order within the hydrographic network of the watershed, as the headerwater stream of the order 5 is the one that passes through the oases form the south of Guerrara, that called “Oued zegrir”.

II.1.5.2.3 Drainage density:

It’s defined as the total length of all the streams and rivers in a drainage basin divided by the total area of the drainage basin. It is a measure of how well or how poorly a watershed is drained by stream channels. (definitions.net, n.d.)

Drainage density is a measure of how well a watershed or drainage basin is drained. A higher drainage density indicates that a greater amount of water is flowing through the watershed, which can have important implications for erosion, sediment transport, and other environmental processes.

The formula for calculating drainage density is:

$$\boldsymbol{Dd} = \frac{\sum \boldsymbol{Lt}}{\boldsymbol{A(km^2)}} \begin{cases} Lt: Total\ lengh\ of\ watercourses \\ A: Watershed\ area \end{cases}$$

$$Dd = \frac{1946.45}{5457} = 0.356\ Km/Km^2 \text{ (Robert, 2021)}$$

Depending on the result we can say that, if the area has a moderate amount of stream channels compared to its size that will indicates a moderately dissected landscape with a mix of valleys, hills, and gentle slopes. Water is likely to flow steadily through the channels, contributing to the formation of smaller rivers and streams.

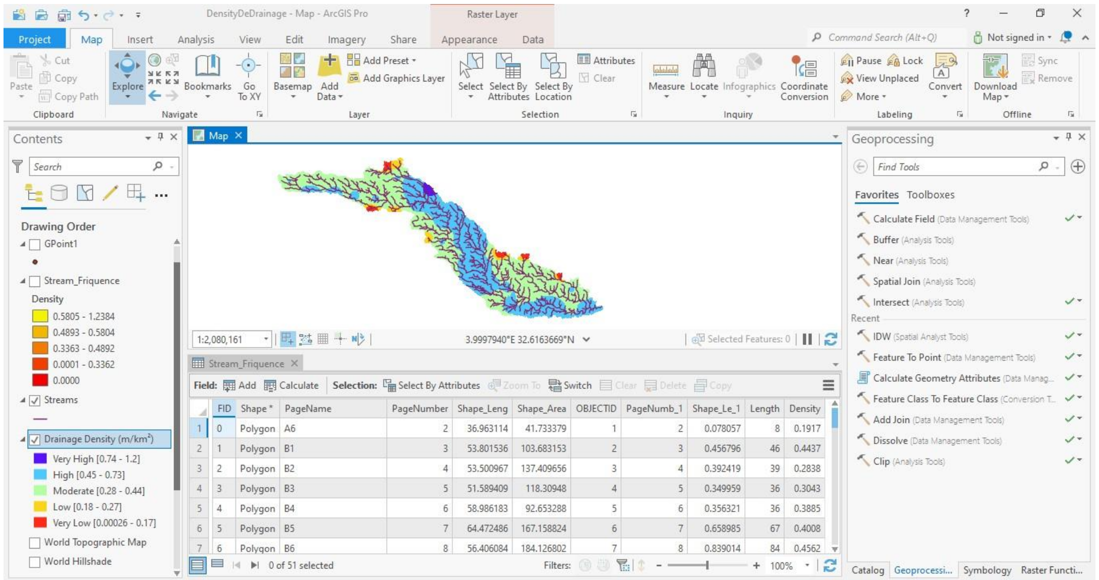


Figure II.6 Drainage Density Calculation in ArcGIS Pro

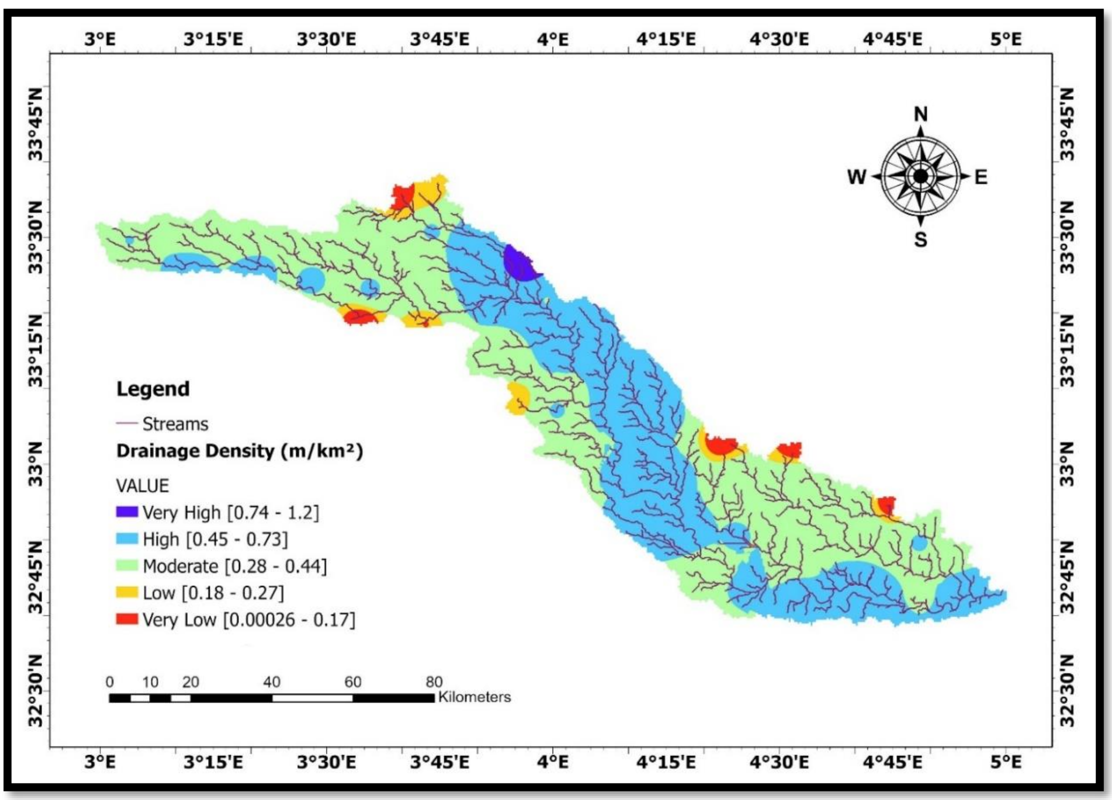


Figure II.7 Drainage Density Map

II.1.5.2.4 Concertation time:

It's defined as a hydrological concept that is used to estimate the travel time of water from the farthest point in a watershed to a specific location, such as a point of discharge, a channel, or a dam.

So, the equation of the concertation time according to Van Te Chow is;

$$CT = 60 * 0.123 * \left(\frac{L}{\sqrt{I}}\right)^{0.64}$$

Where;

- **Tc:** is the time of concentration in minutes.

- **L:** is the length of the longest flow path in the watershed in meters.

- S: is the average slope of the watershed in meters per meter.

And according to Giandoutti is low;

$$CT = \frac{4\sqrt{A} + 1.5L}{0.8\sqrt{H_{moy}} - H_{min}}$$

Where;

A: Surface of the watershed

H moy = 2175m, H min = 1400m

So, CT result of **Van Te Chow** equation is: **37 H**

$$CT = 60 * 0.123 * \left(\frac{253.30}{\sqrt{0.27}}\right)^{0.64}$$

And for the **Giandoutti** equation is: **387 Min**

$$CT = \frac{4\sqrt{5457} + 1.5 * 366.81}{0.8\sqrt{2175} - 1400}$$

II.1.5.2.5 Water streaming speed (SP):

Stream velocity is the speed of the water in the stream. Units are distance per time (e.g., meters per second or feet per second). Stream velocity is greatest in midstream near the surface and is slowest along the stream bed and banks due to friction. (columbia, 2019)

Its equation presented as follows;

$$SP = \frac{PL}{CT}\left({}^{km}/_{h}\right)$$

PL: Main stream length (Km); **CT:** Concentration time (h).

SP= 6.84 km/h; which means that the steam speed is very slow.

II.1.5.2.6 Circular ratio:

It is the ratio that compares the shape of the basin represented by its area with the circle who's the circumference is equal to the perimeter of the pelvis.

The closer the result is to 1 Evidence of irregularity and crooked watersheds, may lead to the appearance of fluvial families in contiguous or overlapping areas between different watersheds and when the shape of the basin approaches the round shape,

It indicates the progression of the morphological phase of the valley as the rivers dig usually. and deepen its course, then begin to broaden it. (Amina, 2021)

So according to Strahler equation we have;

$$CR = \frac{4\pi * A}{P^2} \begin{cases} \boldsymbol{A}: Watershed\ Surface. \\ \boldsymbol{P}: Watershed\ Perimeter. \end{cases}$$

$$CR = \frac{4\pi * 5457}{763.38^2} = 0.11$$

And this results is less than 1, which means that the low Circulatory Ratio implies that the feature is more compact, and the length of the feature is considerably shorter than what would be expected for a circle with the same area, indicating a concentrated or enclosed shape.

II.1.5.3 Topographic of the Study Area:

Contours:

Contour maps can be used to create a digital elevation model (DEM), which is a digital representation of the land surface that can be used to create flood models. The resulting model can be used to simulate how water will flow during a flood event and identify areas that are at risk of flooding.

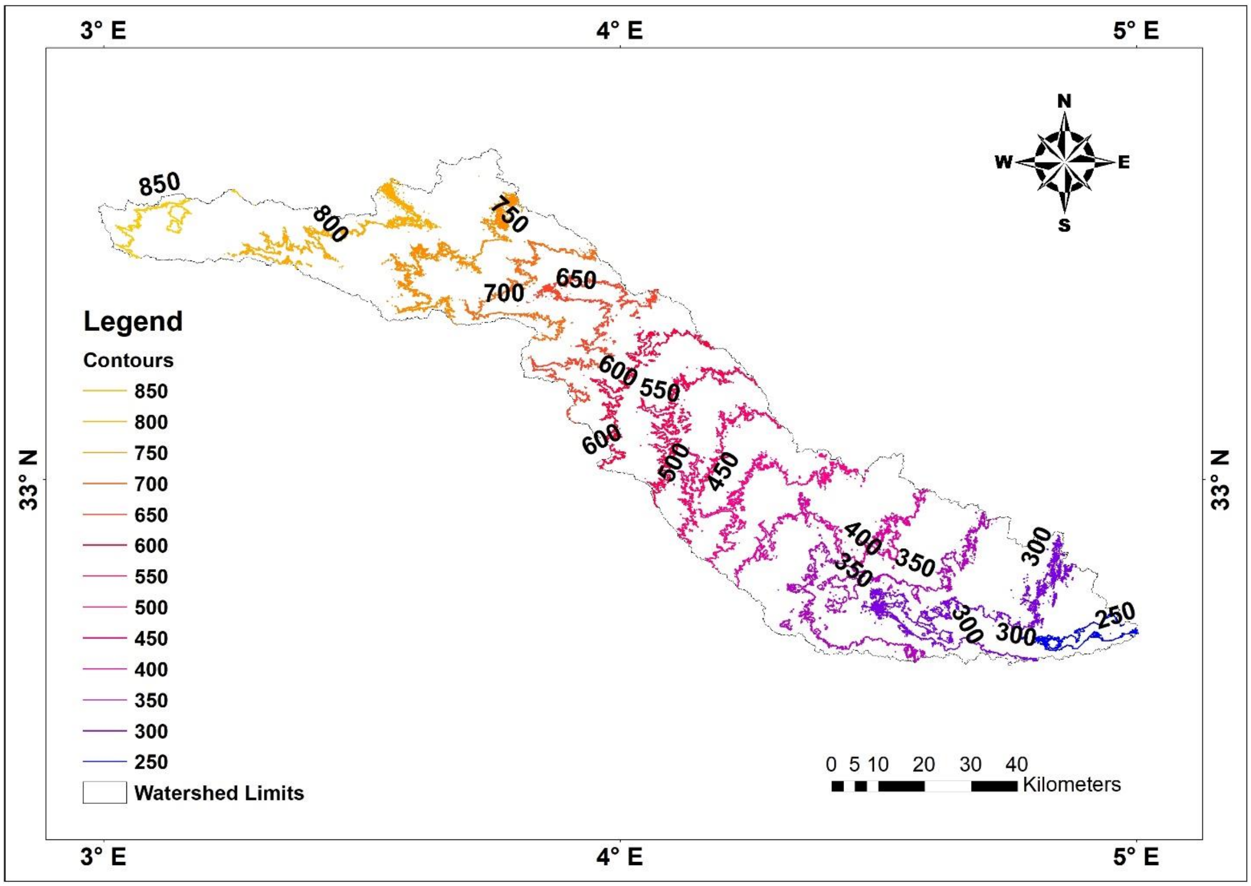


Figure II.8 The Contour Map of Study Area

This contours map give us more insight about the area elevation points that has the low range of 150 – 210 m and the higher range of 420 – 510 m.

Elevation:

Elevation maps are useful tools for studying floods because they provide detailed information about the value of the elevation and shape of the land surface, which are important factors in determining how water will flow and where flooding is likely to occur.

By examining a topographic map, you can identify the location of low-lying areas and areas with steep slopes, which are more prone to flooding.

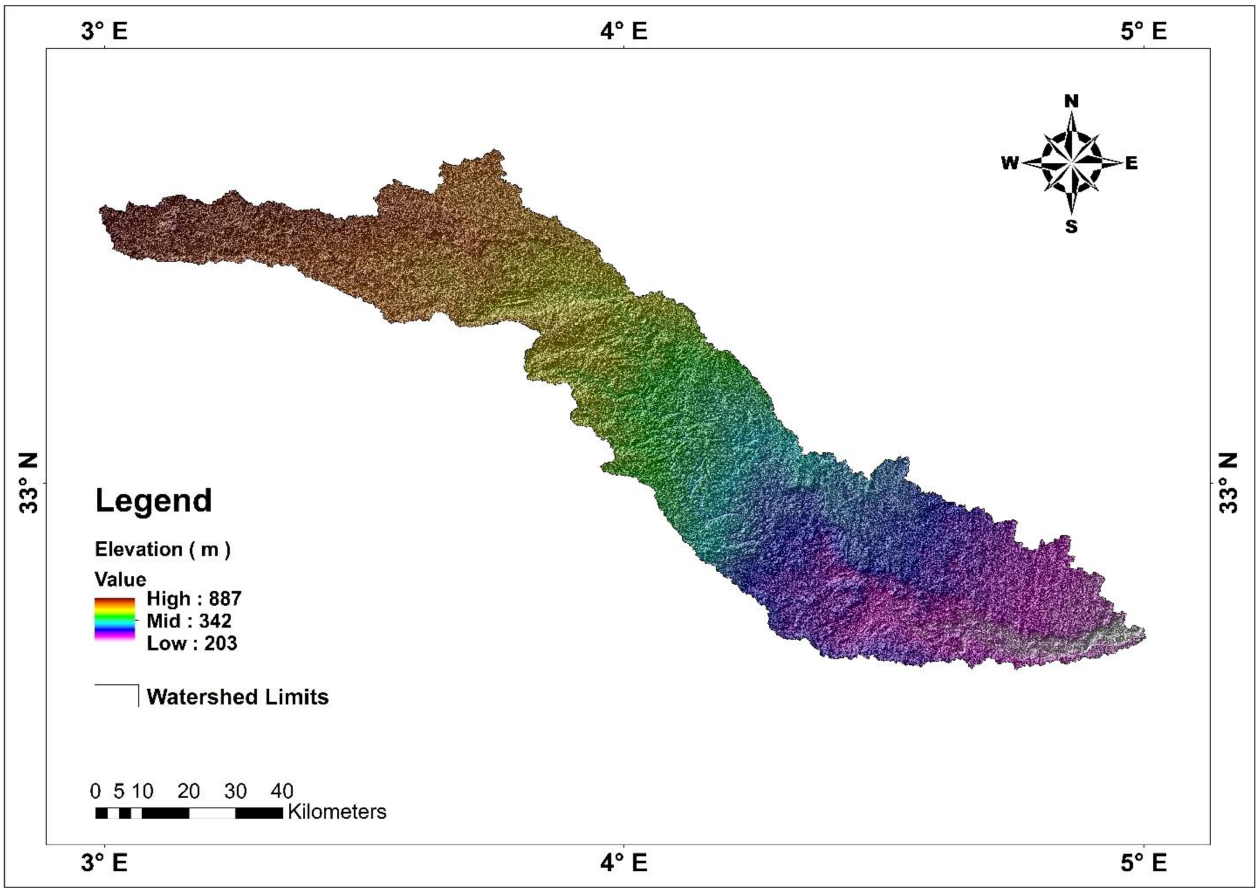


Figure II.9 The Elevation Map of Study Area

So, here is we have an elevation map with values of the highest altitude that marked in brown color with value of 887m, and 342m for medium altitude, then finely we had the value of 203m as the lowest altitude in our study area.

II.1.5.3.1 The slope degrees of the watershed:

In flood risk analysis, the slopes of a watershed are an important consideration. The characteristics of the land surface, including the slope and topography, can significantly impact the amount and speed of water that flows into a river or stream during a flood event.

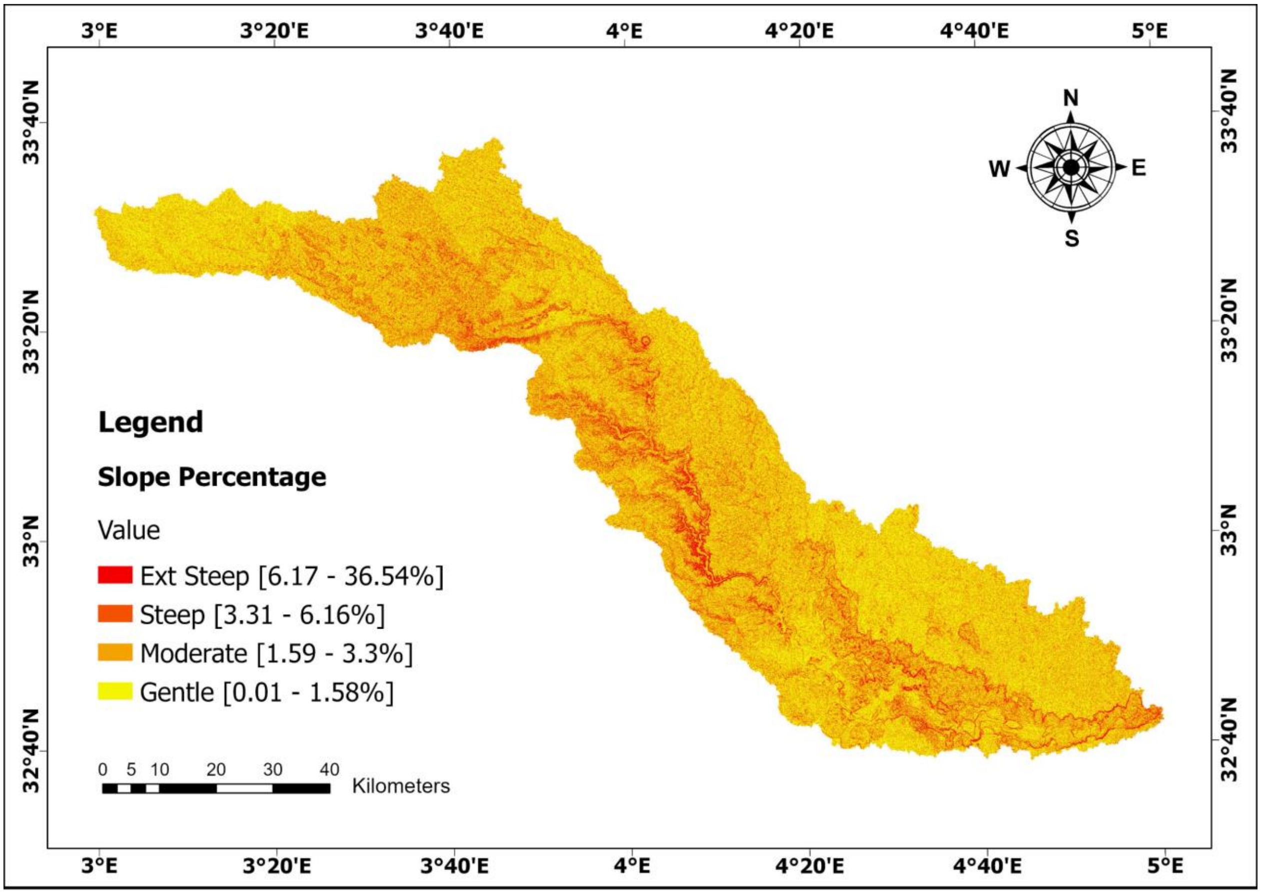


Figure II.10 : The watershed Slopes

The map shows the slopes of the land surface surrounding the stream, with different colors indicating different degrees of steepness.

The steeper the slope, the more quickly water will flow downhill and the more erosive power it will have. Therefore, areas with steeper slopes are generally more prone to flooding and erosion during heavy rainfall events.

II.1.5.4 Topographic Wetness Index (TWI):

TWI is a commonly used index in hydrological analysis for describing the tendency of an area to accumulate water. It basically tells us how likely an area is to be wet. Important for wetland identification as you can imagine. It is based on slope and contributing area. Areas with higher topographic wetness index values are likely to be wetter relative to areas with lower values. (Deenik, 2021).

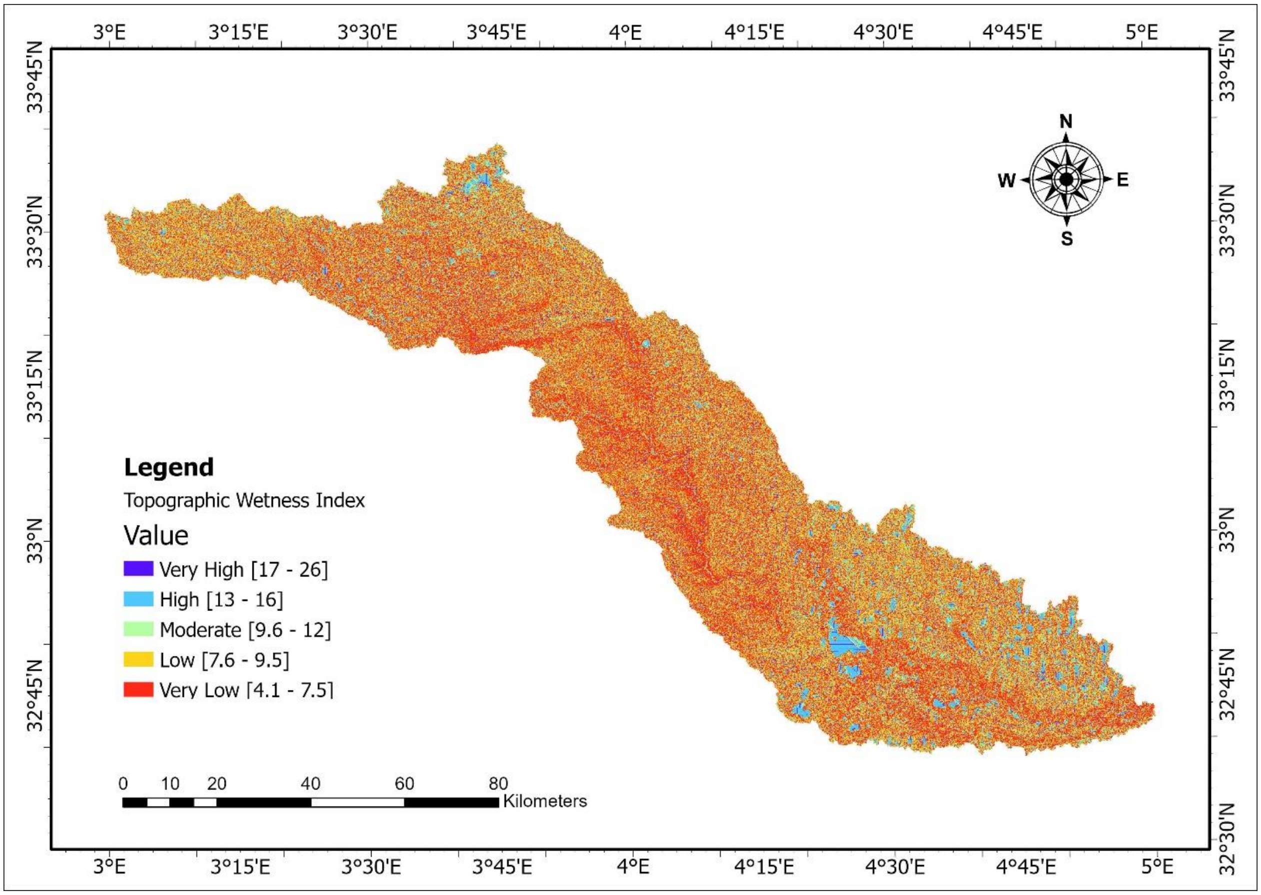


Figure II.11 Water Gathering Places by TWI

II.1.5.5 The type of soil:

Soil type affects how quickly water can be absorbed or drained from an area, as well as how much water can be retained in the soil.

Soils with a high percentage of clay tend to have a low permeability, which means that water cannot easily penetrate into the soil and may cause surface runoff and flooding. On the other hand, soils with a high percentage of sand tend to have a higher permeability and can absorb water more easily, reducing the risk of flooding.

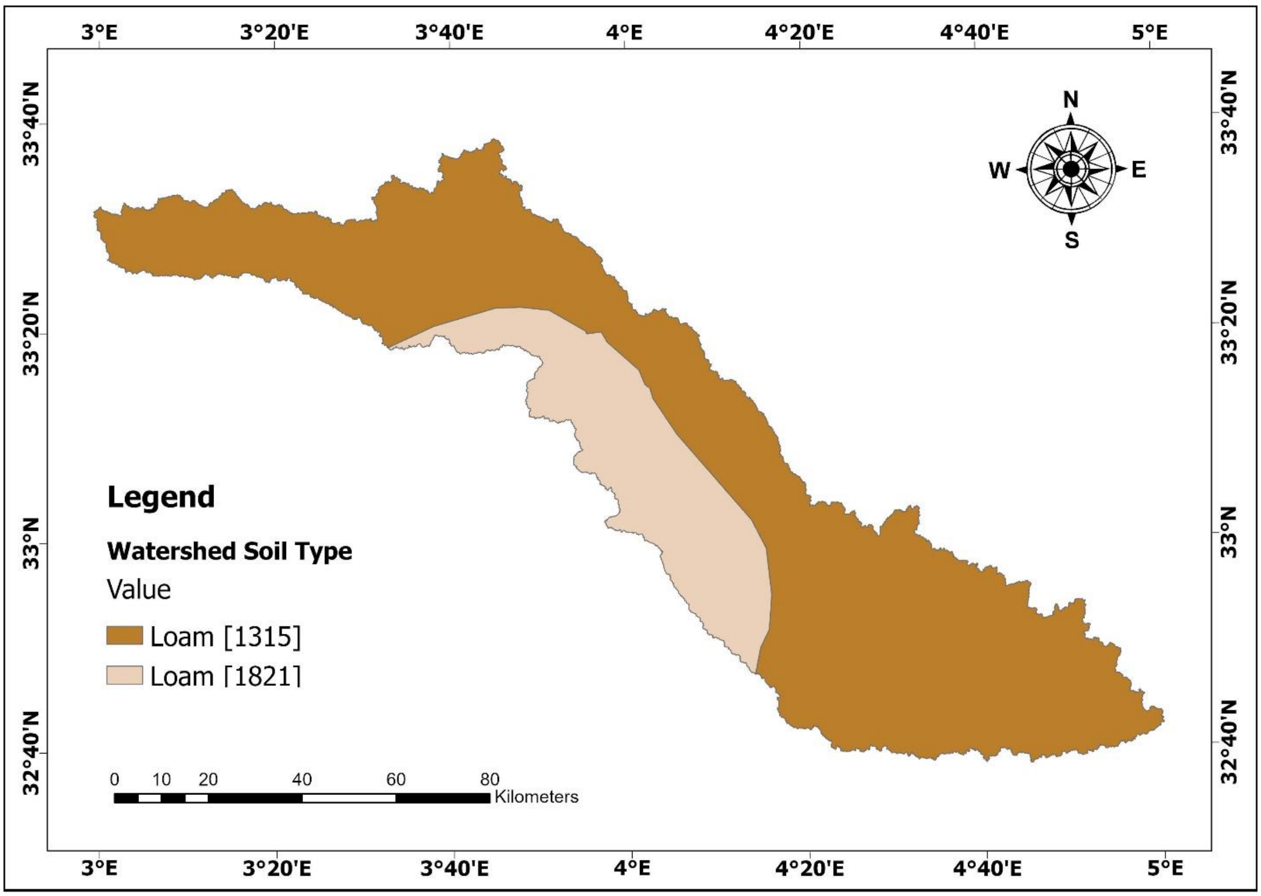


Figure II.12 The Soil Type

Loam soils have moderate permeability, meaning they allow water to flow through at a reasonable rate without excessive runoff or waterlogging. This balanced drainage helps maintain soil moisture while preventing erosion. (fao.org, n.d.)

II.1.5.6 The ndvi of the study area:

In the simplest terms possible, the Normalized Difference Vegetation Index (NDVI) measures the greenness and the density of the vegetation captured in a satellite image. Healthy vegetation has a very characteristic spectral reflectance curve which we can benefit from by calculating the difference between two bands – visible red and near-infrared. NDVI is that difference expressed as a number – ranging from -1 to 1. (system, 2017)

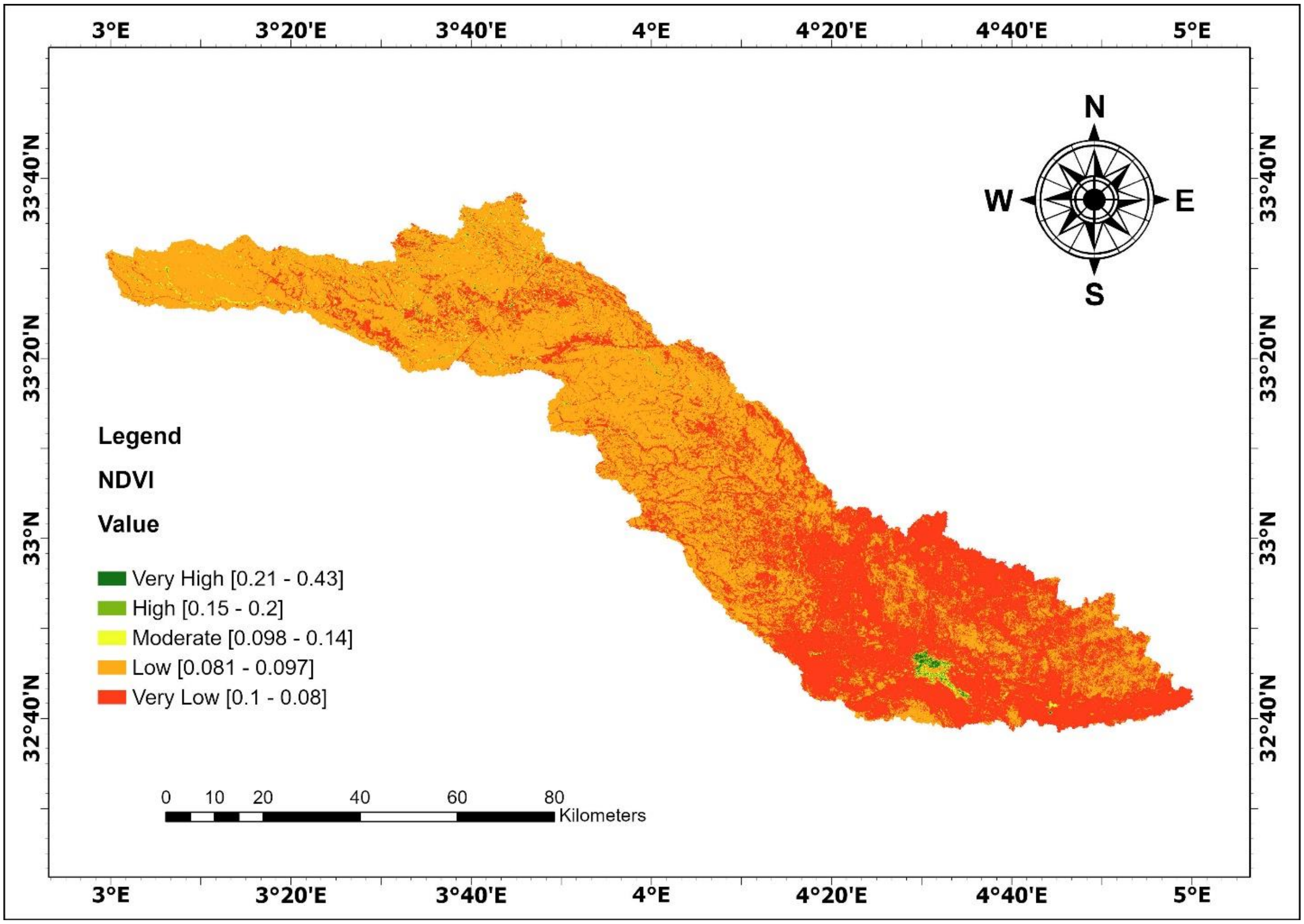


Figure II.13 Normalized Difference Vegetation Index of Study Area

II.1.5.7 Geological map:

Geological maps can be used monitor the underlying geology of the area that could help in identifying the areas that are more likely to be prone by the flood, due to the amount of water that will be absorbed, and how deep the flood waters will get, and when the flood will arrive.

The map is made by georeferencing geological image in ArcGis Pro and digitalizing our study area that presented as watershed.

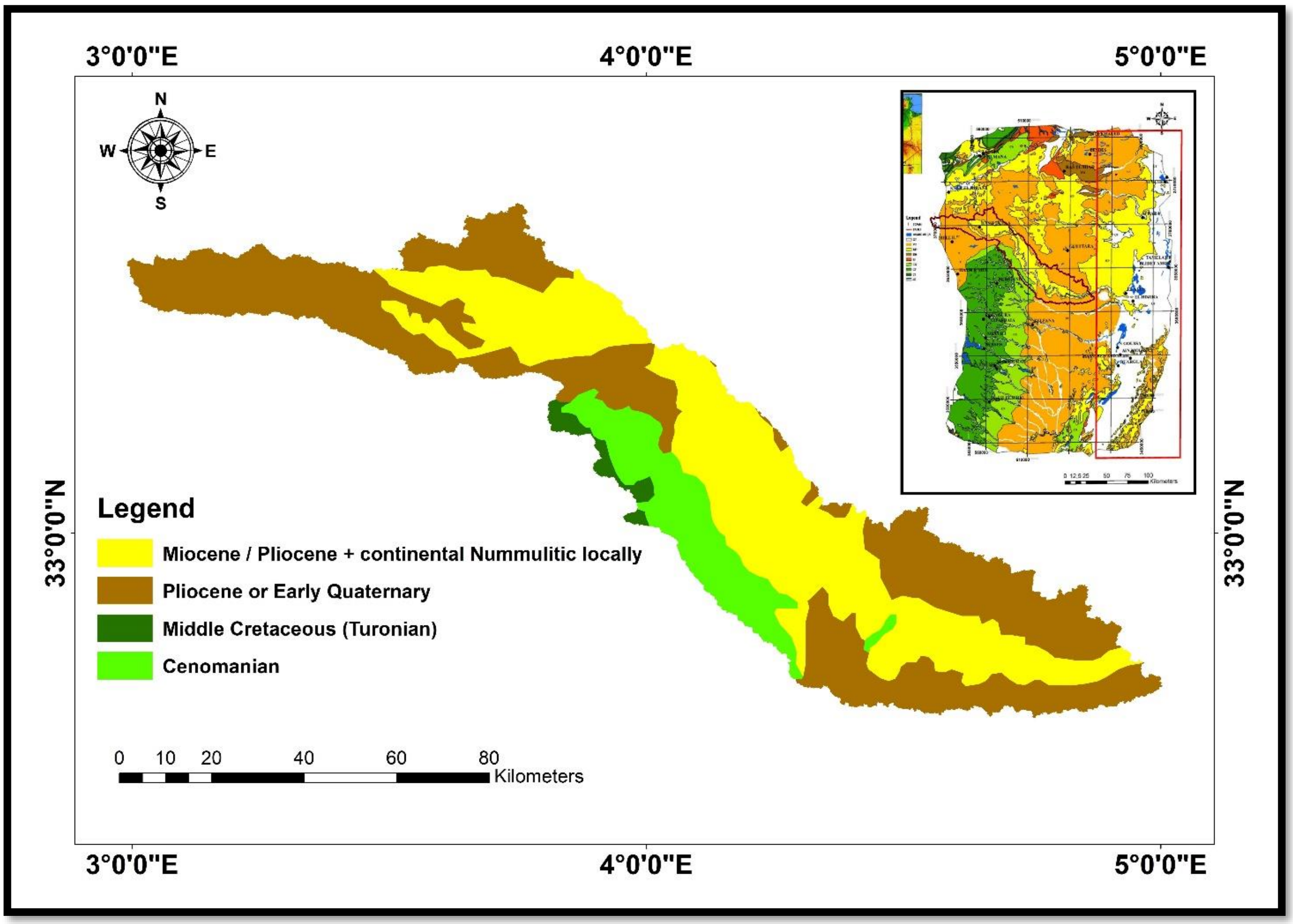


Figure II.14. Geological Map of the Watershed

II.1.6 Climatological study:

Climatology studies provide information about the long-term climate patterns that influence the frequency and magnitude of floods.

By analyzing historical climate data, we can identify patterns of climate variability and the likelihood of extreme weather events, such as heavy rainfall or prolonged drought, which can impact the frequency and magnitude of flooding.

Annual precipitation data over a long period of time are used to estimate the return period of flooding events with a certain probability, such as a 10-year flood or a 100-year flood and in order to make an estimation we use historical precipitation data as shown in the figure below.

II.1.6.1 Monthly Precipitation Statics of (1958-2022):

These statics of the highest precipitation values recorded for each month over the period of (1958-2022) provide insights into the extreme weather conditions experienced in different months.

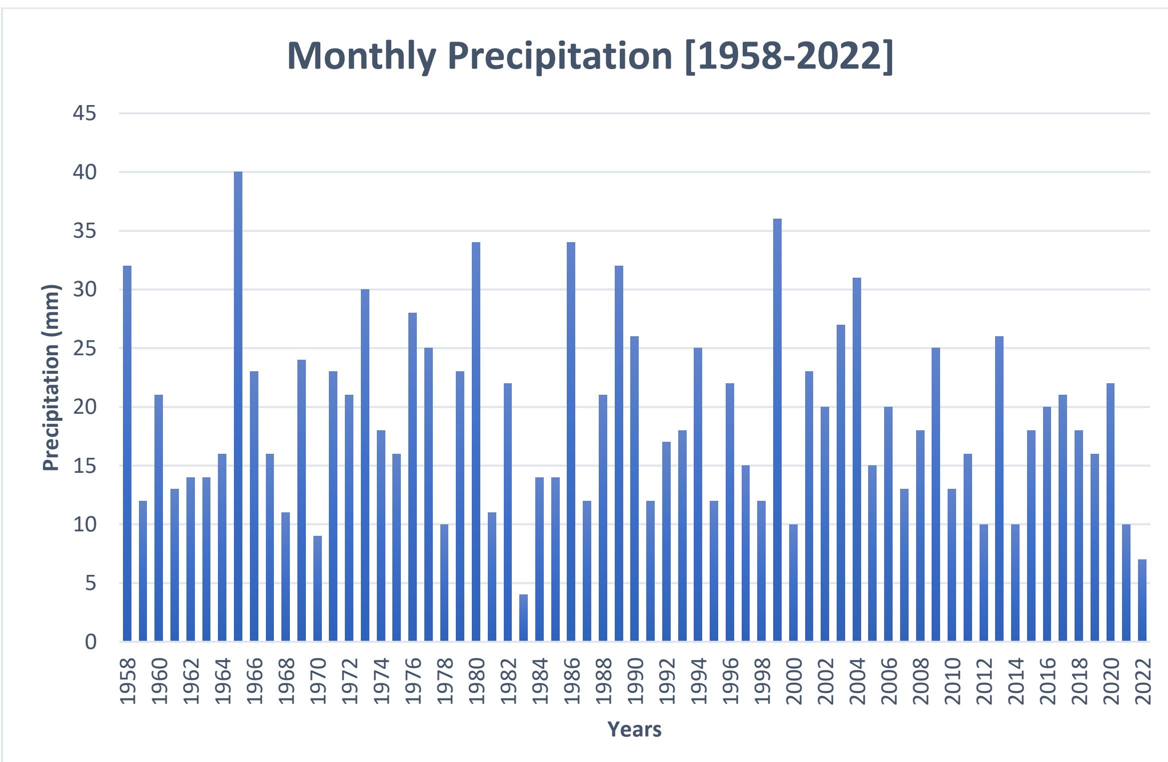
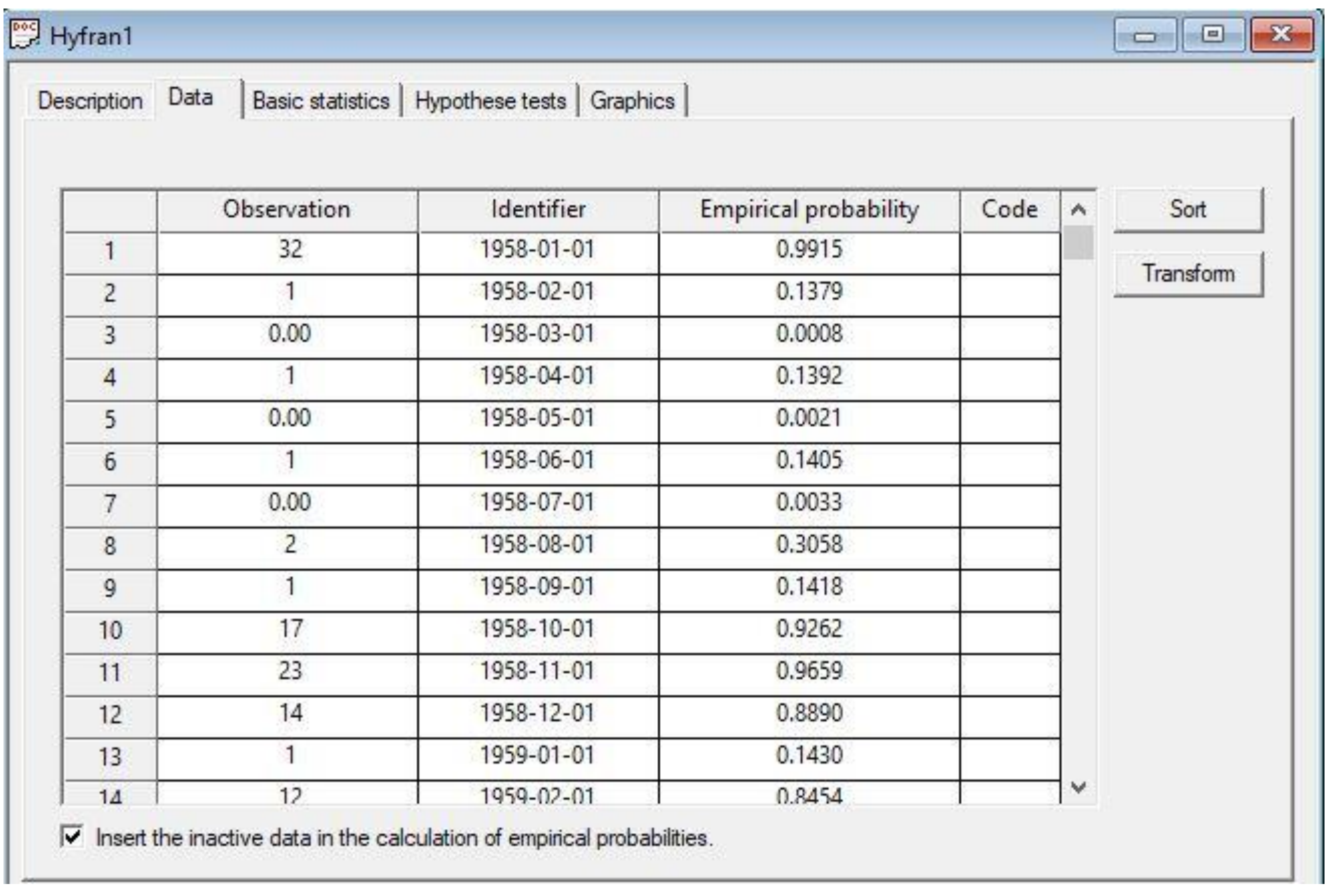


Figure II.15 The Max Monthly Precipitation from 1958 to 2022

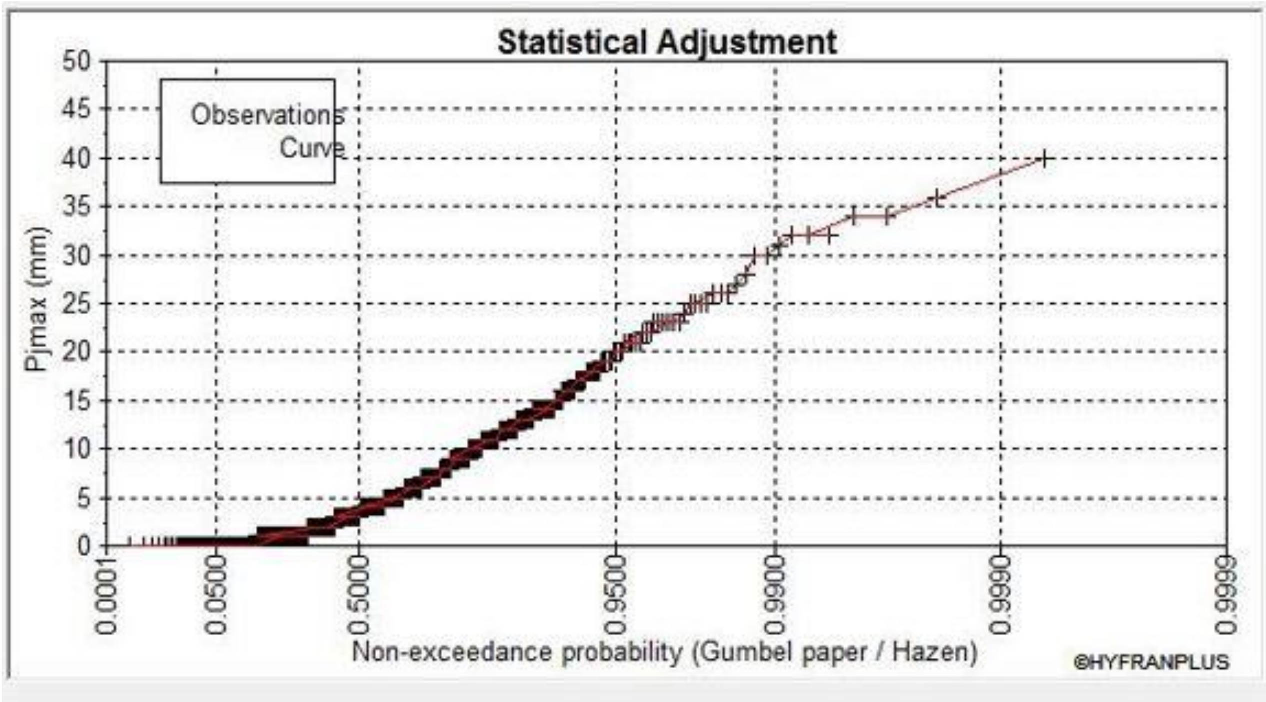
II.1.6.2 The monthly precipitation adjustment for the period of [1959-2022] using Normal low in Hyfran:

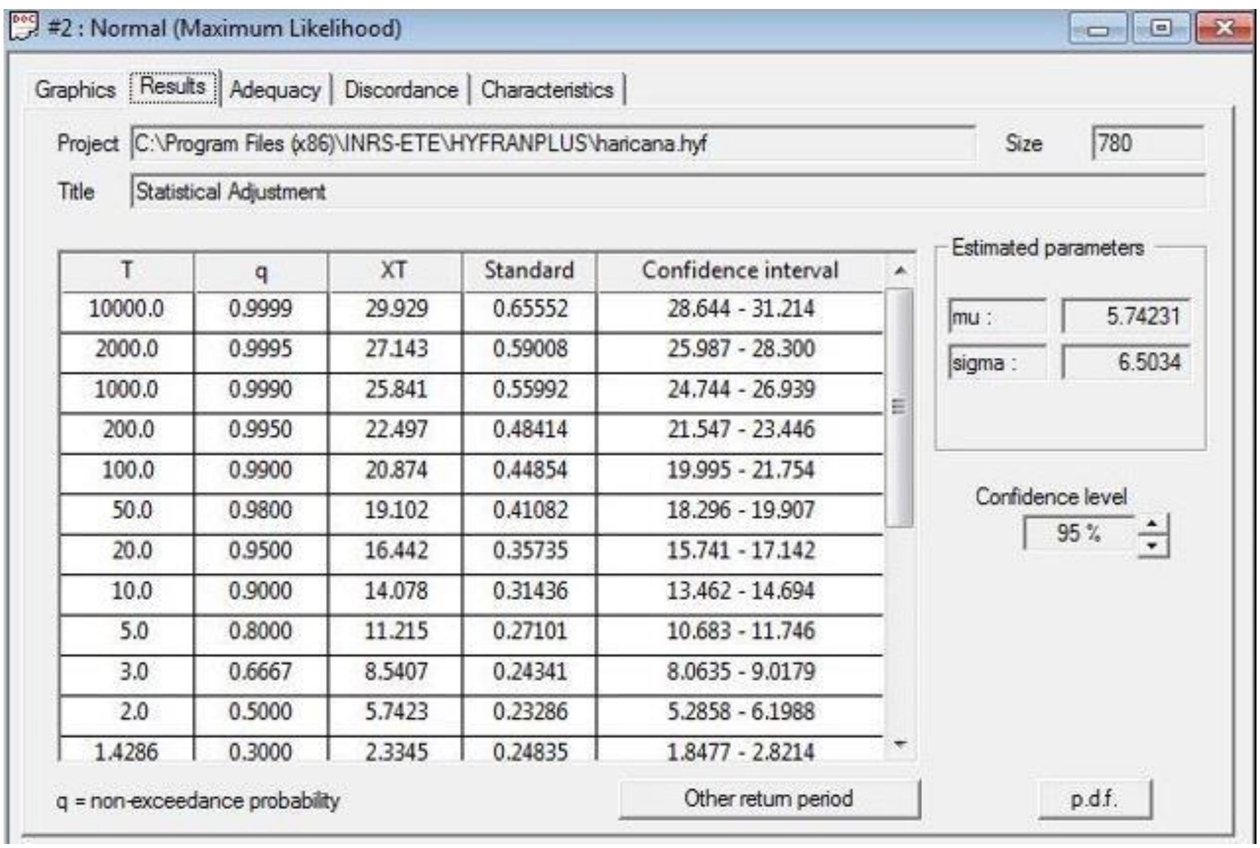
The normal distribution is theoretically justified by the central limit theorem as the distribution of a random variable formed by the sum of a large number of random variables. However, in frequency analysis of extreme values in hydrology, the distributions are not symmetric, which poses an obstacle to its use. Nevertheless, this distribution generally applies well to the study of annual magnitudes of hydro-meteorological variables in temperate climates.

The log-normal distribution is advocated by some hydrologists, including V.-T. Chow, who justify it by arguing that the occurrence of a hydrological event results from the combined action of a large number of factors that multiply together. Therefore, the random variable follows a log-normal distribution. In fact, the product of variables can be reduced to the sum of their logarithms, and the central limit theorem allows us to affirm the log-normality of the random variable. (echo2.epfl.ch, n.d.)



	Observation	Identifier	Empirical probability	Code
1	32	1958-01-01	0.9915	
2	1	1958-02-01	0.1379	
3	0.00	1958-03-01	0.0008	
4	1	1958-04-01	0.1392	
5	0.00	1958-05-01	0.0021	
6	1	1958-06-01	0.1405	
7	0.00	1958-07-01	0.0033	
8	2	1958-08-01	0.3058	
9	1	1958-09-01	0.1418	
10	17	1958-10-01	0.9262	
11	23	1958-11-01	0.9659	
12	14	1958-12-01	0.8890	
13	1	1959-01-01	0.1430	
14	12	1959-02-01	0.8454	




#2 : Normal (Maximum Likelihood)

Graphics | Results | Adequacy | Discordance | Characteristics

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Title Statistical Adjustment

T	q	XT	Standard	Confidence interval
10000.0	0.9999	29.929	0.65552	28.644 - 31.214
2000.0	0.9995	27.143	0.59008	25.987 - 28.300
1000.0	0.9990	25.841	0.55992	24.744 - 26.939
200.0	0.9950	22.497	0.48414	21.547 - 23.446
100.0	0.9900	20.874	0.44854	19.995 - 21.754
50.0	0.9800	19.102	0.41082	18.296 - 19.907
20.0	0.9500	16.442	0.35735	15.741 - 17.142
10.0	0.9000	14.078	0.31436	13.462 - 14.694
5.0	0.8000	11.215	0.27101	10.683 - 11.746
3.0	0.6667	8.5407	0.24341	8.0635 - 9.0179
2.0	0.5000	5.7423	0.23286	5.2858 - 6.1988
1.4286	0.3000	2.3345	0.24835	1.8477 - 2.8214

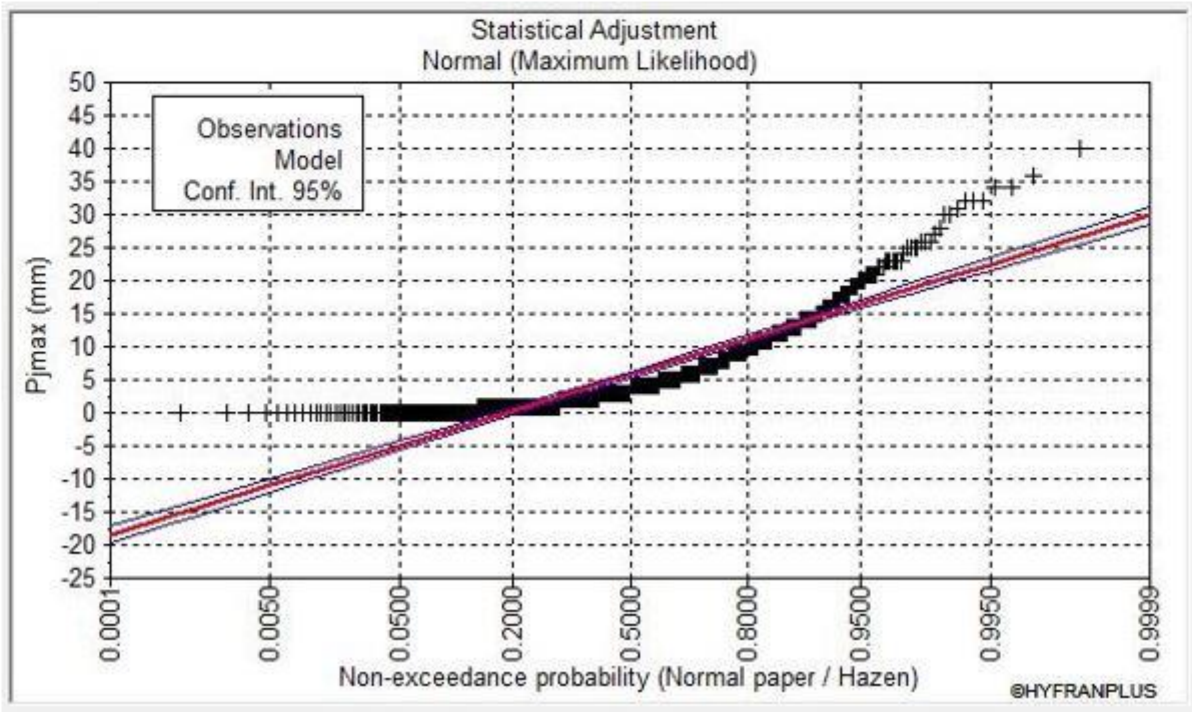
Estimated parameters
mu : 5.74231
sigma : 6.5034

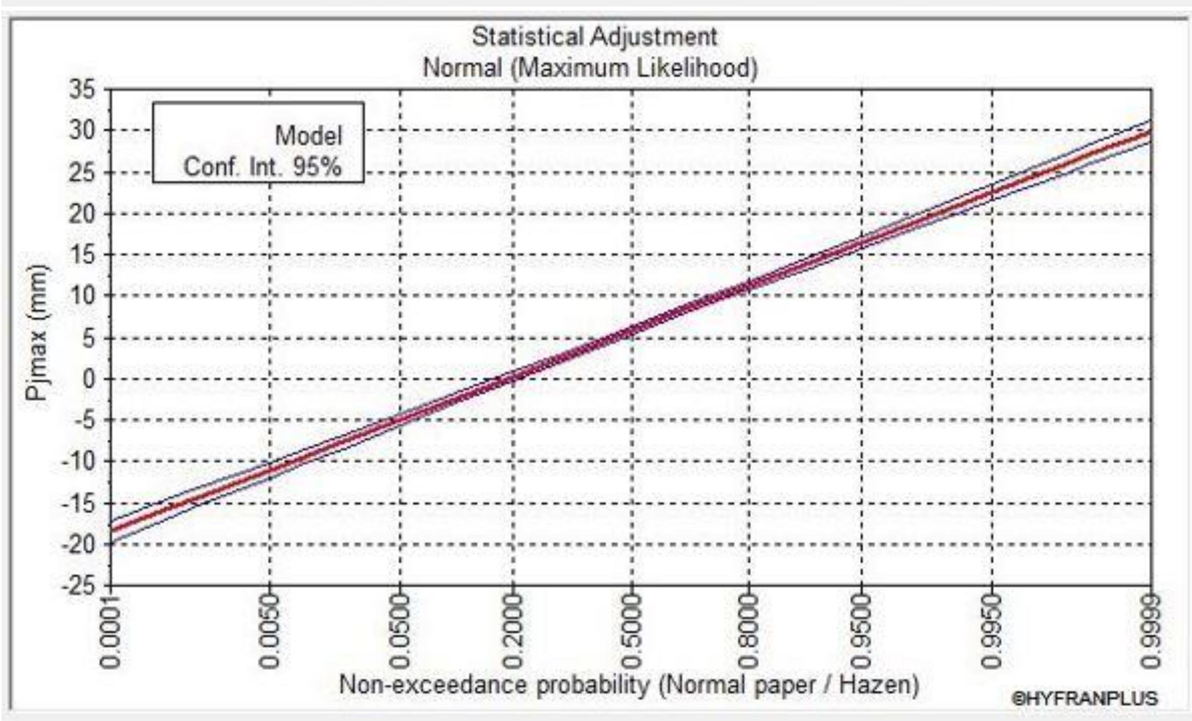
Confidence level 95 %

q = non-exceedance probability

Other return period

p.d.f.


Statistical Adjustment
Normal (Maximum Likelihood)
Observations
Model
Conf. Int. 95%
Pjmax (mm)
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
0.0001
0.0050
0.0500
0.2000
0.5000
0.8000
0.9500
0.9950
0.9999
Non-exceedance probability (Normal paper / Hazen)
©HYFRANPLUS


Statistical Adjustment
Normal (Maximum Likelihood)
Model
Conf. Int. 95%
Pjmax (mm)
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
0.0001
0.0050
0.0500
0.2000
0.5000
0.8000
0.9500
0.9950
0.9999
Non-exceedance probability (Normal paper / Hazen)
©HYFRANPLUS

II.1.6.3 The Precipitation Map From 2011 to 2020:

The map allows for the examination of long-term precipitation patterns and trends. It helps identify areas that consistently receive high and low levels of rainfall, providing insights into the climate characteristics of the region.

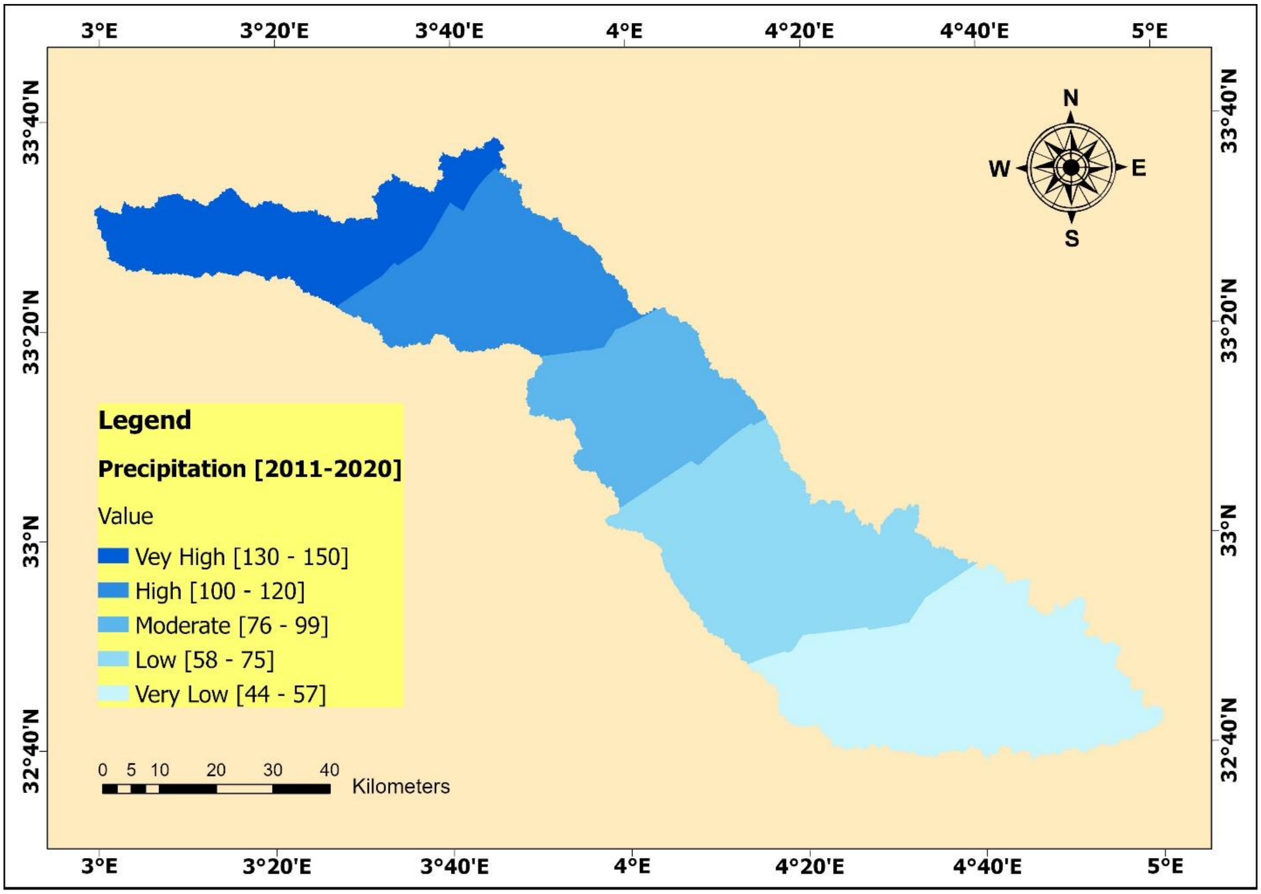


Figure II.16 The Annual Precipitation Map From 2011- 2022

II.1.6.4 Intensity Duration Frequency (IDF):

The rainfall intensity–duration–frequency (IDF) curves are graphical representations of the probability that a given average rainfall intensity will occur within a given period of time (Dupont and Allen 2000). Providing mathematical relationship between the rainfall intensity **(i)**, the duration (**d)**, and the return period (**T)** (or equivalent to the annual frequency of exceedance f), the IDF curves allow for the estimation of the return period of an observed rainfall event or conversely of the rainfall intensity corresponding to a given return period. (Dadiyorto Wendi, 2019)

m	*Year (d)*	*Rainfall/mm*	*Probability P= m/(N+1)*	*Time T= 1/P*
1	1665	40	0.02	66.00
2	1999	36	0.03	33.00
3	1880	34	0.05	22.00
4	1886	34	0.06	16.50
5	1558	32	0.08	13.20
6	1889	32	0.09	11.00
7	2004	31	0.11	9.43
8	1773	30	0.12	8.25
9	1776	28	0.14	7.33
10	2003	27	0.15	6.60
11	1990	26	0.17	6.00
12	2013	26	0.18	5.50
13	1777	25	0.20	5.08
14	1994	25	0.21	4.71
15	2009	25	0.23	4.40
16	1669	24	0.24	4.13
17	1666	23	0.26	3.88
18	1771	23	0.27	3.67
19	1779	23	0.29	3.47
20	2001	23	0.30	3.30
N+….	N+…..	N+…….	N+……	N+……
N+….	N+…..	N+…….	N+……	N+……
62	2021	10	0.94	1.06
63	1770	9	0.95	1.05
64	2022	7	0.97	1.03
65	1883	4	0.98	1.02

Table 1. Excel Work Sheet

N+… = it means there is a values withing the table, removed because; the list was too long.

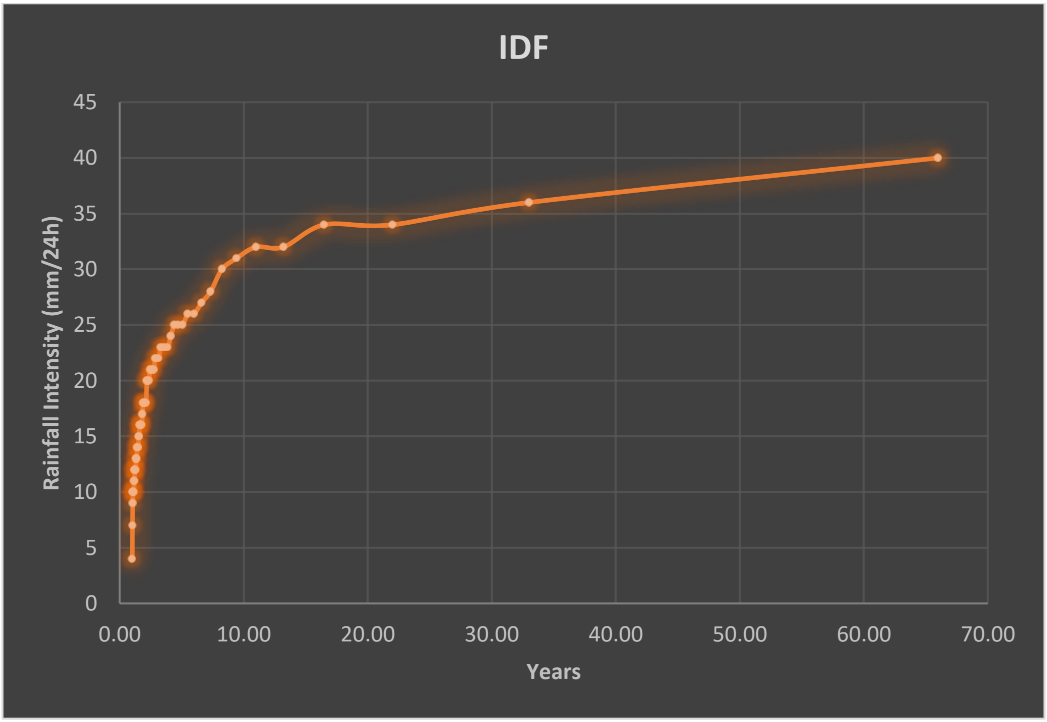


Figure II.17 IDF of the period (1958 – 2022)

- This means that the rainfall of 32 mm/Hr could happen every 11 years, with probability of 9%.
- And the rainfall of 34 mm/Hr could happen every 22 years, with probability of 5%.
- And the rainfall of 36 mm/Hr could happen every 33 years, with probability of 3%.

These are the highest values that were recorded during the given period of 1958 to 2022.

Chapter 2. Flood Control System of El Guerrara City

II.2.1 Introduction:

The flood control system in the city of El Guerrara demonstrates the remarkable foresight and ingenuity of the Mozabites, who have harnessed the power of floods to create an efficient hydro-agricultural planning. Since the 1900s, the Mozabites have recognized the value of floods and their potential for agricultural benefits. In response, they have developed an extensive network of infrastructure to effectively manage and utilize floodwaters while ensuring the safety of the community.

At the heart of this flood management system is a significant ancestral dam that stretches 1.8 km along the Zegrir River. This dam acts as a water barrier, allowing the local people to control the flow of floodwaters and take advantage of their potential benefits. The floods serve as a vital source of raw water, supporting the irrigation needs of an impressive 80,000 palm trees.

II.2.2 Flood Control System:

Location:

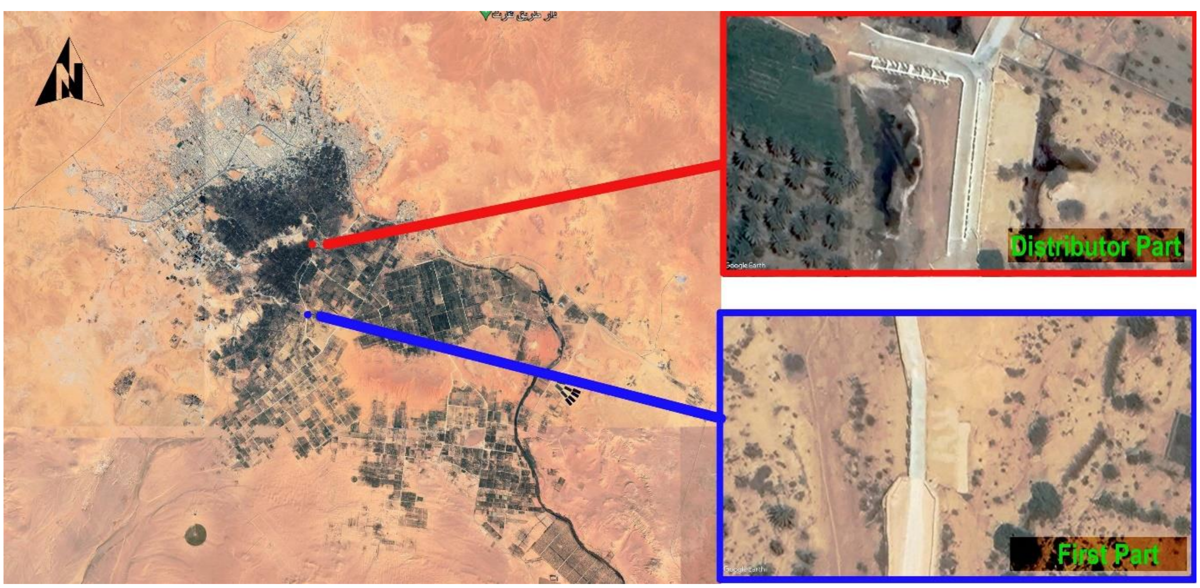


Figure II.18 The Location of the Water Barrier

Control Mechanism:

The flood control system in El Guerrara prominently features the "Ahbes" water barrier, a significant structure stretching 1.8 km along the Zegrir River. This water barrier acts as a pivotal component of the system, regulating the flow of floodwaters. Connected to the dam, a network of channels and alleys extends over a total length of 10 km, efficiently directing and distributing the floodwaters throughout the oases.

As an integral part of the flood management system, 32 sliding doors **(Figure II.19)** have been strategically installed. These doors serve as essential control mechanisms, allowing for the precise management of water flow during flood events. By adjusting the position of these doors, the system can effectively divert or contain floodwaters as needed, mitigating potential risks and ensuring the safety of the community.

Figure II.19 Sliding Doors (B, 2019)

Water drainage channels:

There is 25 water drainage channels (**Figure II.20)** designed to efficiently evacuate excess water during flood events. These channels serve as crucial outlets, effectively diverting and channeling the surplus water away from the city, minimizing the risk of flooding and damage to infrastructure.

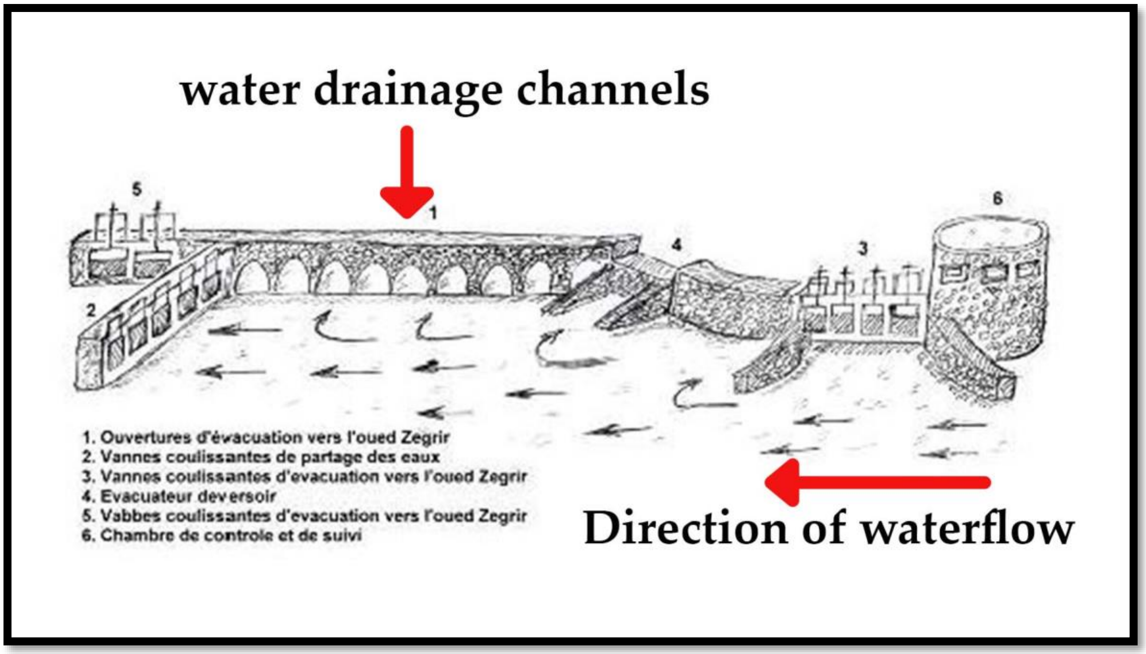


Figure II.20 Flood Water Drainage System (B, 2019)

Water barrier altitude:

The altitude of the water barrier "Ahbes" is strategically positioned 2.9 meters below the base altitude of the central city houses "El Kasar" **(Figure II.20)**. This deliberate elevation difference ensures that the dam can effectively receive and control the floodwaters, preventing overflow and reducing the likelihood of water reaching residential areas. By designing the dam at a lower altitude, the flood management system minimizes the potential impact on the surrounding community and enhances overall flood safety measures.

Figure II.21 Dam Water Level Comparing To City Houses

The inclusion of water drainage channels and the careful consideration of the dam's altitude in relation to the city's housing further exemplify the comprehensive approach taken in El Guerrara's flood management system. These additional features work in conjunction with the dam, channels, alleys, and sliding doors to optimize flood control and protect the community from the potential hazards associated with flooding.

Flood occurrence:

According to a study conducted by DUBIEF (1953), it was found that during the period from April 1938 to March 1951, there were 26 months of floods, while for the period from 1921 to 1950, there were 33 months of floods. This can be explained by the fact that flood months can occur at highly variable intervals, ranging from a few months (sometimes 5 months of floods in one year) to a few years (28 months without floods between May 1946 and August 1948). In general, floods are observed during autumn or spring. (DJILI, 2004)

II.2.3 Historical Flood Events of El Guerrrara:

The flood has two different impacts; positive like the irrigation of forest land and negative which presents as properties and crops damage. Some of these examples will be shown on this part that happened during the last few years in the city of El Guerrara the relay on our study area.

Figure II.22 Oldest El Guerrara Flood of 1890

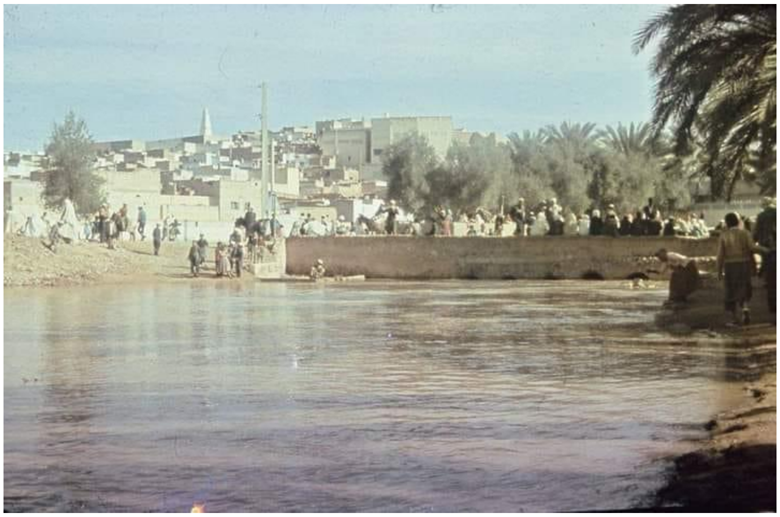


Figure II.24 El Guerrara Flood of 1962

Figure II.23 After Algeria independence 1962

Figure II.28 Flood Aug 15th 2015

Figure II.27 The Massive Flood of Oct 01st 2008

Figure II.26 El Geurrara flood oct 1st 2008

Figure II.25 Floods 2008

Chapter 3. Prevention Plan of Guerrara Floods:

II.3.1 Introduction:

Flooding is a natural disaster that continues to pose significant challenges to communities worldwide. Its destructive consequences, ranging from loss of life to extensive property damage, emphasize the critical importance of understanding the underlying causes and dynamics of such events.

Flooding is rarely the result of a single isolated event. Rather, it is often a culmination of several interrelated causes that amplify its magnitude. Primarily, natural factors such as heavy rainfall, rapid snowmelt, and geological characteristics of the land play a fundamental role in initiating floods. Intense precipitation, exceeding the soil's capacity to absorb and retain water, leads to surface runoff and subsequent flooding. Moreover, regions situated in low-lying areas or near river basins are particularly vulnerable, as the natural topography favors water accumulation.

However, the story of flooding extends beyond natural causes alone. Human activities significantly contribute to the cumulative factors that exacerbate flood risks. The alteration of landscapes through urbanization, deforestation, and improper land management practices can disrupt natural drainage systems, reducing the ability of the land to absorb water. Paved surfaces and impermeable infrastructure further accelerate runoff, channeling water into rivers and exacerbating flood conditions.

Understanding the complex web of cumulative causes is crucial for effective flood mitigation and management strategies. By comprehensively analyzing the interplay between natural phenomena, human activities, and climate change, we can develop holistic approaches to minimize the impact of flooding on both human and natural systems. The findings presented in this chapter shed light on the multifaceted nature of flooding, serving as a foundation for informed decision-making and the development of sustainable solutions.

II.3.2 Material and Methods of Data Analysis:

In order to define the zones that can be flooded using remote sensing, we had to use Landsat 8-9 and 7, sentinel 2 data from flood crisis, that an able us to extract cartographic maps with a data which used in mathematical analysis and we treated the data in different platforms (ArcGIS Pro 2.8, ENVI 5.3, SNAP 9, Hyfran).

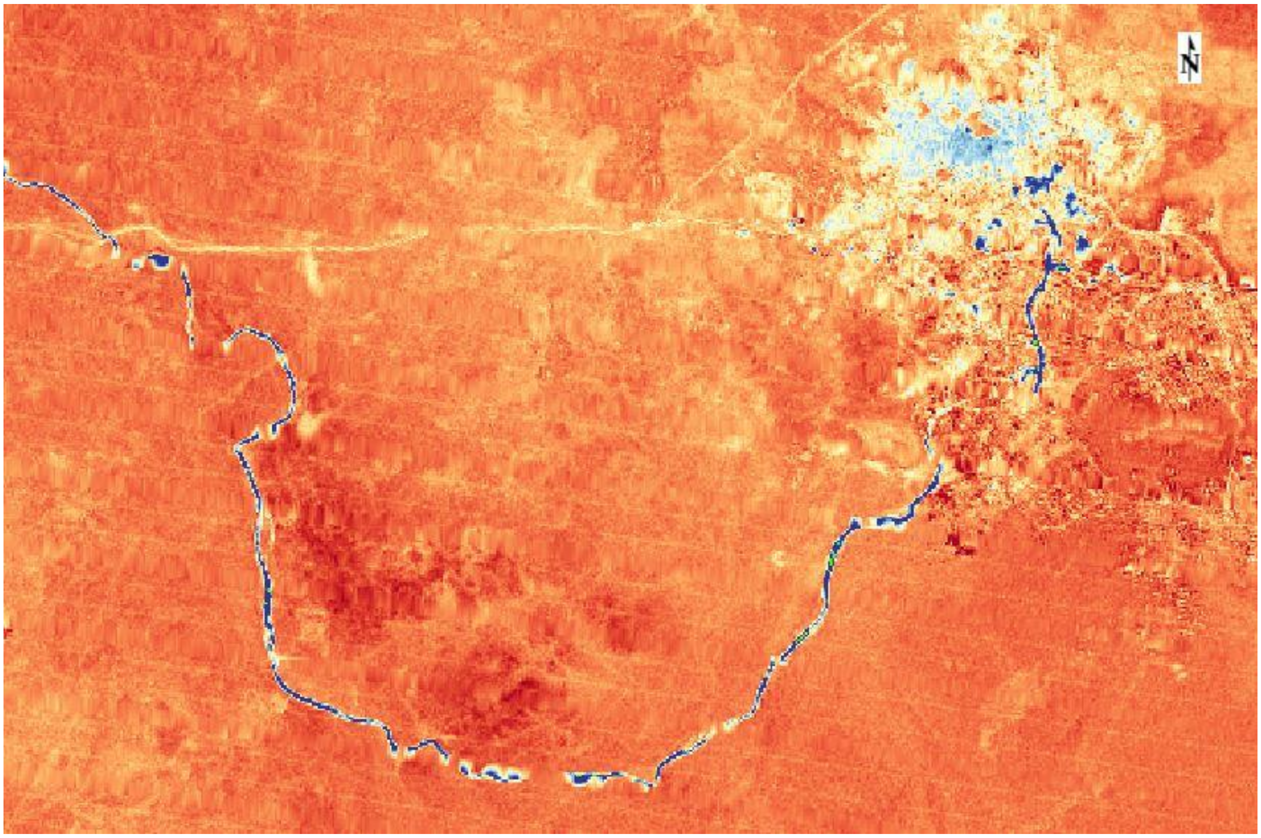


Figure II.29. The water extent of Oued Zegrir in flood of 2020

By investigating at all the flood crisis, we were able to find some bands that has been captured during that time, from different satellite, in the limits of the available information, due to the lack of some data that can cover our entire study area, so we focused on the city that suited in the watershed as mentioned before.

II.3.3 Image Selection and Download Satellite:

First, we determine the satellite imagery sources to Identify the available satellite imagery sources that provide high-resolution or medium-resolution images suitable for flood assessment according to desirable date. In my case the source was from the USGS **(Figure II.30)** which an able me to download Landsat 8, 7 and second one was Copernicus Open Access Hub **(Figure II.31)** that contains sentinel 1,2,3 data.

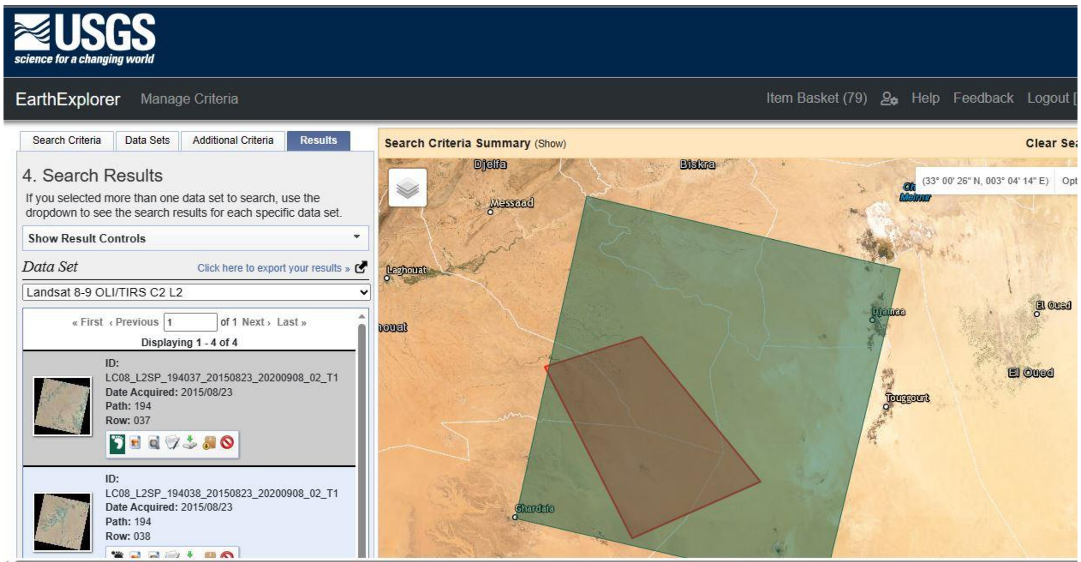


Figure II.30 The USGS Platform Website

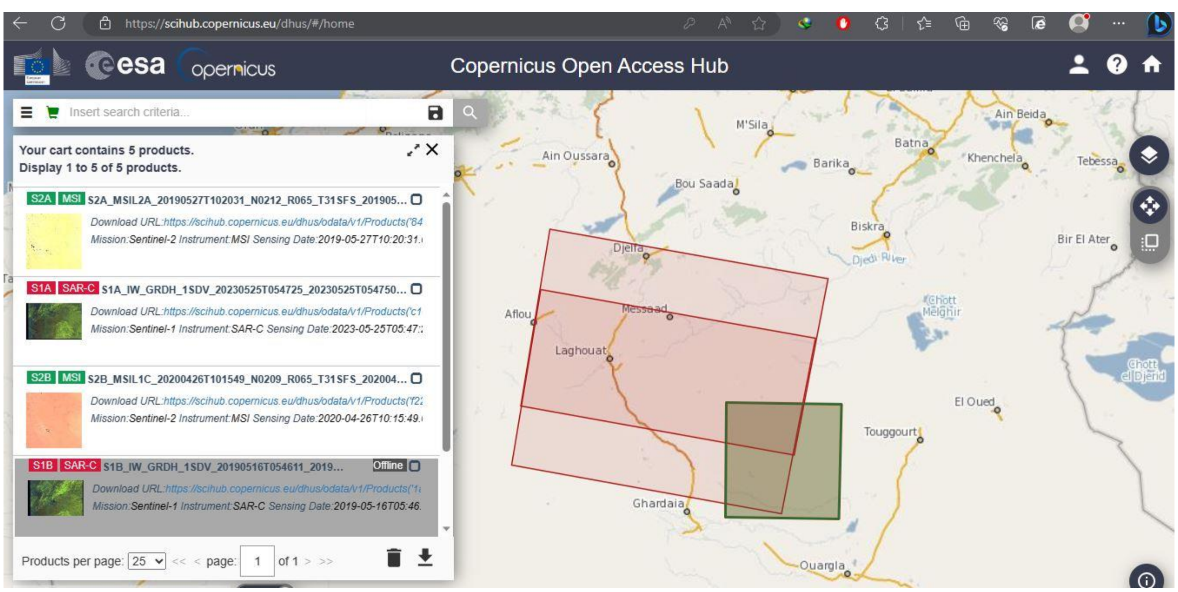


Figure II.31 Copernicus Website interface

So, we Identify the Study Area by Determining its geographic extent, and see the available data for the given period of time, and the image selection criteria will be considering some factors such as spatial resolution (pixel size), spectral bands available, cloud cover percentage, and image quality. Prioritize images with lower cloud cover to minimize interference during flood assessment.

II.3.4 Image Preprocessing:

After the download Landsat 8, we have to make the common preprocessing steps include radiometric calibration, atmospheric correction, Although The USGS EarthExplorer platform provides satellite images have already undergone geometric and radiometric correction, but these additional preprocessing steps gives more enhancements to the image, regardless of the Landsat 7 that needs other preprocessing called "Gap Filling" or "Gap Masking" due to the error of missing pixel values which appears as lines with no data, this caused the Scan Line Corrector (SLC) failure that occurred in 2003.

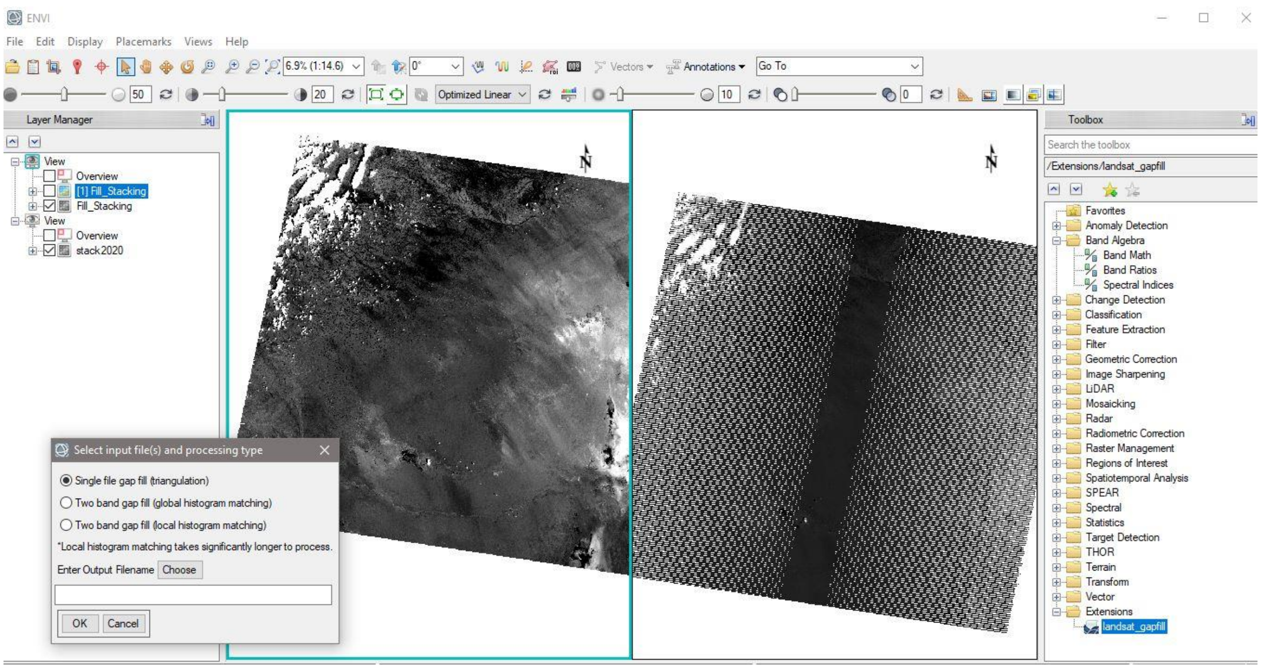


Figure II.32 Envi Err Line Correction of Landsat 7 image

Here, I used the extension “landsat_gapfil” in ENVI 5.3 Software to fix the err after stacking the required bands form (1 to 7), for water detection.

II.3.5 The water detection results of flood crisis:

During the flood, the areas of the watercourse exposed to water, resulting in a distinct reflection that can be effectively detected and quantified using the Normalized Difference Water Index (NDWI).

The NDWI is used to monitor changes related to water content in water bodies. As water bodies strongly absorb light in visible to infrared electromagnetic spectrum, NDWI uses green and near infrared bands to highlight water bodies. It is sensitive to built-up land and can result in over-estimation of water bodies. The index was proposed by McFeeters, 1996. (sentinel-hub, 2023)

And these are the formulas used to calculate the Normalized Difference Water Index (NDWI) for different satellite sensors are as follows;

Sentinel-2 NDWI = (B03 - B08) / (B03 + B08)

Landsat 7 ETM+ NDWI = (B02 - B04) / (B02 + B04)

Landsat 8 NDWI = (B03 - B05) / (B03 + B05)

MODIS NDWI = (B04 - B02) / (B04 + B02) (sentinel-hub, 2023)

NDWI Values:

Values of water bodies are larger than 0.5. Vegetation has much smaller values, which results in distinguishing vegetation from water bodies easier. Built-up features have positive values between 0 and 0.2. (eos.com, 2017)

NDWI Results:

The data is used for flood detection are the sentinel 2 images of May 27th 2019, and April 26th 2020 with resolution of 10m/pixel. The software used for image correction and NDWI calculation is SNAP.

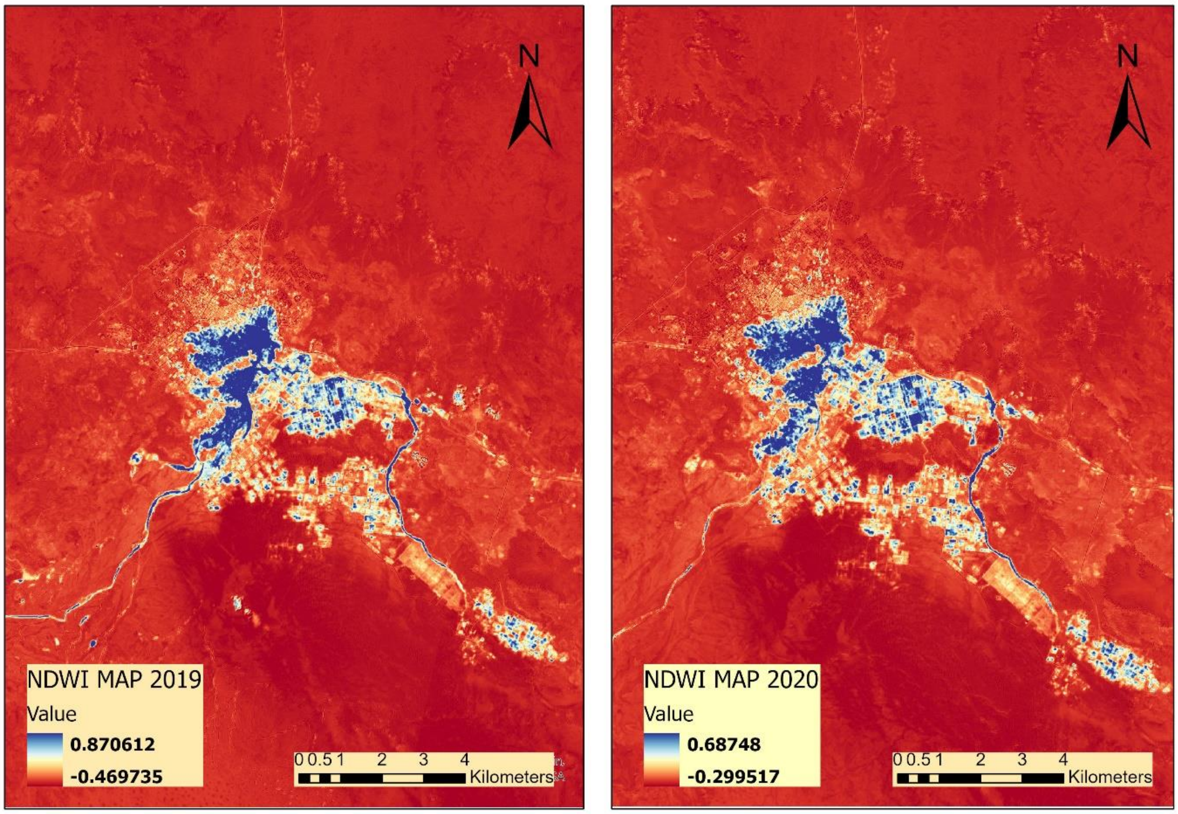


Figure II.33 NDWI maps for two flood periods

The water colored with bleu color, with higher values of NWDI, but as we see that flood of 2019 was higher a mount of water, with a value of 0.8 comparing to the flood of 2020 that comes with a little bit less a mount of water, which has a value of 0.6 only. So the flood amounts is various from time to time, and that's for different factors of climate.

II.3.6 Result and discussion:

The result of the flooding vulnerability mapping was achieved through the implementation of the Analytic Hierarchy Process (AHP) in ArcGIS Pro. This approach involved overlaying and weighting seven maps, including land cover, precipitation, drainage density, slope, elevation, topographic wetness index (TWI), and normalized difference vegetation index (NDVI), to assess the vulnerability to flooding of the study area.

By applying this method, we were able to find these results from excel sheet.

VN	Variable Name	Weight	%
1	Land use	0.06	6
2	Rainfall	0.14	14
3	Drainage Density	0.25	25
4	Slope	0.1	10
5	Elevation	0.15	15
6	Topographic Wetness Index	0.2	20
7	NDVI	0.1	10

Table 2 AHP results

After the calculation we set the values in the ArcGIS PRO to do the weight sum and that in order to show the result in the map.

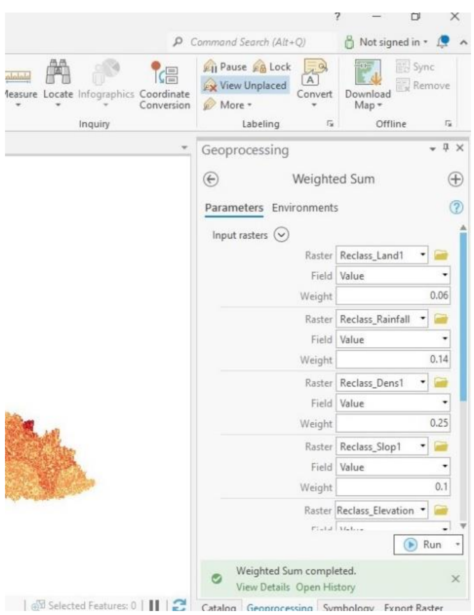


Figure II.34 Weighted Sum Process

And here is the result that shows us the vulnerable areas in our study area.

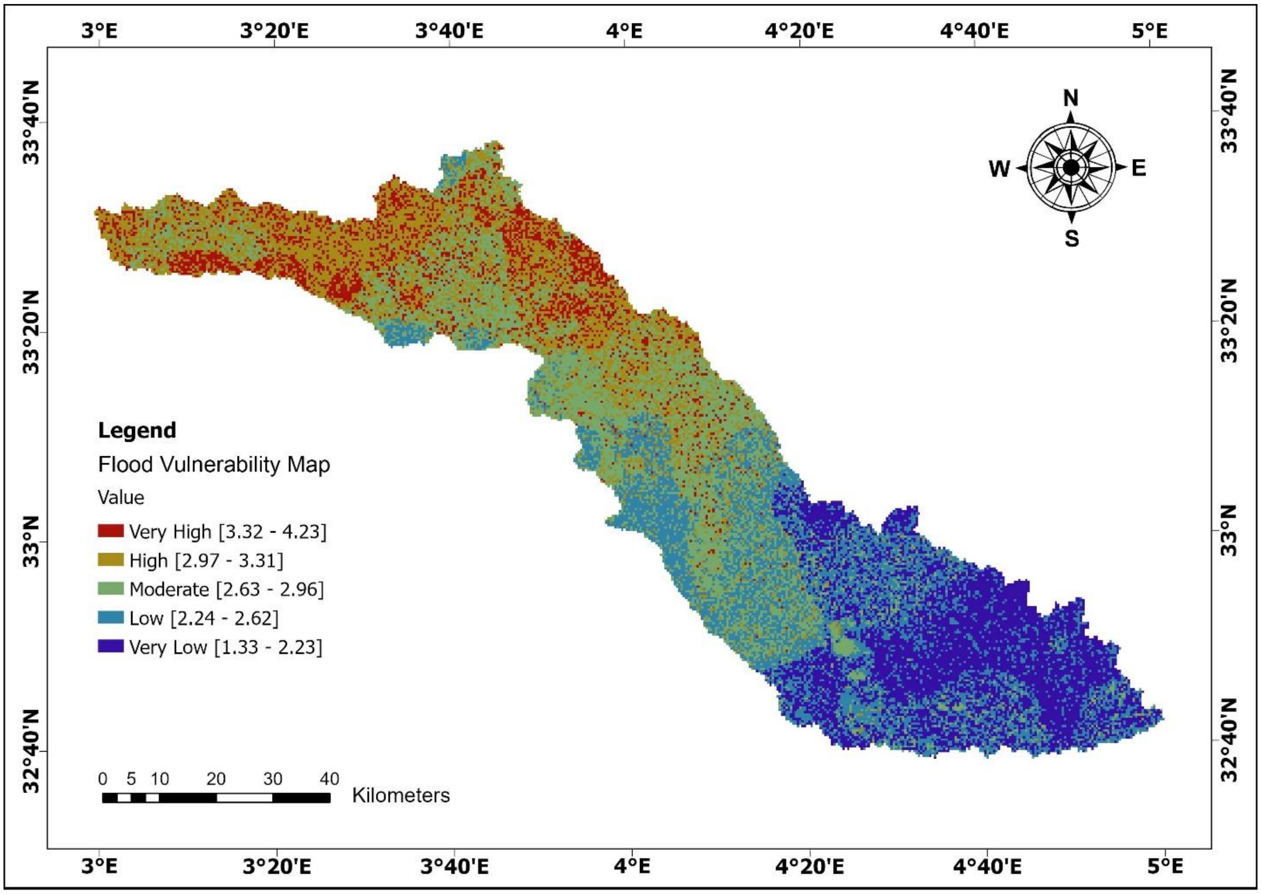


Figure II.35 Flood Vulnerability Map

The Analytic Hierarchy Process (AHP) is a method for organizing and analyzing complex decisions, using math and psychology. It was developed by Thomas L. Saaty in the 1970s and has been refined since then. It contains three parts: the ultimate goal or problem you're trying to solve, all of the possible solutions, called alternatives, and the criteria you will judge the alternatives on. AHP provides a rational framework for a needed decision by quantifying its criteria and alternative options, and for relating those elements to the overall goal. (passagetechnology, n.d.)

II.3.7 Recommendations:

1. Conduct a comprehensive flood risk assessment: Start by evaluating the current flood risk in the city, considering factors such as rainfall patterns, topography, drainage systems, and the impact of human activities. This assessment will provide a baseline understanding of the flood risk and help identify vulnerable areas.

2. Implement strict enforcement measures: Since building inside the forest is forbidden due to flood risk and environmental infringements as cutting trees that has a benefits in soil infiltration, enhancing the soil's capacity to absorb and retain moisture, which helps prevent runoff and promote groundwater recharge., it is crucial to enforce this regulation strictly. Increase monitoring and surveillance in the forested areas to prevent illegal activities such as unauthorized construction or deforestation. Implement penalties and fines for violators to deter illegal acts.

3. Enhance public awareness and education: Develop and implement public awareness campaigns to educate the residents about the importance of preserving the forested area and the risks associated with illegal activities. Promote responsible behavior and encourage community participation in flood prevention measures.

4. Improve drainage and water management systems: Invest in the development and improvement of drainage systems to effectively manage excess water during heavy rainfall or floods. This may include constructing additional canals, reservoirs, or retention ponds to capture and redirect water away from vulnerable areas.

5. Establish early warning systems: Install a reliable early warning system that can detect and provide timely alerts for potential floods. This system should include monitoring rainfall, water levels, and other relevant parameters to enable early evacuation and preparedness measures.

6. Collaborate with relevant stakeholders: Foster collaboration between government authorities, environmental agencies, community organizations, and other stakeholders to jointly work towards flood prevention. Encourage the sharing of resources, expertise, and data to develop a holistic and effective flood prevention plan.

7. Implement nature-based solutions: Explore the use of nature-based solutions, such as afforestation, wetland restoration, and green infrastructure, to enhance natural water retention and infiltration capabilities. These measures can help mitigate flood risks and preserve the ecological balance of the forested area.

8. Continuously monitor and adapt: Regularly monitor and assess the effectiveness of the flood prevention measures implemented. Adapt the plan as necessary based on new data, changing weather patterns, or evolving circumstances to ensure long-term resilience against floods.

Remember that implementing a comprehensive flood prevention plan requires collaboration, resources, and sustained efforts from various stakeholders. It is essential to prioritize the preservation of the forested area while effectively managing the flood risk to protect the city and its inhabitants.

II.3.8 Conclusion:

Our approach encompassed a multi-faceted analysis that integrated mathematical modeling, cartography, and geospatial data processing techniques. Leveraging the wealth of information provided by remote sensing technologies, we accessed high-resolution satellite imagery, including Landsat 8 and 7 as well as Sentinel 2 and 1. These satellite platforms offered invaluable insights into the study area, enabling us to gain a comprehensive understanding of the flood dynamics.

To extract essential indicators of flood susceptibility, we employed key spectral indices, most notably the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Water Index (NDWI). These indices, obtained through meticulous correction processes, allowed us to quantify vegetation density and water content, respectively. By carefully analyzing the NDVI and NDWI values across the study area, we were able to identify regions prone to flooding and delineate their corresponding levels of risk.

Beyond the satellite imagery and spectral indices, our research encompassed a wide array of additional data sources. We considered topographic data, historical flood records, land cover classifications, and demographic information. By integrating these diverse datasets, we attained a holistic understanding of the factors contributing to flood hazard and the potential impact on human settlements.

Our ultimate goal in this research was to develop a flood prevention plan that would enhance preparedness and resilience in the face of future flooding events. By accurately assessing flood hazard and risk, we aimed to provide decision-makers and emergency management authorities with actionable information to inform their mitigation efforts. The flood hazard map and flood risk map presented in this chapter serve as crucial tools to guide land-use planning, infrastructure development, and the implementation of effective early warning systems.

Through the amalgamation of geomatics techniques, remote sensing technologies, and a comprehensive analysis of diverse datasets, our study offers a robust foundation for flood risk management. We believe that the insights and recommendations derived from this research will contribute significantly to safeguarding vulnerable communities and fostering sustainable development in flood-prone areas. In the following sections, we delve into the materials and methods employed to generate our flood hazard and risk maps, unraveling the intricacies of our approach and presenting the valuable results of our endeavors.

General conclusion:

In conclusion, the integration of geomatics tools and techniques has proven to be instrumental in understanding and managing the complex nature of floods. Through spatial and temporal scale analysis, hydrological investigations, and geomorphological assessments, we have gained valuable insights into the dynamics of flood events and their associated risks.

Our research has highlighted the significant role of human irrational acts in exacerbating flood hazards. From improper land management practices to inadequate infrastructure planning, these factors contribute to both direct and indirect impacts, amplifying the vulnerability of communities to flooding events.

The implementation of advanced software has been pivotal in processing and analyzing the vast amount of geospatial data required for comprehensive flood studies. These tools have facilitated the generation of flood hazard maps, risk assessments, and the identification of areas requiring targeted prevention measures.

Moreover, the interdisciplinary nature of geomatics has paved the way for new applications and innovative approaches in flood prevention planning. By integrating remote sensing, geospatial analysis, and hydrological modeling, we have identified promising strategies to enhance flood resilience, including early warning systems, land-use planning, and infrastructure adaptation.

To develop an effective flood prevention plan, it is crucial to consider the interplay between natural processes, human activities, and the application of geomatics techniques. This integration allows for a holistic understanding of flood dynamics, risk assessment, and the identification of appropriate mitigation measures.

However, it is important to acknowledge that flood prevention is an ongoing and adaptive process. As new technologies emerge and our understanding of floods evolves, the prevention plan must continually be updated and refined to address emerging challenges and capitalize on innovative solutions.

Ultimately, by leveraging the power of geomatics and the insights gained from our research, we have laid the groundwork for effective flood prevention and management. The findings presented in this study provide a foundation for policymakers, land managers, and communities to develop proactive strategies, build resilience, and protect lives and livelihoods in flood-prone areas. It is our hope that this research will contribute to a safer and more sustainable future in the face of increasing flood risks.

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