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The use of remote sensing techniques to identify and evaluate a potential site for water harvesting in eastern Missan, Southern Iraq

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In
(Remote Sensing and Engineering Geology)

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بسم الله الرحمن الرحيم

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Dedication….

To the pure soul... always and forever

To the woman who inhabited the way of knowledge until the last moments

To the warrior who resisted the disease

To the teacher who will remain in our minds

To Dr. Sahar, rest in peace

Zahraa …

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Abstract

According to large climatic changes, there is a need to establish non-traditional systems and methods for storing and managing water, especially projects on a small scale (fields and farms with an area of several hectares). In the current study, the focus was on the eastern region of Missan due to its agricultural, economic, and environmental importance to the province. The thematic map was prepared by the Directorate of Agriculture of Missan for distribution of agricultural areas in the study area.

As a first stage, satellite images captured by the (Landsat) satellite for the year 2020 were used. After that they were processed using the (Image Enhancements) method using the (Erdas) program. The results were analyzed statistically using Analytical hierarchy processes. At the end of the stage, the possibility of establishing two types of water harvesting systems in the region was revealed. The first is the floodwater harvesting system, which is concentrated in the valleys of rivers and torrents, and the second is the rainwater harvesting system, which is in the hillside areas. When matching the results with the map of the distribution of agricultural fields in the region, it was found that the two types can be used to solve the water crisis problem in the study area.

The second stage relied on analyzing and studying the geomorphology of the landscape (landscape) for the purpose of analyzing the water path lines and their velocity towards agricultural lands. The slope of each region was also analyzed and the soil models were analyzed in order to know the areas of erosion and sedimentation, and thus the determination of the key point area and the drawing of the key line to choose the best site for constructing a water collection site or digging a watering pond.

In the third stage, the projects established or planned to be established in the study area were studied. The environmental ethical scale method was used to determine the strengths and weaknesses of each of them. The most important projects planned to be built are Teeb, Al-Chafta, Kuissa, Arus Missan, and Geni dams. As for the projects that are operating, they are the Dewerige Dam and the East Missan Canal Project. At this stage, images taken from small drones were used after some photometric calculations were made to obtain high-accuracy results.

The study showed the importance of analyzing topographical elements, soil characteristics, wind direction, and solar incidence angle to establish effective water

harvesting projects that can withstand themselves without the need for any type of maintenance in the future.

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Abbreviations

WHS Water Harvesting System

FWH Floodwater Harvesting

RWH Rainwater Harvesting

GPS Global Positioning System

NASA National Aeronautics and Space Administration

USGS United States Geological Survey

OLI Operational Land Imagery

DEM Digital Elevation Modal 3D Three Dimension

GIS Geographical Information System

AHP Analytical Hierarchy Process

TWI Topographic Wetness Index

TRI Topographic Ruggedness Index

SAVI Soil – Adjusted Vegetation Index

MNDWI Modified Normalized Difference Water Index

GSI Topsoil grain size

NDSI Normalized Difference Sand Index

NIR Near Infrared

SWIR Short Wave Infrared

Chapter One
Introduction

CHAPTER ONE
INTRODUCTION

1.1 Background

The Earth’s climate is changing, and the global climate is projected to continue to change over this century and beyond. This has led to water crises in various regions of the world (Hanjra and Qureshi, 2010) (Fig.1.1) shows the world physical water scarcity across the world.

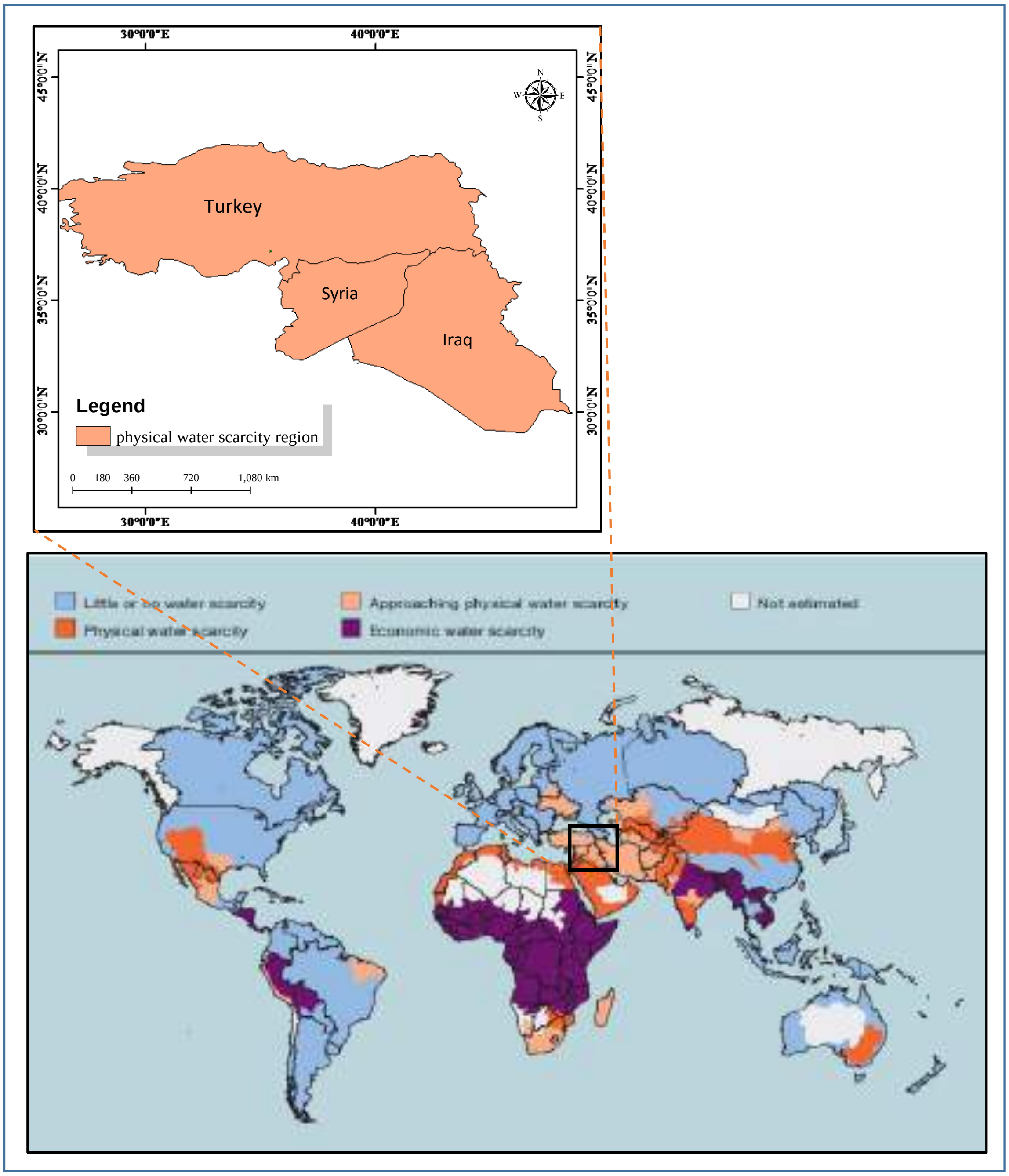


Fig.1.1 Water scarcity across the world modified after (von Grebmer et al., 2012)

The sources of Tigris and Euphrates rivers have been located within approaching physical water scarcity. These changes and problems require a new vision and practical solutions to the water problem in Iraq. Remote sensing and GIS have always been effective and important tools in the study and analysis basins and management surface and sub-surface water. In addition to, connecting between hydrological phenomena and topography such as: slope, drainage density, stream length (Magesh, *et al*., 2014). In this study remote sensing and GIS were applied to determine appropriate site for water harvesting techniques by analyze satellite imagery (Landsat8, the operational land imager, OLI) and sentinel 2A-MSI sensor. Multi- remote sensing spectral indices are used to estimate the soil texture, vegetation density, water bodies and drought conditions based on spectral signature of materials in the earth surface

1.2 Research Problem

The water crisis in Missan has caused many problems. These problems are the degradation of agricultural areas, migration of people from many areas, damage to pastures, and many conflicts over water. Therefore, there is an urgent need to find new technologies that store rainwater and flood water and use them in agriculture, develop grazing areas, and reduce environmental damage resulting from the long dry seasons and devastating floods in the area.

1.3 Objective of the study

The main objectives of this study can be summarized as:

1. Studying the agricultural map to detect the sites of agricultural activity in the area.

2. Using satellite imagery to determine suitable sites for rain and flood water harvesting in the study area.

3. Landscape analysis and classification of selected sites to determine rainwater and flood harvesting paths and sites.

4. Studying previous projects in the study area to anticipate the expected problems in the future.

1.4 The Study Area

Missan eastern desert is situated in the south-eastern of Iraq at 260 km from Baghdad Fig.1.4. Its lies between longitude 32º47' 44.59''N, 31º58' 2.54''N and latitude 46º31' 55.27''E, 47º35' 57.48''N, also encompasses an area of (3870) km^2. The study area extends from the north of Missan to the southeastern Fig.1.2.

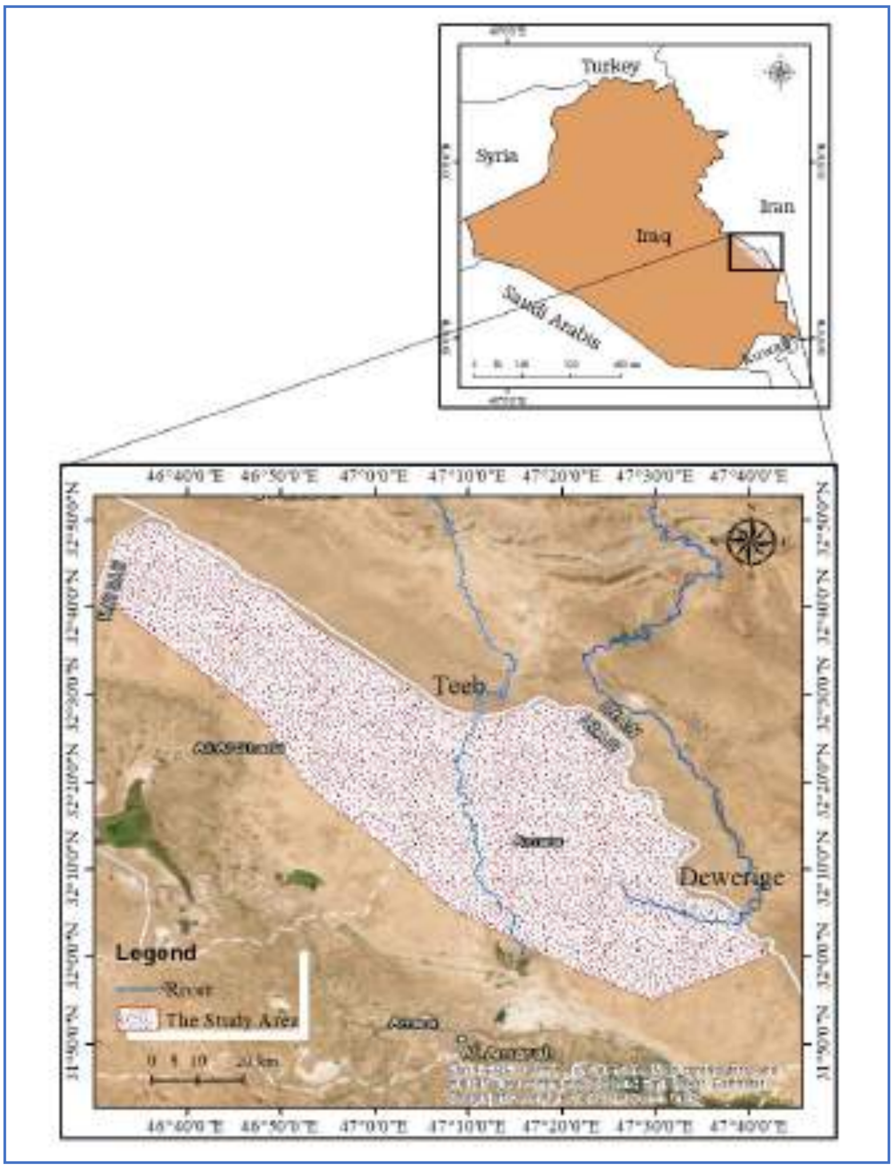


Fig.1.2 Location of the study area

1.5 Geology Setting

1.5.1 Topography

Based on topographic map (Fig.1.3) the elevations of the under investigated area range from (0 -235)m. The topography in the study area is gradual from high terrain regions (Hemrin and Al-Bend hills), which reach up to 253m. Whereas, the elevation decreases gradually to ward Al-Amara city about 5m and less in the southwestern parts of the study area.

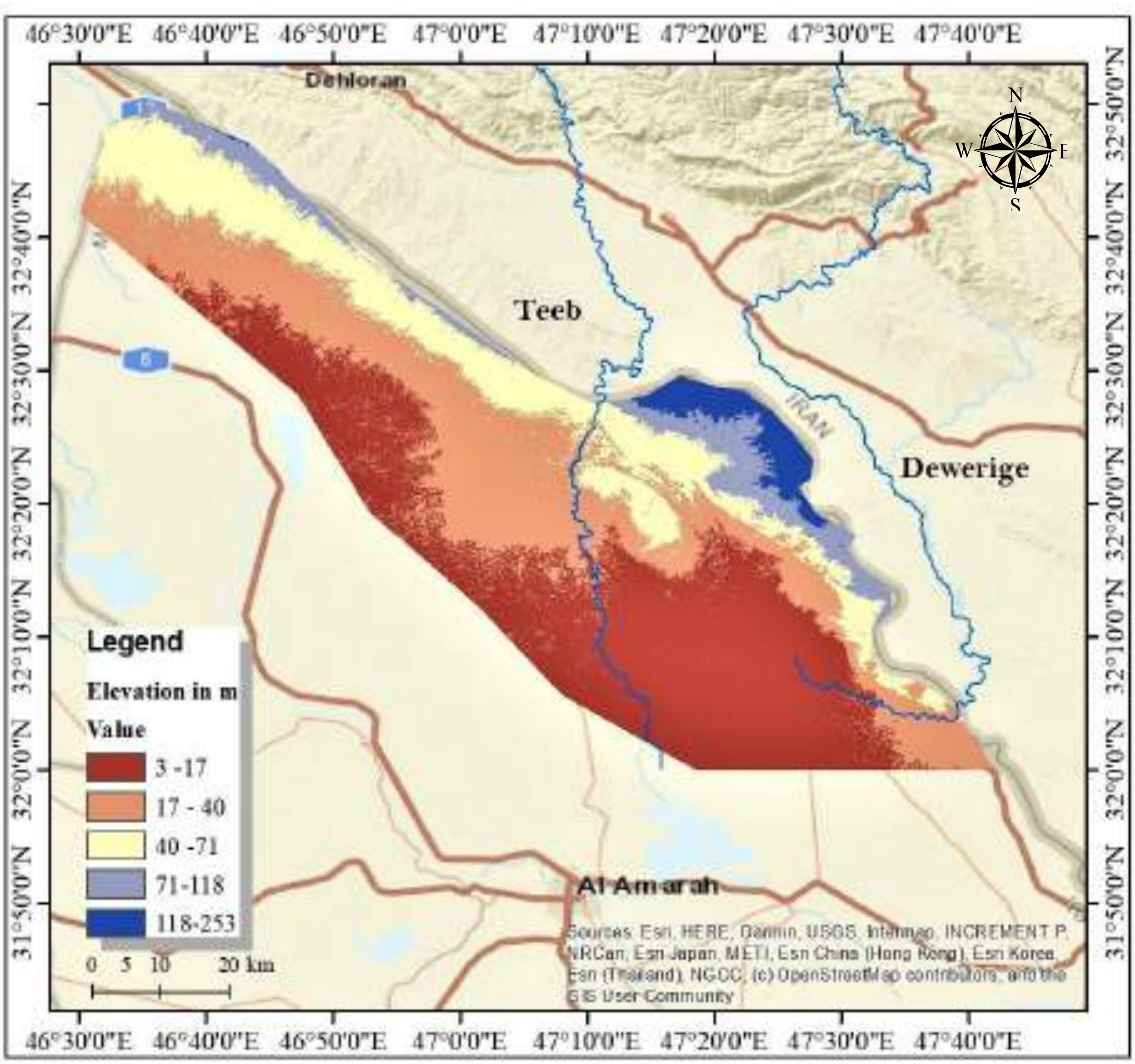


Fig.1.3 Topography of the study area

1.5.2 Lithology and Stratigraphy

The study area is a part of the flood plain covered with Quaternary deposits (Fluvial and aeolian sediments) (Fig.1.4). The stratigraphic column of Quaternary is about (120)m. These sediments are estimated to be 95% of the study area. The exposed rocks into the area are belong to tertiary (Pliocene) covering the eastern area (Barwary, 1993).

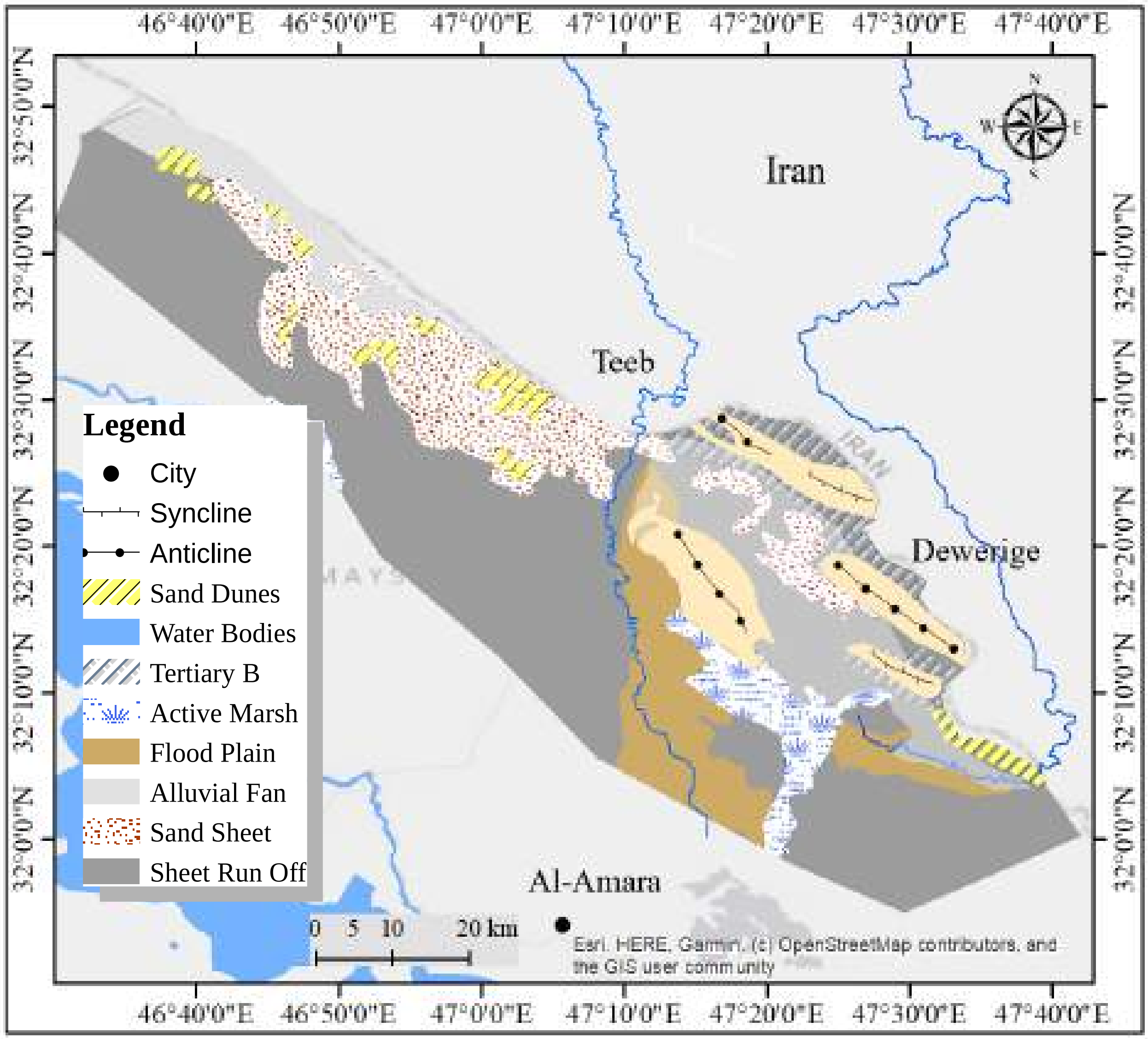


Fig.1.4 Geologic map of the study area modified after (Sissakian and Fouad, 2015)

The stratigraphic column of study area is briefly illustrated :

1. Tertiary Sediments

This period sediments are exposed in high terrain areas (Hemrin hill) in northeastern part of the study area. The certain formations are Mukdadya and Bai Hassan Formation (Aqrawi, *et al*., 2010). Stratigraphic column in the area as following:

I. Euphrates Formation

In lithology, the formation comprises of limestone with texture ranging from oolitic to chalky limestone, In addition to conglomeratic limestone. Sedimentary environment of Euphrates formation is Neritic environment in the lower, whereas continental environment in the upper. The geological age of formation belongs to the late early Miocene sequence (Jassim & Goff, 2006).

II. Fat'ha Formation

The Fat'ha Formation is widely spread formation in Iraq, belongs to middle Miocene sequence. The stratigraphic column of this formation can be categorized into two members. Each member began with Marl to thin beds of limestone and thick beds of Gypsum. Euphrates formation is the lower contact while Injana is the upper contact (Lateef, 1975).

III. Injana Formation

The formation varies in thickness, maximum formation thickness is 900m was observed in Kirkuk. The geological age belongs to upper Miocene. Injana formation deemed the transiently environment between marine and continental environments. The formation contains the sequence of sandstone, claystone, and siltstone. Mukdadya Formation is the upper contact of the formation (Jassim, & Goff, 2006).

IV. Mukdadya Formation

This formation characterizes as varies in facies and thickness around 1411m in the northeast of Missan, parallel to Hamrin Mountain. The maximum thickness up to 2000 m of fining upwards cycles of gravely sandstone, sandstone is red mudstone. It was previously called lower Bakhtiari Fm and consist of a finning upward sequence: sandstone, pebbly sandstone, grey mudstone, and siltstone. The sedimentary environment of Mukdadya formation was fluvial environment, with geological age belongs to early Pliocene (Aqrawi, *et al*.,2010).

V. Bai Hassan Formation

The upper part of Bakhtiari formation, that overlies Mukdadya called Bai Hassan recognized as coarsening upward sequence. This formation was deposited during late Pliocene in fluvial environment. The average thickness of Bai Hassan Formation is about 3500m (Jassim, & Goff, 2006). It was descripted by coarsing upwards cycles of siltstone and claystone with gravel. There is thin bed of conglomerate deemed the contact between this formation and Mukdadya. The outcrops of Mukdadya and Bai Hassan Formations are exposed in northeastern parts of study area (Barwary, 1993).

2. Quaternary Sediments

Under investigated area comprises a totally of quaternary deposits at most sand and alluvium deposits. These sediments are characterized by fine grained sediments finer grained compared to Mukdadya and Bai Hassan. The fundamental units of quaternary deposits in the understudied area are an alluvial fan, aeolian deposits, and flood plain. The major thickness of the alluvial fan is about 15m, coarse and poorly sorted deposits of boulder and gravel, in addition to layers of fluvial sediments. Silty clay and clay are deemed mostly sediments of floodplain in the study area with a depth 1m or less (Lateef, 1975).

1.5.3 Hydrology of Study Area

1. Rivers

Missan eastern desert characterized by the presence of two seasonal streams flows through, (Fig.1.5). These streams are Teeb and Dewerige, which suffer from sudden flooding that occurs in short duration and high amounts of sediments (Table:1.2). The discharge of the two rivers is changing during the year (Tables 1.3).

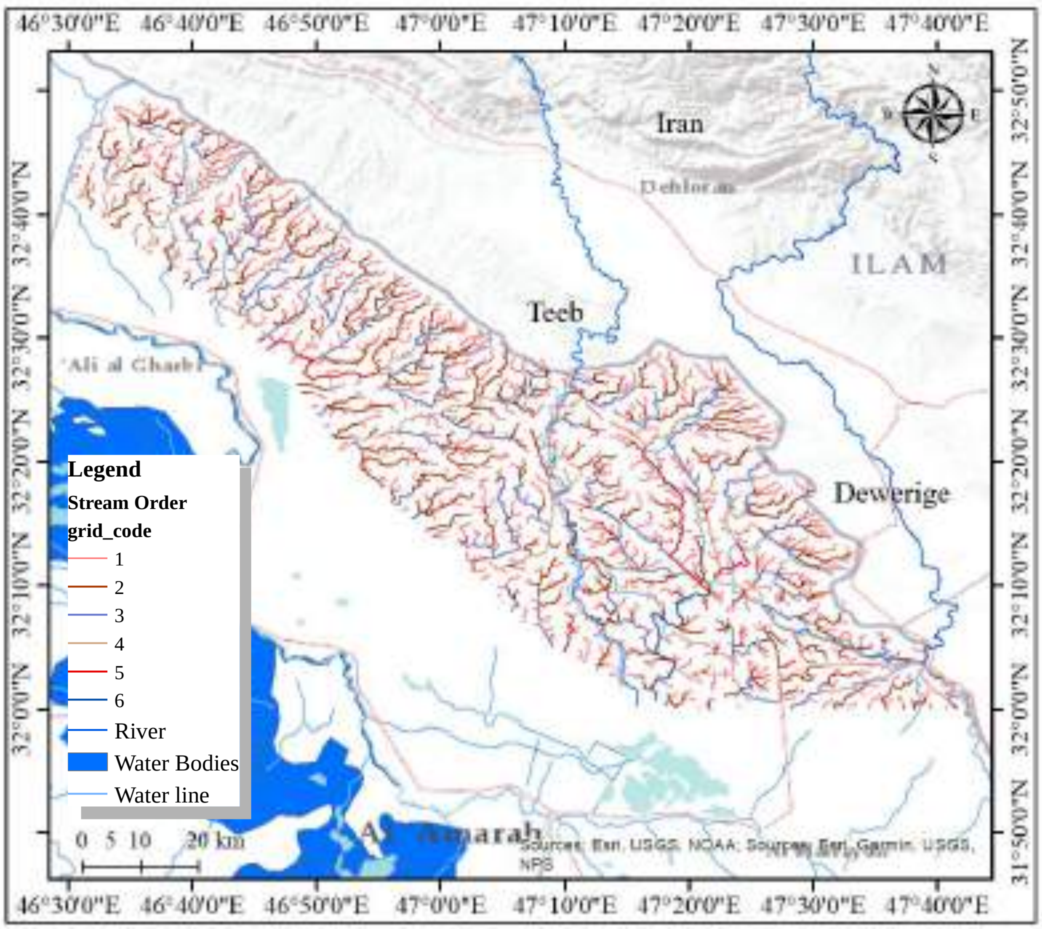


Fig.1.5 Hydrologic map of the study area

Table1.2 shows the average monthly discharge (m^3/s) in Teeb & Dewerige (Ministry of water resources, 2015):

River	Jun.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Teeb	350	800	650	125	50	12	10	10	10	5	8	75
Dewerige	200	300	400	65	25	5	-	-	-	5	10	27

Table 1.3 Hydrological data of study area

Hydrological Item	Details	References
Teeb River	• Total length is 500km. • Length in Iraq is 65km. • flood discharge is 898 m^3 • average width is 50m.	(Al-Abadi, 2012), (Ministry of Water Resources, General Commission of Groundwater, 2019).
Dewerige River	• Total length is 202km. • Length in Iraq is 27km. • Average width 30m.	

2. Climate

In general, the climate of the study area is a part of Mesopotamian and classified as Mediterranean climate, hot, dry summer, cold winter and a moderate spring and fall. The data were taken from Al-Amarah station records. Al-Amarah station is a meteorological station in the study area with coordinates (707446.08 E and 3523715.01 N) at 9m elevation. The major climate parameters are available in this station are rainfall (mm), mean temperature (C°), monthly average relative humidity (%), and evaporation (mm) (Iraqi Meteorical Organization, 2019).

2.1 Rainfall

The average monthly rainfall varies extremely between high altitude region (Hamrin hill) and the low region. It ranges from 150mm- more 200mm (Fig.1.6).

2.2 Temperature

Generally, there is a various considerably in temperature between summertime and winter, also day and night. The maximum value is recorded in July, whereas the minimum was in January. Temperature reaches to 50 C° is commonly occurring within the study area (Fig.1.7).

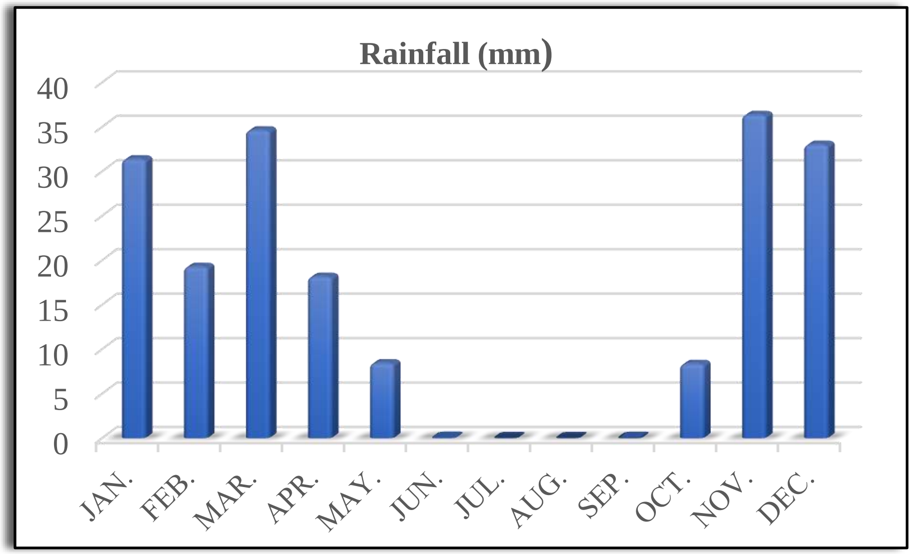


Fig.1.6 The average of monthly rainfall values

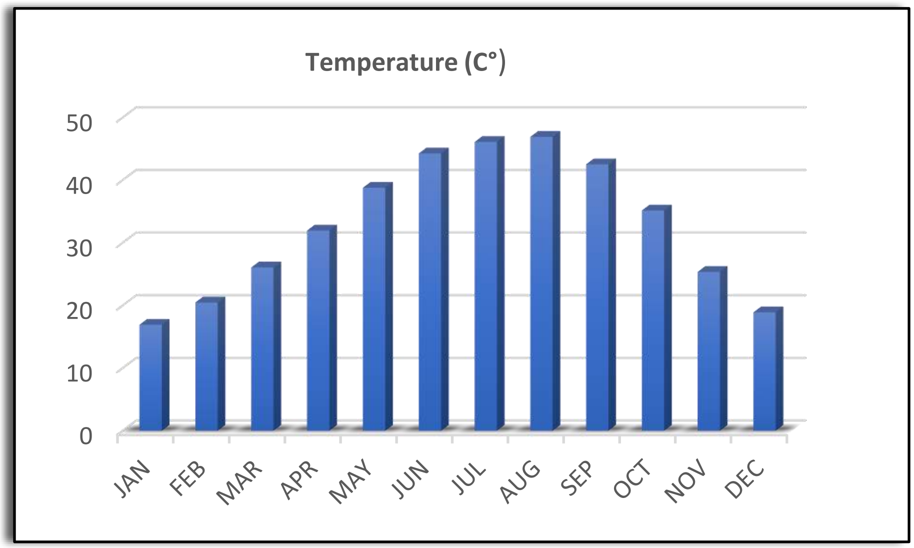


Fig.1.7 The average of monthly temperature values

2.3 Evaporation

Water lost by evaporation in study area is the major factor of losses water in water bodies. The average annual evaporation values is recorded by Al- Amara meteoric station for period (1991-2020). Maximum average value is observed in July 479.1mm. In contrast, the minimum was in Des. 59.9 mm (Fig.1.8).

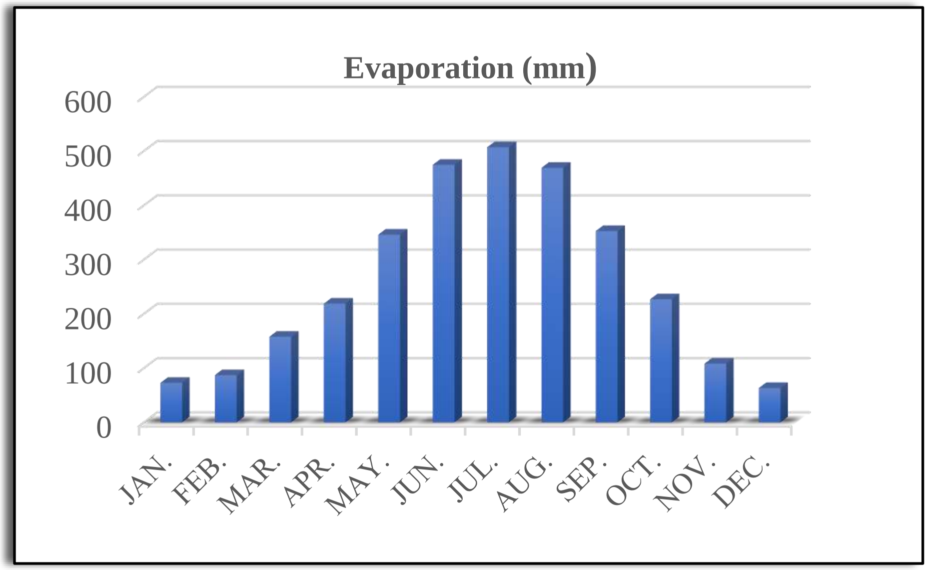


Fig.1.8 The average of monthly evaporation values

2.4 Relative Humidity

The average annual relative humidity within under investigation area is about 47% in winter. The monthly average reaches 72% while it drops to 25% in summer. Figure 1.9 clarifies average monthly relative humidity for the period between (1991-2020).

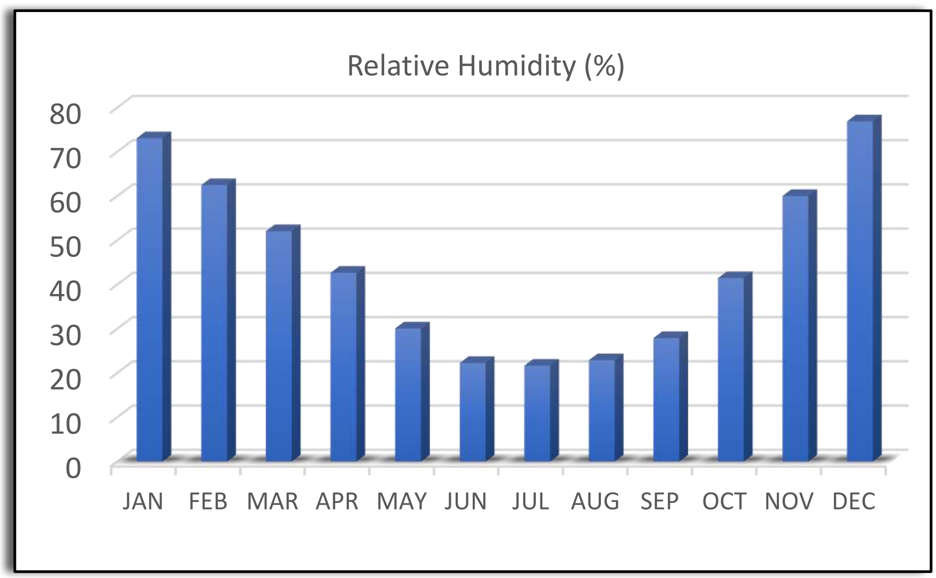


Fig.1.9 The average of monthly Relative Humidity

3. Groundwater Wells

Many of the groundwater wells are produced by the general commission of groundwater /ministry of water resource, and several of the hand-dug wells are found in the area which is used to stock life and agriculture purposes (Barwary, 1993). The area characterized by deep Artesian wells with drinkable water had been drilled in the Al-Zubidat town near to Hamrin hill (Fig.1.10).

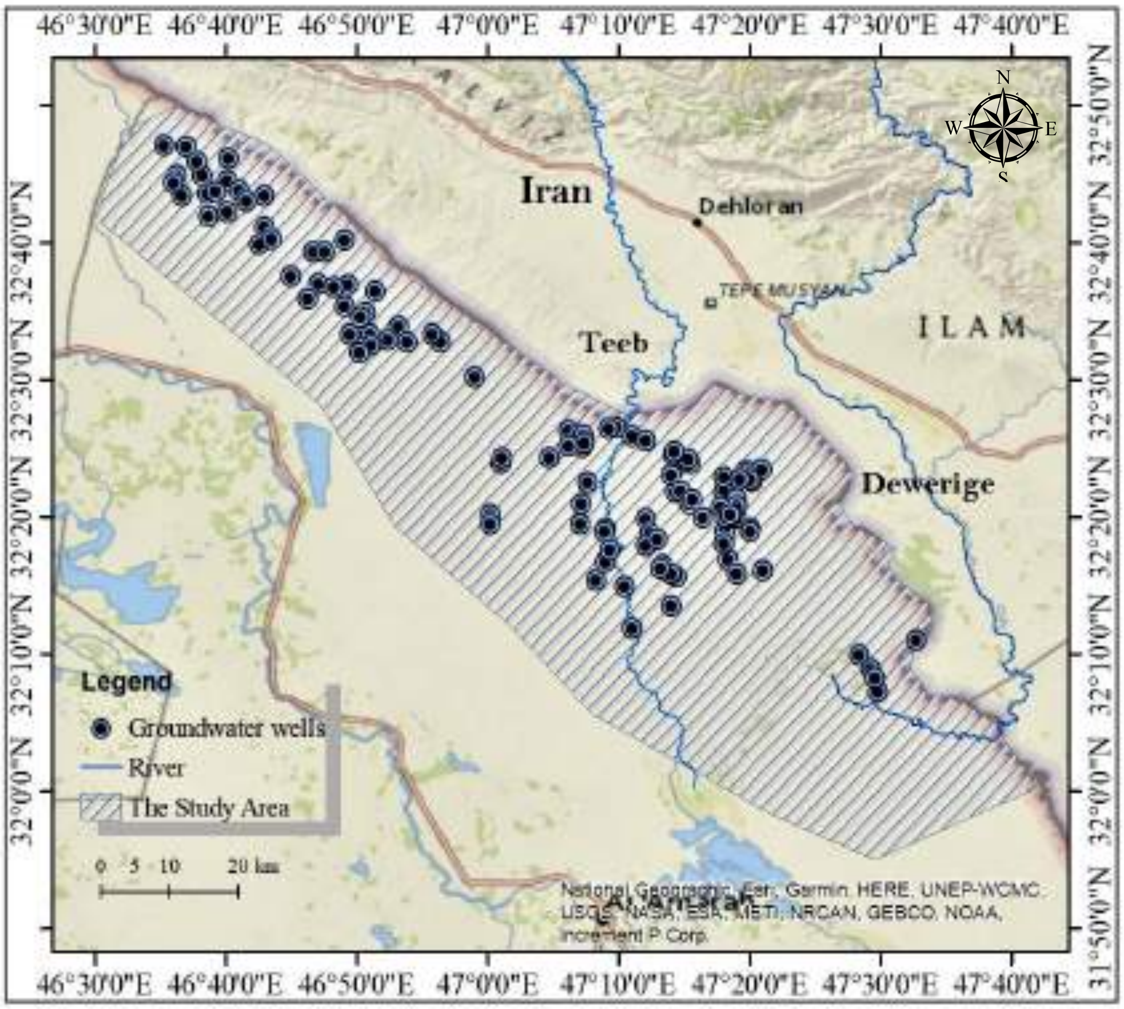


Fig.1.10 Distribution of groundwater wells in the study area

Mukdadya and Bai Hassan formations contain the main upper aquifer in the area near the Iranian border, whereas Quaternary deposits represent the upper aquifer in the rest area. The surface layers of quaternary deposits characterized by impermeable strata reach 10m. Therefore, the geological aquifer there usually found under this depth (Krasny, 1982).

4. Climate changes

The climate changes have caused fluctuations in recorded precipitation in watersheds in the study area (Teeb and Dewerige). Table 1.4 shows annual precepitation values along 24 years ago (Iraq meteorological orgnization, 2019), (World Weather Online, 2019):

Table:4.1 Annual presepetation in study area

Recorded years	Teeb watershed (mm)	Dewerige watershed (mm)
1995	198.0	-
1996	220.0	-
1997	183.4	-
1998	105.8	-
1999	130.0	-
2000	096.1	-
2001	100.3	-
2002	134.6	-
2003	-	-
2004	-	-
2005	-	-
2006	-	-
2007	-	-
2008	-	-
2009	035.2	191.9
2010	040.7	262.5
2011	054.2	270.3
2012	043.4	206.0
2013	188.6	284.3
2014	053.7	260.8
2015	060.3	071.0
2016	079.7	095.4
2017	062.8	159.4
2018	037.6	121.2
2019	451.7	809.8

1.6 Water Harvesting Concept

The water harvesting system (WHS) is generally defined as accumulation, storage, and management of rainwater and flood water runoff. Water collected from specific area called "catchment area" to supply water availability for agriculture, livestock, domestic use, and eco-system. Also, to get economic reserve which would be benefit in future. Its represents an ancient and simple process which is used for providing water (Liniger and Critchley, 2007).

1.6.1 Water harvesting components:

Water harvesting system consist of the following components (Critchley and Finket, 2013): (1) Catchment or accumulative area, (2) Conveyance or transporting system of runoff, (3) Storage parts, and (4) Application or implementation place. There components' may be nearby each other or linked by transporting system. Sometime storage area and application area are in the same place. Fig.1.11 and table1.5 explain the ideal form of water harvesting system component.

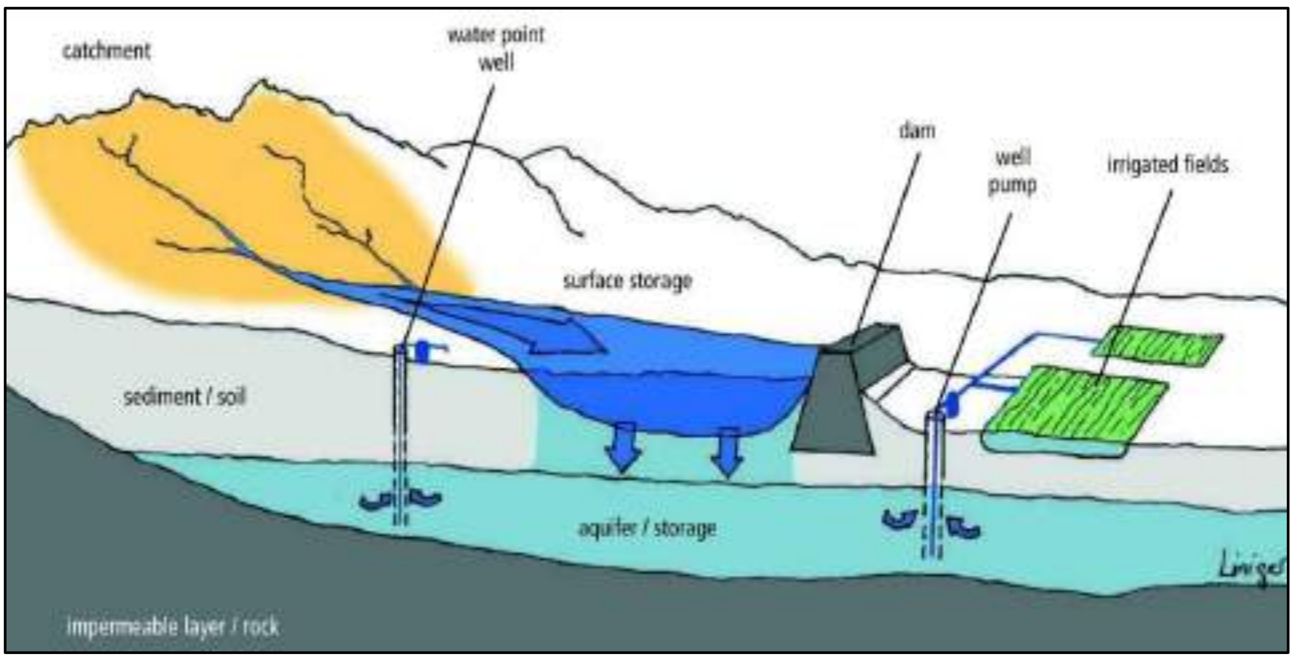


Fig.1.11 Water harvesting components (Mekdaschi and Liniger, 2013)

Table 1.5 Optimum components of water harvesting system (Datta, 2019)

Parts	Details
Catchment area	Defined as the specific location where flood and rainwater are collected, this area may be large extent for several kms or small just few meters. For instant, catchment
Transporting system of runoff	Conveyance or transporting system which is used for transport runoff water by pipes, rill, or gully into specific storage area.
Storage area	The prepared place for storing harvested water until further notice. The water may be saved at the surface in form of ponds or reservoirs, or underground in aquifers (recharge groundwater).
Application Area	**I**s the place where stored water in water harvesting system put into use in difference usage. For example, irrigation of crops, livestock, domestic use.

In general, water harvesting technique can happen naturally or artificially, for instant collect runoff water in depression is natural WH system. In contrast, difference type of dams and man-made construction are examples for artificial WH system (Hudson, 1987).

1.6.2 Classification of water harvesting system

Water harvesting systems can be classified based on catchment type into main types: floodwater harvesting and rainwater harvesting. These two types also, subdivided into classes, Table 1.6 explains techniques and specification of these types.

Table 1.6 Classifications of water harvesting systems (Falkenmark et al., 2001)

	Water harvesting system (WHS)			
	Floodwater	Rainwater		
Group	FloodWH	MacroWH	MicroWH	Rooftop WH
METHOD	Collect water outside farm, then spreading floodwater	Capture rainwater (runoff) outside the farm	Capture water in the farm	Capture water in the container
CATCHMENT AREA	Large and external area	Large and external area	Area within the farm	Household area
RUNOFF FLOW	Flow within certain course	Rill &sheet flow	Sheet and sometimes rill	Sheet flow
THE STORAGE OF WATER	Within the soil + Groundwater recharge	Within the soil + Groundwater recharge + Dam, bounds, or tanks	Within the soil + Trench, bunds, or bits	Surface & subsurface tanks
WATER USAGE	Supplementary irrigation + Groundwater recharge	Demotic, livestock + Supplementary irrigation + Groundwater recharge	Supplementary irrigation + Limited Groundwater recharge	Demotic, livestock + Limited Supplementary irrigation
EXAMPLES	The irrigation network (www.spate-irrigation.org);	Rainwater Harvesting Implementation Network (RAIN).	International Rainwater Harvesting Alliance (IRHA) (www.irha-h2o.org);	Rainwater Harvesting Implementation Network (RAIN).

1.6.3 Characteristic of Water Harvesting System

General advantages and properties of water harvesting system (Hudson, 1987):

- Provide independent water resource away from international treaties and restrictions.
- Provide pure and drinkable water.
- Avoid flooding risk, spatially in low regions.
- Minimize the need to utilize groundwater wells and save water reserve in aquifers.
- Protect freshwater bodies from polluted runoff.
- Generate water resource easy to set up and maintained by farmers or people in cites.
- Reducing damages in subsystem wastewater.

1.7 Keyline historical review

The keyline system has been started in 1943 in Sydney. In 1945 this strategy was widely used and constructed many dams with large, irrigated areas. After that, the keyline procedure has been applied throughout Australia according to farmers' desire to increase and evolve their water resources. Nowadays keyline programs were adopted in a didactic approach in schools and many colleges around the world. The keyline design was invented by Percival Alfred Yeomans. He is an Australian geologist. P.A. Yeomans can develop cultivation by creating a hydrologic system based on climate and landscape (Yeomans, 1954).

1.7.1 Keypoint and keyline terminology

The keyline technique is defined, as a combination of rules and principles that, is subjected to evolve the landscape through setting up a plan to organize and develop the landscape (both urban and rural) Fig.1.12.

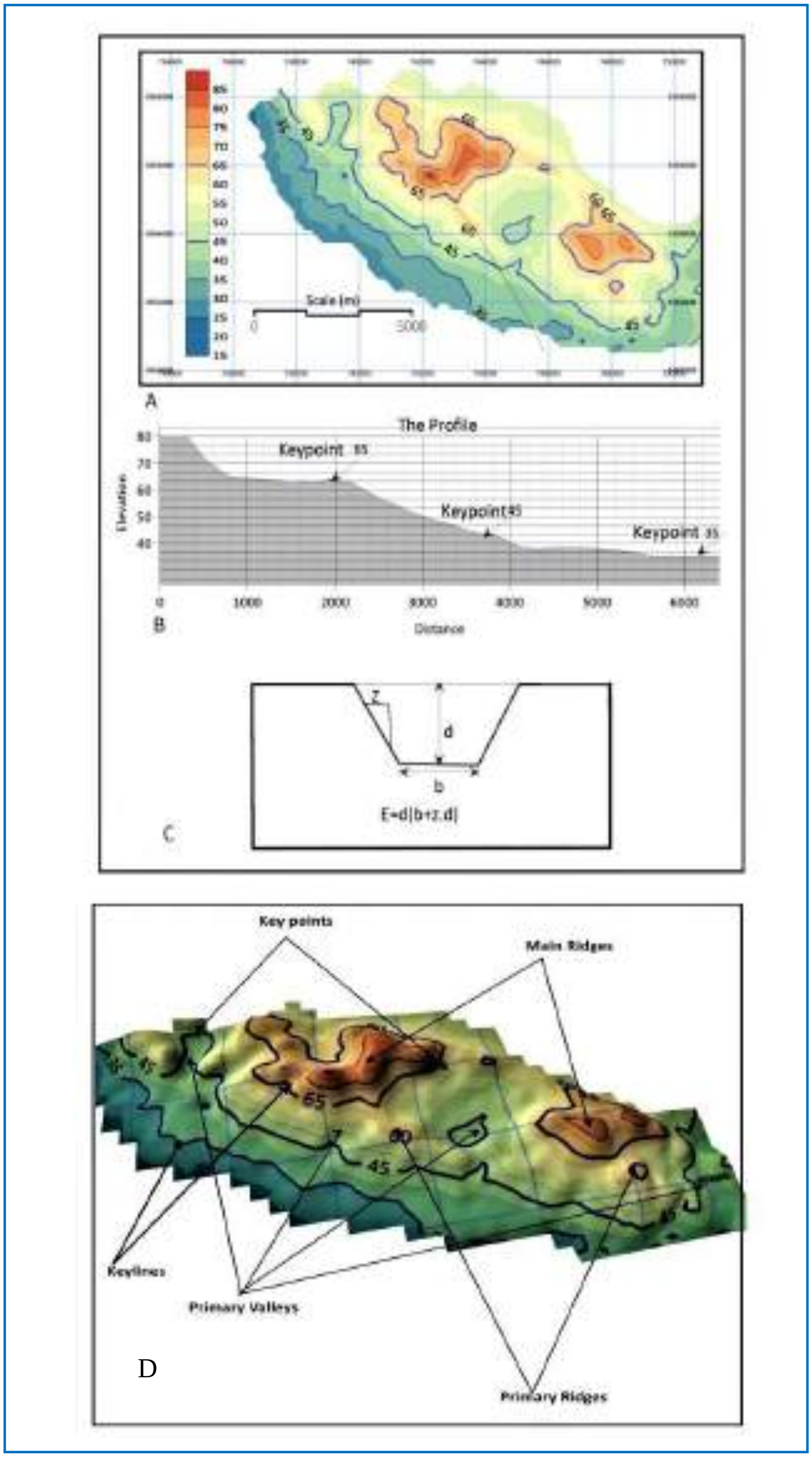


Fig.1.12 A, B, C, and D Landscape analysis and Keyline methodology (Al-Siaede, 2022)

Keypoint is a vital and significant position. Defined as a transition point when the hillside transforms from convex shaped to concave. Water behavior also changed at this point from erosional to depositional force. The situation of key point based on P.A.Yeomans, in between steeper and gentler slope. In otherworld the key point is the inflection point on a slope. This point can be located downhill close to the transition point, where the contour lines move away from each other. Lush plants and deep soil are usually observed at a key point. The connection between key points is called “keyline" (Yeomans, 1971).

1.7.2 The importance of keyline design

Keyline plan is a natural technique to overcome soil problems like salinity and erosion. The general advantages of keyline design to soil were expressed in Fig.1.13.

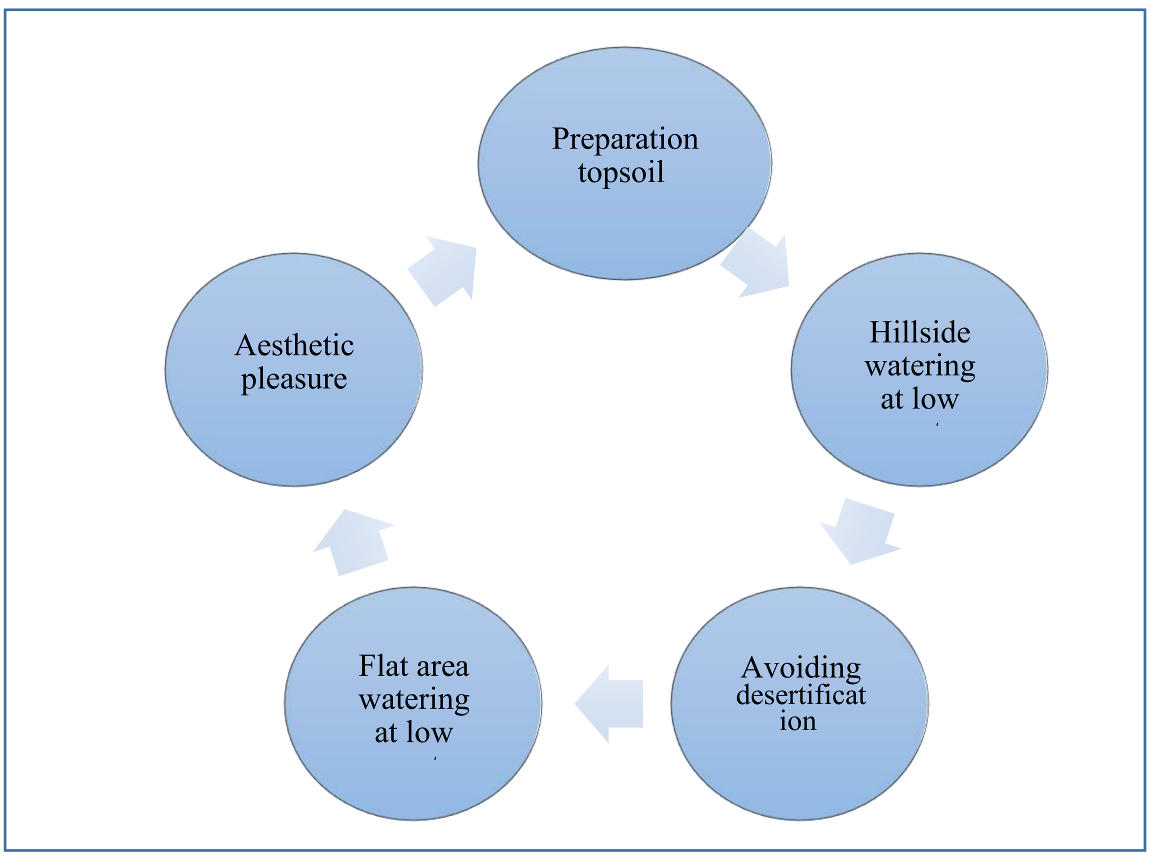


Fig. 1.13 The Influence of Keyline system on soil modified after Yeomans, (1958)

1.7.3 Component of keyline

The planning of keyline mainly depends on climate and the existence form of landscape that effected by geological condition in the site. The keyline components can be briefly explained in (table 1.7) and (Fig.1.14) (Duncan and Krawczyk, 2018).

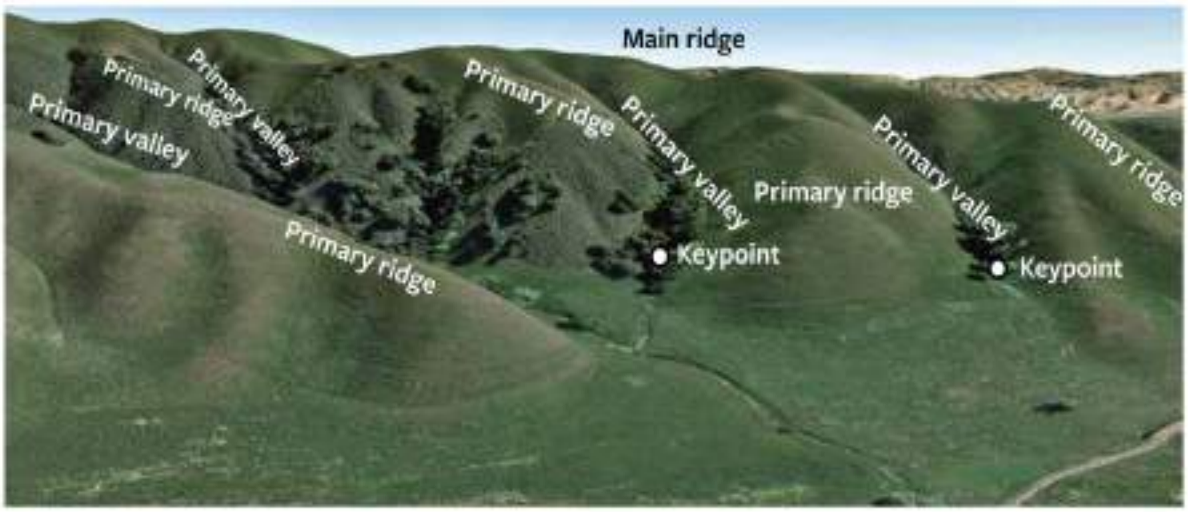


Fig.1.14 Keyline elements (Lomax, 2016)

Table 1.7 The main parts and details of keyline (Yeomans, 1973)

Parts	Details
Main Valley (MV)	Water moves and distribution in landscape a long side of main ridge within sets of valleys. These valleys are primary valley divided by smaller ridge called "primary ridge". The valley located in the sides of main ridge and extend from the steep slope until flats areas. Rainfall in keyline system flow and concentrated through valleys and flow down by smaller rounder valley.
	It is a large valley represent the lowest part of keyline system when main valleys connection and position of Keypoint and keyline. The length of landscape can be described as:

Primary Valley (PV)	o Short length landscape with length about 0.5km. o Medium length 1 to 2 km. o Long length about a few kilometers from the main ridge to the lower part of landscape. To summarize, the fundamental of landscape in keyline system is main ridge (the main portion of system), primary ridge and primary valley which is separated by it.
Main Ridge (MR)	The main ridge is the major landform in keyline plan categorization, and it is the junction of rainfall and runoff paths. The main ridge contains a water divide line that may connect to another main ridge, also that dividing line has a low area called a "saddle". That means there is no standard shape or size to describe it. Landforms began decreasing in elevation away from the main ridge and water path connect away from it. In general, the main ridge is controlled in keyline design and located in between two nearby water paths.
Primary Ridge (PR)	This part of the keyline system lies on the side of primary valley. The union of two primary ridges produce primary valley in between. The origin of primary ridge is undisturbed section of main ridge that residual after the erosion process by valley.

1.7.4 Classification of keyline water

All agriculture areas have more than 95 % of its importance based on the existence of water in it. Water stored on the farm to meet requirements later. Low amount of water has a negative effect on vegetation, is similar in that high amount of water in soil. Because it prevents the necessary natural aeration to soil. The keyline water can be classified in table 1.18.

Table 1.8 Types of keyline water (Yeomans, 1954):

Parts	Details
Precipitation absorbed water	It was classified as the most quality type of water available to the farms. Its falls and directly absorbed by soil to be farmers own with no cost. Modern strategies are using to achieve the higher absorption of water.
Runoff water	The second type of keyline water connected and related to rainfall. Runoff flow through the farms and distribution by valleys to the low area. Farmers can use special design to exploit runoff in their land. To control, storage and use to meet the requirements. Same time's soil subjected to erosion process by the effects of runoff.
Surface water with external sources	Keyline water that comes from out of the farm and enter to the farm through primary valley. This type of water is suitable for irrigation purpose. It is necessary to make sure that external water has allowed quantity of salt content and must be controlled.
Groundwater	The existing water below the earth surface of the farm itself. The saturated zone stored and saved groundwater in aquifers away from the contamination source. That water usually adopted in case of no water sources in farm. Finally. The first category of keyline water in the key to all type above in many cases. Sometime there is no runoff in farm, no external source water, and no groundwater in farm itself.

1.8 Type of Storage System

According to the properties of the selected sites, reservoir has to construct to store water for meeting the water requirements. Practically, the catchment site must not be very small or very large. In case of a very small catchment site, the catchment yield is low and low amount of siltation carried by water. The lack of silt sediments may be increasing seepage in dams. After many years the accumulations of silt sediments will form a natural sealant against leakage. In contrast, a very large catchment site will be subjected to the risk of intensive floods, which require a costly spillway of concrete. Dams can be classified into two types depending on the runoff source:

- Waterway dams, dams constructed cross streamline.
- Off-waterway dams are dams located away from the streamline.

There are various types of small dams for storage yield, but there is no standard terminology used to define them. The most common types of small dams are (Lewis, 2013):

Table 1.9 Farm scale water harvesting structures (Lewis, 2013)

Small dam types	Properties
The gully dams	Can be defined as an earth structure has been constructed cross the water way, valley, and provided by spillway. The gully dams are usually equipped with pipe spillway to avoid erosion occurrence. The perfect location of these types of dams is the narrow valley and deemed the biggest economical kind of storage system and the more suitable for irrigation purposes.
Dam of hillsides	An earth structure situated in hillside and high slope area not cross river valley or water way. The form of hillside dam always be in curved or 3sides shaped. The hillside dams are suitable in low evaporation region for irrigation purposes.

Tanks with a ring-shaped	This storage system characterized by completely confined reservoir, has been built using earth materials within storage area. The ring tank is normally storing water below and above the earth surface. Through tanks of a ring-shaped reservoir within radial system. The tanks can be filled by surplus water of streams or groundwater plumping. Generally, ring tanks method is applied inflate land for irrigation purposes. The significant feature in this method is monitoring on inflow and outflow without using high-cost spillway.
The tanks of turkey nest	It's also having a ring - shaped reservoir and inaccurately known as "turkey nest " reservoir. The tank is accumulating water on the earth surface using an earth material originally away from storage area. Although tanks of turkey nest depend on gravity, nevertheless the tanks need to pump to control on the storage. The objective of usage this type of reservoirs is to balance the supply level, store water, and windmills.
The Excavated reservoir	Can be defined as a subsurface storage system, which is limited for flat area. The Excavated reservoir is situated away from gully dam and hillsides dam (not the same conditions). There is no specific design or shape for this type, but its sometime built-in shape of inverted pyramid. The reservoir depth must be more than 3m synchronized with minimize the surface area to avoid high ratio of evaporation. When the run-off filled the excavated reservoir, the water will contain accumulation of silt sediments. Therefore, its necessary to construct silt trap to reduce the velocity of water and catching siltation. The embankment must provide by fencing to save water and avoid pollution.

1.9 Previous studies

Under investigated area has been studied from varies aspects of geological studies. For instance, hydrology, hydrochemistry, hydrogeology, geological hazard, etc.

- **MacFadyen, 1938**, dealt with comprehensive study for water resource in Iraq and explained that the productivity of groundwater wells in Bai Hasan and Mukdadya is about 775 m^2 / day.

- **Krásný, 1982a**, pointed out in an assessment study of compiled data In the regions: Kut, Ali Al-Garbi, and Al-Teeb the depth of groundwater are about (10 m to more than 20 m), and the direction of groundwater flow is in the southeast direction from the mountainous area. also concluded that the average amount of TDS is (2000-3500 ppm) but in some places especially the southwestern part of the region may reach (11000 ppm).
- **Al-Abadi, 2000,** PhD thesis used GIS to analyze hydrological and hydrochemical characteristics of northeast Missan, south of Iraq. According to the conceptual model of the study area, the aquifer system within the area is subdivided into three aquifers: shallow, main, and artesian. Hydraulic conductivity values of the Quaternary deposits range (from 0.5-15.5 m/d) and less than that for Tertiary (2-25 m/d). Also, the flow groundwater heads is from northeast to southeast like the topographic elevation trend. The north and northeast areas of the study area represent the recharge zone while the south and southwest areas represent the discharge zone.
- **Lazim, 2002**, In her study on the possibility of exploiting groundwater in the Bazargan area for human and industrial use, most of this water is unfit for human use. The groundwater is towards the southwest, and I concluded that

the percentage of sales increases with the direction of water movement subterranean.

- **Al-Moozani, 2008**, indicated through geomorphological and hydrological conditions study to the eastern part of Missan that the spatial variation in the groundwater water (quality and quantity) and the general flow direction correspond to the topography and its surface and subsurface linear structures from north and northeast toward south and southeast.
- **Fhadil, 2009,** the study was carried out the evaluation of drought in upper parts of Mesopotamian. Which concluded the major part has been exposed to drought.
- **AL-Shammary and AL-Hamzawy,2014,** applied RS & GIS techniques to analyze AL-Chabab river basin based on morphometric properties. The study indicated that there is no flooding risk in the area.
- **Al-Saedi, 2017**, assessed in her study the geological hazards (flooding, desertification, earthquakes, etc.) in Missan province and the environmental changes. And create maps to detect geohazards in Missan using remote sensing techniques and GIS.
- **AL-Sudani,2018**, estimated potential sites for water harvesting in Bedra using GIS. The study categories study area into three classes depends on water harvesting suitability.
- **Al-Sudani, 2018,** deals with the hydrological and geotechnical properties of the Dewerige dam, eastern Missan. The study concluded that is the dam body and reservoir are exposed to geotechnical problems (siltation, dispersive soil, piping, and sulfates attack).
- **Kadhim, 2022**, Delineated in her study the suitable sites for water harvesting downstream of Teeb watershed in Missan. The study showed when compared the produced maps using the Fuzzy gamma overlay technique and the

Weighted overlay technique to determine the suitable rainwater harvesting sites were clearer when using the weighted overlay technique.

Chapter Two

Methodology

CHAPTER TWO
METHODOLGY

2.1 Introduction

This chapter will discuss the general techniques and approach which is used in the study and clearly explained (Fig.2.1).

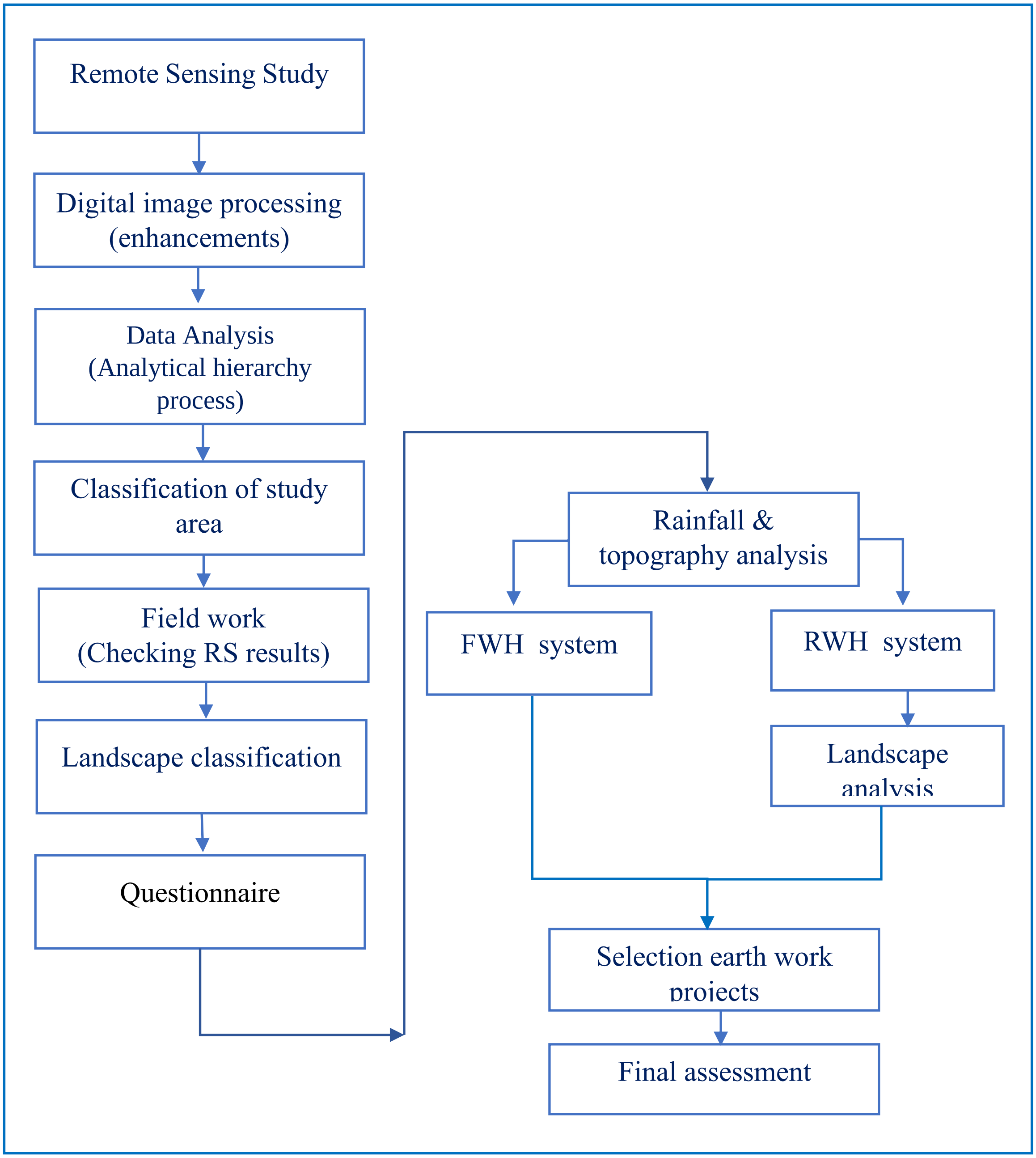


Fig. 2.1 Flow chart explains the approach of the study

2.2 Remote Sensing Data

The remote sensing data which is used in this study were acquired from NASA (earth explorer, earth data search) websites. Table 2.1 demonstrate details of utilized data.

Table: 2.1 The remote sensing data which is used in the study

Remote sensing data	Specifications
Operational Land Imager (OLI)	The Operational Land Imager (OLI) This sensor preparers global seasonal coverage to land surface at resolution 30 m. Landsat 8 collects data at altitude 705 km and a coverage area of about 185 km. The OLI is a mechanical sensor which began on 11 Th February 2013 and gathered formation in nine spectral bands (Schmidt et al, 2013), Fig.2.4 shows OLI is covering the study area.
Sentinel 2	France was launched sentinel-2A on 23 June 2015, whereas sentinel-2B by Russia on 7 March 2017. The two mechanical sensors work on the same orbit and same time but are separated at 180-degree angles. High-resolution pixel (10, 20, and 60) m and revisit time is 10 days (Zhongming et al, 2021). Fig.2.5 explains the study area covering by Sentinal2.
Digital Elevation Model (DEM)	The concept DEM is a matrix that usually refers to both (DTM and DSM). The procedures of obtained DEM are: lidar, radar, photogrammetry, aerial surveys, GPS, and topographic mapping. The resolution of utilized DEM in the study is 12.5m (Mossa, 2019). Fig.2.3 display DEM covering study area.

The remote sensing methodology adopted in this study is illustrated schematically in Fig.2.2

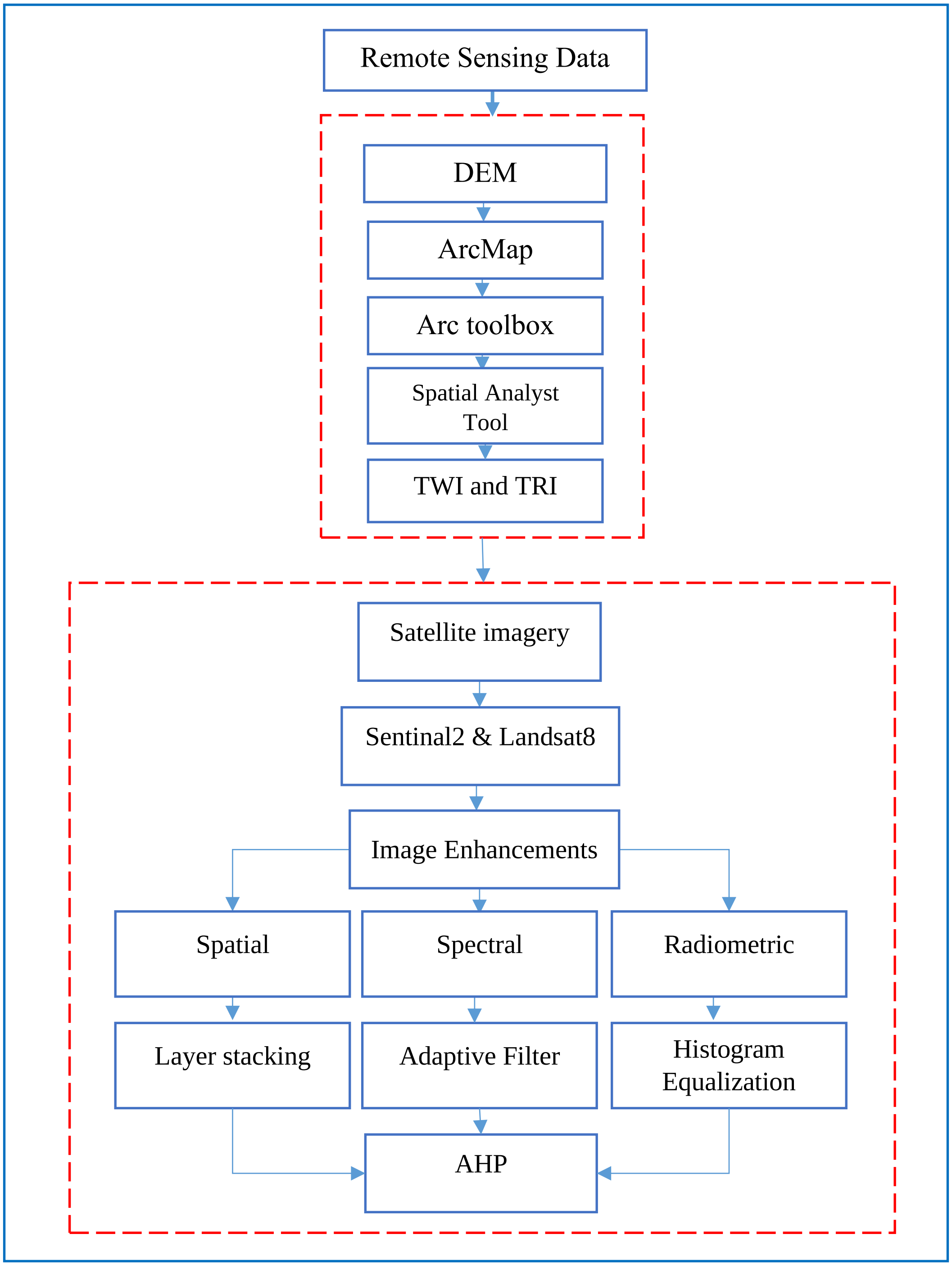


Fig.2.2 Remote sensing adopted procedures

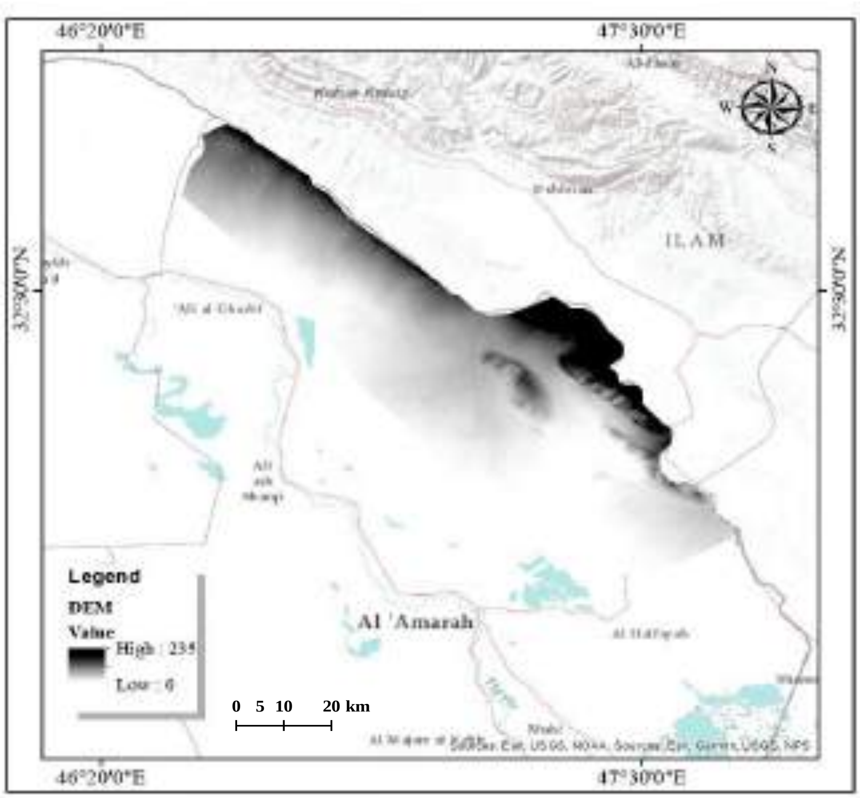


Fig.2.3 Digital Elevation Model, covering the study area

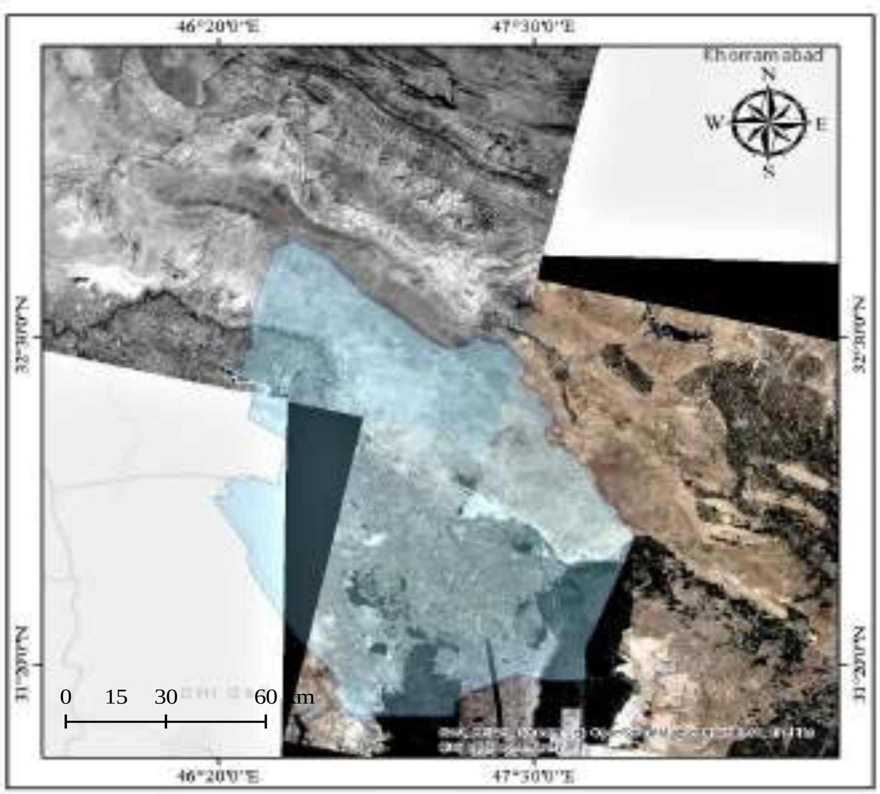


Fig.2.4 OLI covering the study area

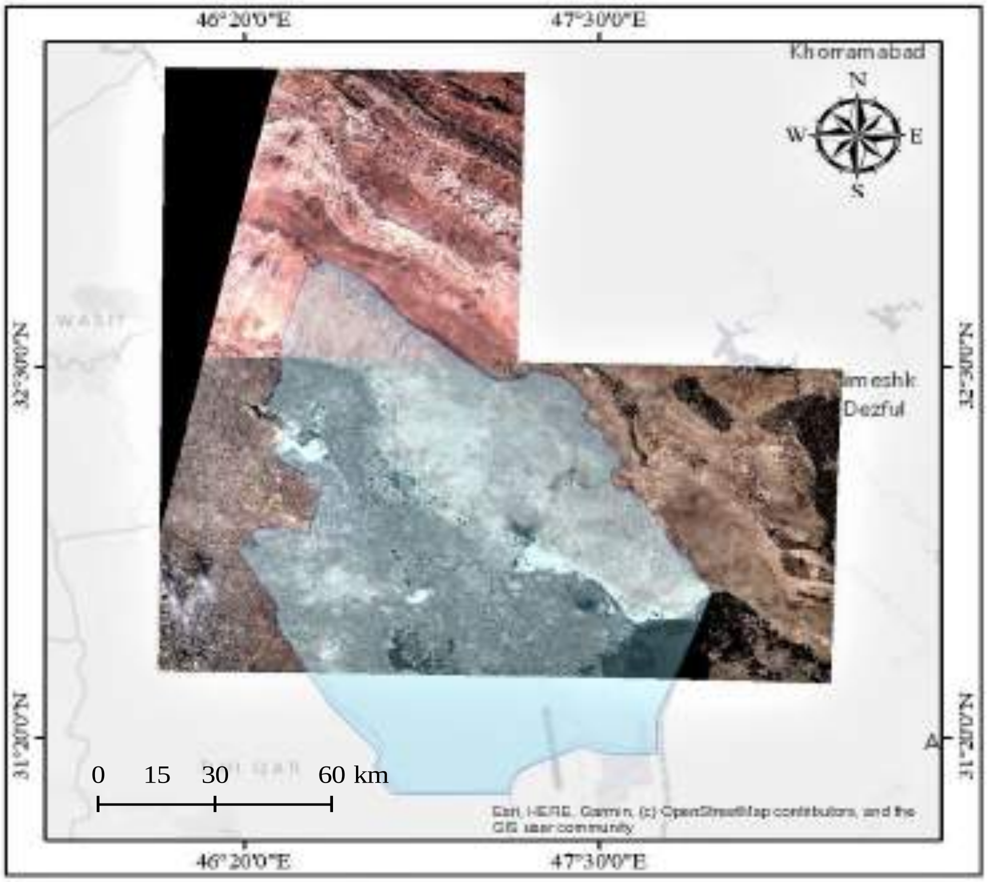


Fig.2.5 Sentinel -2 A covering the study area

2.3 Image enhancements

Satellite imagery outputs always involve high-quality data, in some cases, there were degradations or noise in these data. Therefore, image processing is applied in digital images, to get treated and manipulated images. Adjustment, modification, and enhancement are forms of image processing (Schowengerdt, 2012). Image enhancements are known as the correction process or refinement of the properties of remote sensing datasets that make image interpolation and analysis easier, accurate, and understood. Many mathematical algorithms are used to correct satellite imagery (Schowengerdt, 2006). The main objective of this correction process is to increase the apparent contrast among various features and produce a new image with noise removal (Richards, 1999). The image enhancements that applied in the study area explained in Table: 2.2.

Table:2.2 The applied image enhancements in the study

Image Enhancement	
Radiometric Enhancements	
Histogram Equalization	Defined as image enhancing method, derived from a powerful algorithm. This method is utilized for the adjustment of images correct the contrast. The histogram shows the appearance frequency of the gray color gradient in the image (Gonzalez and Wintz, 1977).
Spatial Enhancement	
Adaptive Filter	It is a widely used technique that improves contrast in satellite images like stretching and creasing spatial resolution. In some cases, this technique is not suitable for marine and water studies in large areas. Adaptive filters characterized by the enhanced variation of multispectral images in contrast to other filters the difference bands should enhance as an individual band (Fisher, 1991).
Spectral Enhancement	
Layer stacking ((bands combinations)	Briefly defined as the method of satellite imagery correction that merges multi-band image to be one band. Makes it has one file, the image must comprise of the same number of raw and column. Using bands combinations (colored band) make feature easy to identify and extract in satellite images better than gray-scale colors. This tool is utilized to maximize the sharpness of the drainage systems, river courses, agricultural (Parsons, 1957).

2.4 Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) /is a multi-criteria analytical method has been evolved in the 1970s. Which is used to simplifying and organizing difficult and complex results, depends on mathematics and psychology foundation (Saaty and Vargas, 2001). The AHP is deemed as a delicate procedure to compute the weights of used criteria. Evaluating the relative magnitude of the criteria by comparing between a series of pairwise (Solomon and Quiel, 2006). Fig.2.6 shows general methodology of AHP.

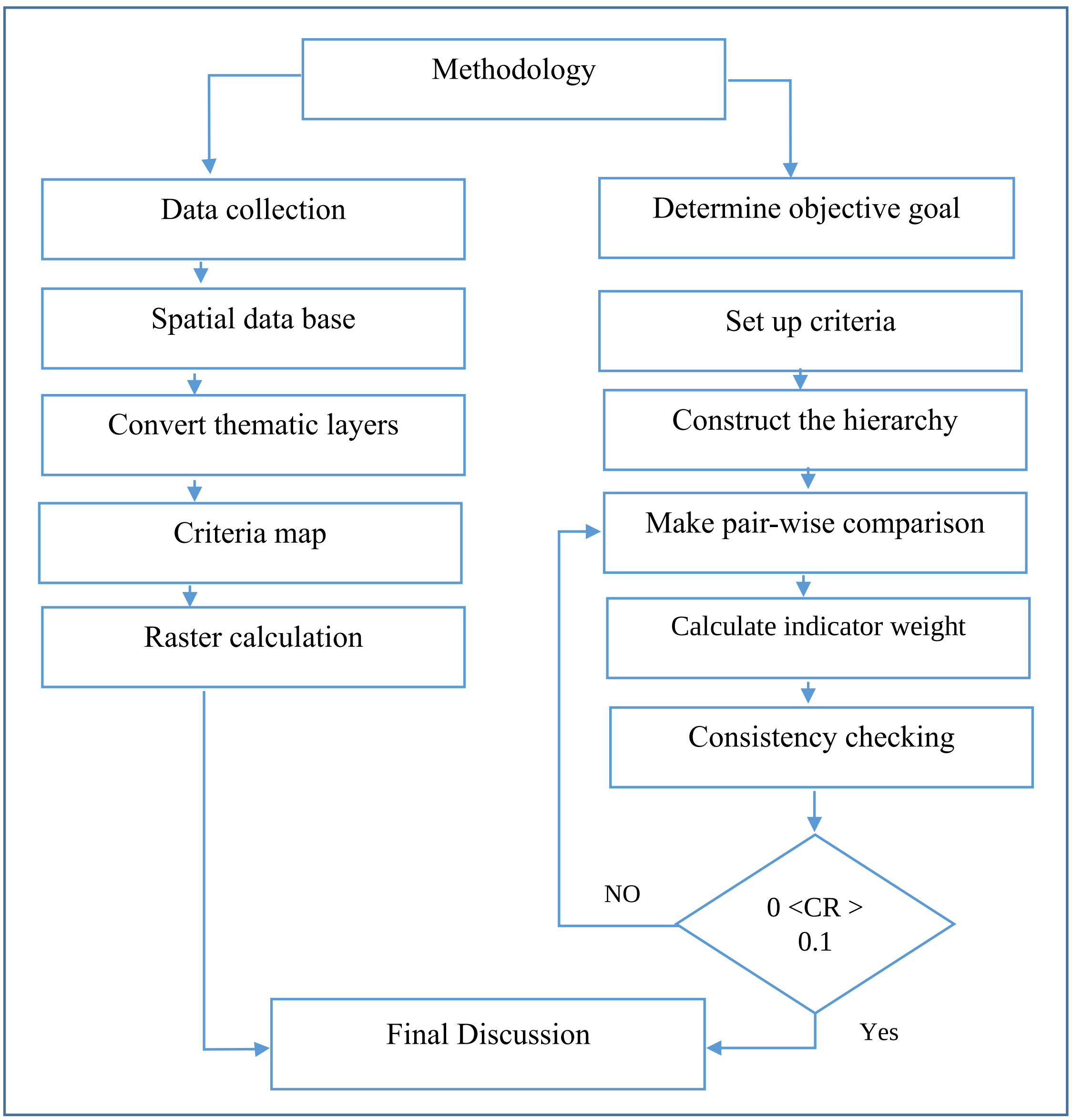


Fig.2.6 Application of AHP in GIS

The main stages of Analytic Hierarchy Process (Saaty, 1980):

1. Assignment the criteria and evaluate the priority of each criterion.
2. Calculation of ʎmax.
3. Finding consistency index (C.I).
4. Estimate random consistency ratio (RI).
5. Computing consistency ratio (CR) and compared it to the standard consistency ratio (Lawal, et al.2012).

2.4.1 The procedure of AHP applied in this study

A. Identify the adopted criteria:

In this study, four spectral parameters have been achieved using GIS and remote sensing techniques Table:2.3. Four sites have been chosen from study area to make it easy to apply AHP. All these parameters have been weighted according to their significance in the water harvesting system.

Table: 2.3 The applied indices in the study

The used indices	Specifications
1.Topographic wetness index (TWI)	Topography is the major factor controlling the hydrologic process. Topographic wetness index (TWI) can be defined as a topographic index which is assigned the potential sites of water accumulation. The high rate of TWI reflects low slope area and vice versa (Sörensen, *et al.*, 2006).
2.Normalized Difference Sand Index (NDSI)	Known as a sand presence spectral index. In Landsat 8, the reflected bands recorded by OLI are ranging from (0.43 -2.29 µm). Sand reflectance values start from minimum wavelength (0.43–0.45 µm) and reach to (0.64–0.67 µm), In other words the wavelength differences between band1 and band4 help to explore sand reflectance in spectral recorder data (Pan, *et al.*, 2018).

3.Topographic Ruggedness Index (TRI)	An important variable which is used to analyze landscape and reflect hydrological process in a certain area. In 1999 TRI had been improved by Riley and others to explain the variation in elevations between surrounding cells in the digital elevation model. In other words, TRI detects the topographic heterogeneity values (topographic roughness) for the center pixel and eight pixels surrounding and calculates it in meters. This index plays a significant role in hydrologic, engineering, and geomorphologic applications (Riley and Elliot, 1999).
4.Modified Normalize Difference Water Index (MNDWI)	The MDWI is one of two significant spectral indices that are used to monitor surface water. MNDWI had been derived from NDWI, which is used near infra-red and short wave infra-red to detect water bodies. NDWI is highly affected by the reflectance of build-up land and vegetation. So, it must minimize the exaggeration in water reflected data. Clear water cannot reflect the electromagnetic spectral of near infra-red and short-wave infra-red. In 2006 NDWI is corrected modified by Hanqiu Xu through utilizing green and shortwave infra-red, as expressed. (McFeeters, 1996).
5.Soil- Adjusted Vegetation Index (SAVI)	Defined as a corrective vegetation index, which is used to reduce or minimize the action of soil luster in reflected spectral bands by enhancing the wave lengths of both NIR and RED (Huete, 1988).
6.Topsoil grain size index (GSI)	This index is greatly related to vegetation cover to explain soil condition. The high value of GSI be evidence of course texture and can be written according to the formula: The equation (R-B) reflects the variation between water or vegetation and uncovered surface soil. The value of (R-B) will be negligible or close to (0) in high vegetation regions. the topsoil grain size index has been created to estimate desertification in arid or semi-arid area (Xiao, 2006).

2.5 Landscape classification

According to the keyline procedure, which explained in chapter one. The following procedure applied in this study, to apply keyline method in the study area (Fig.2.7).

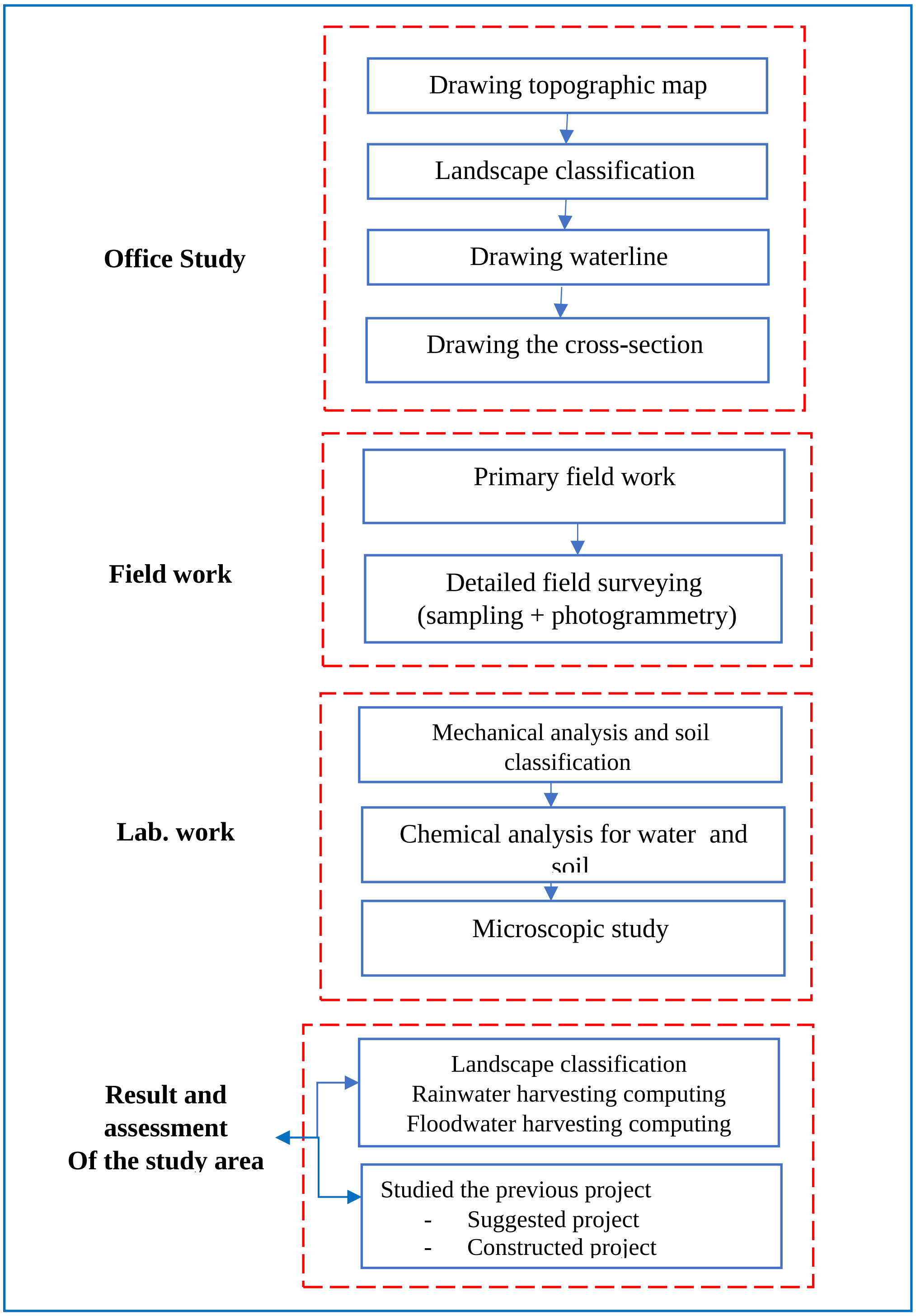


Fig.2.7 Adoptive approach in landscape classification

2.6 Field work

The field work is dividing into two main stages:

Stage I / Primary field work the main purpose includes a reconnaissance visit to the Dewerige river and Teeb River to study the topographic feature and landscape in theses flooded zones.

The date / 11 Sep. 2021 at 5:30 Am, (Figs.2.8, 2.9, and 2.10).

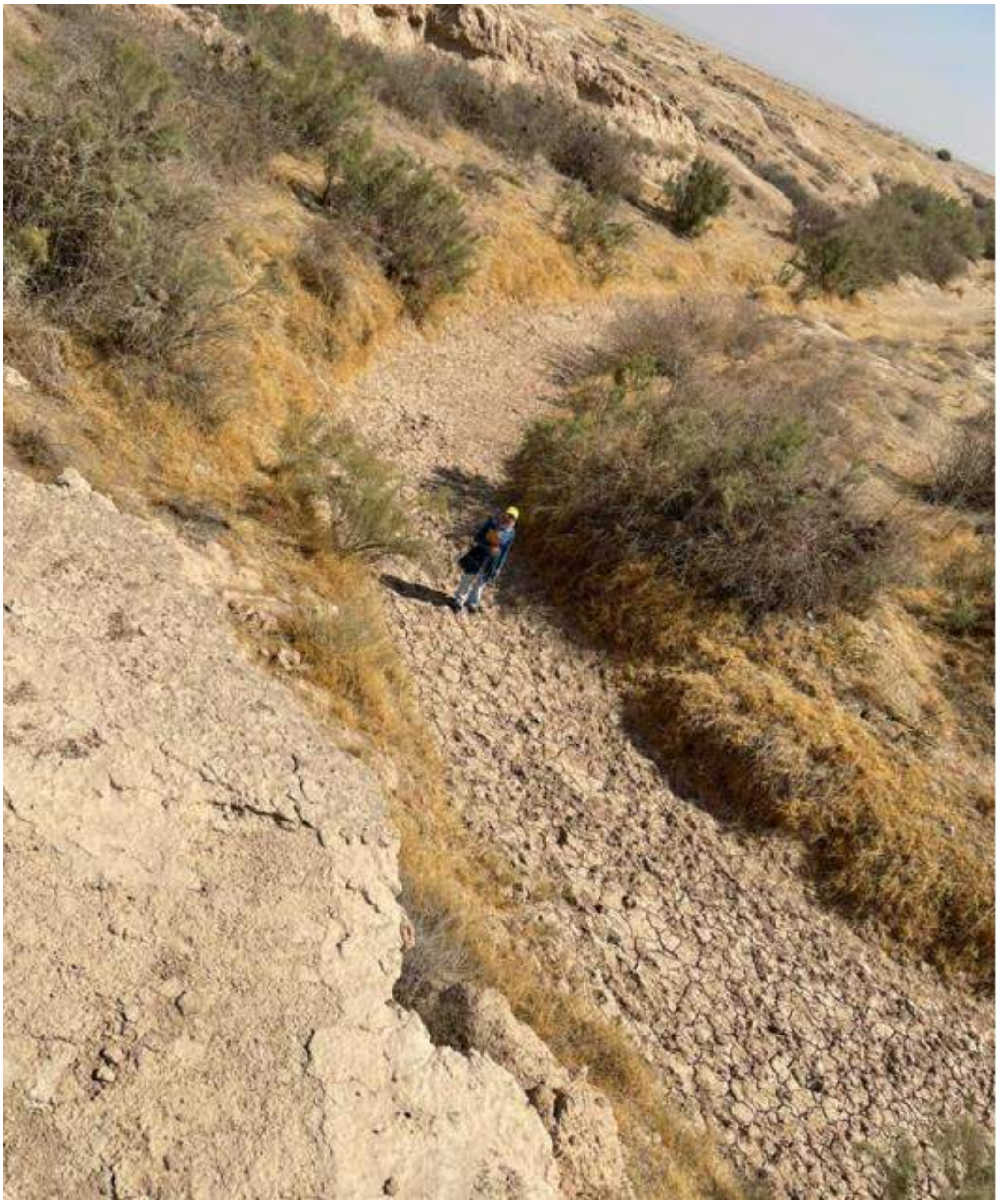


Fig.2.8 The primary valley in study area (site4)

Fig.2.9 Flooding area in site1 (Bird Eye Imagery)

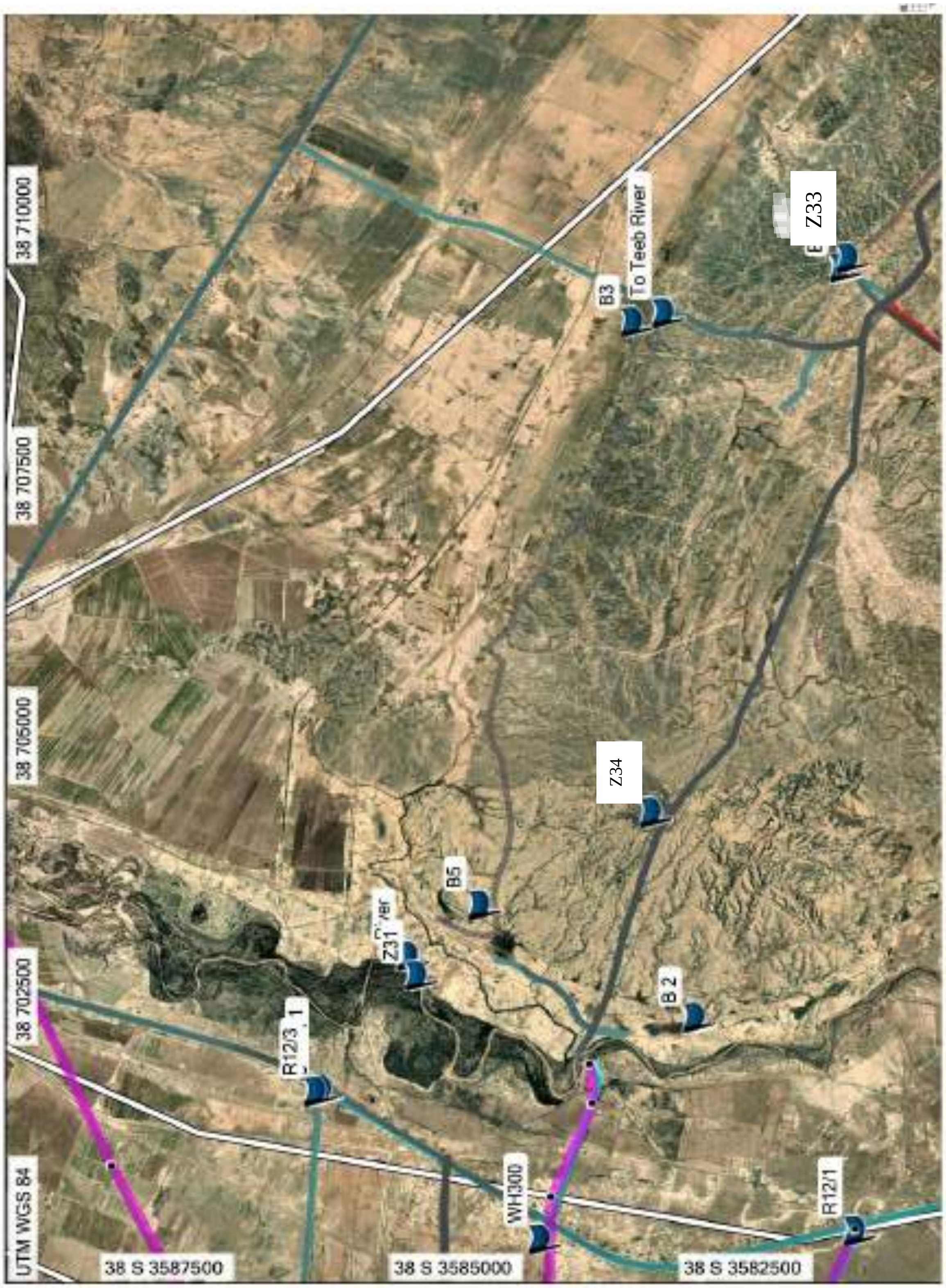


Fig.2.10 Flooding area in site4 (Bird Eye Imagery)

Stage II / Detailed field work / focusing on surveying and sampling the chosen sites Figs.2.11, 2.12, 2.13, and 2.14.

Fig.2.11 Samples locations site1

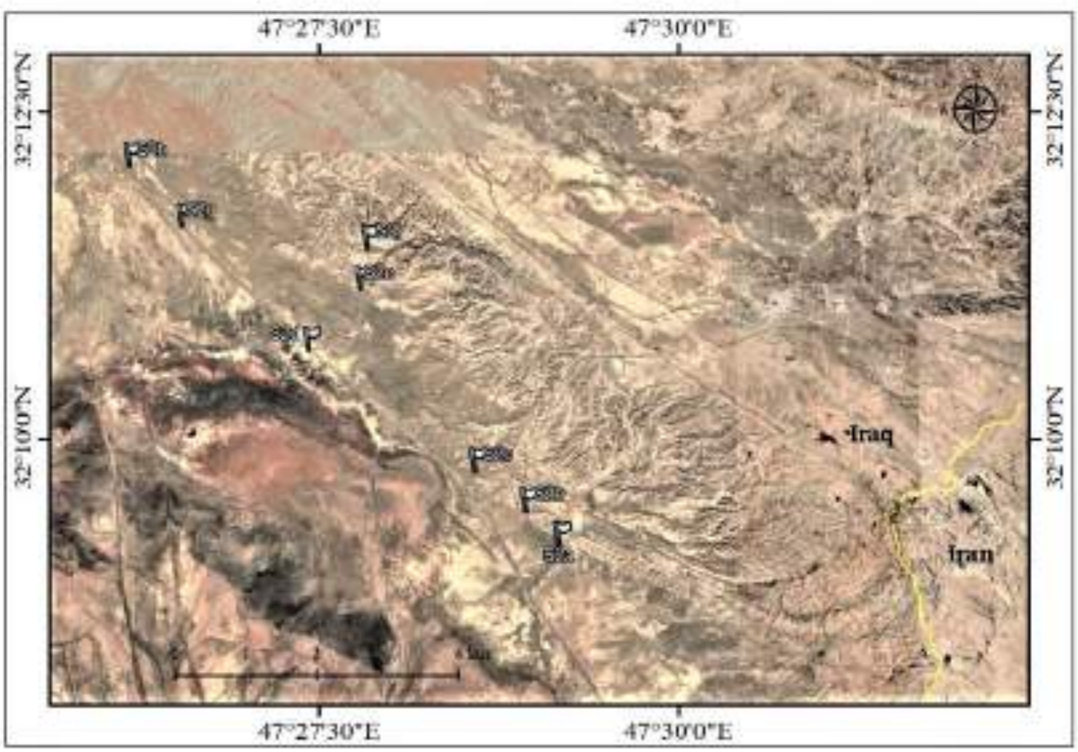


Fig.2.12 Sample location site2

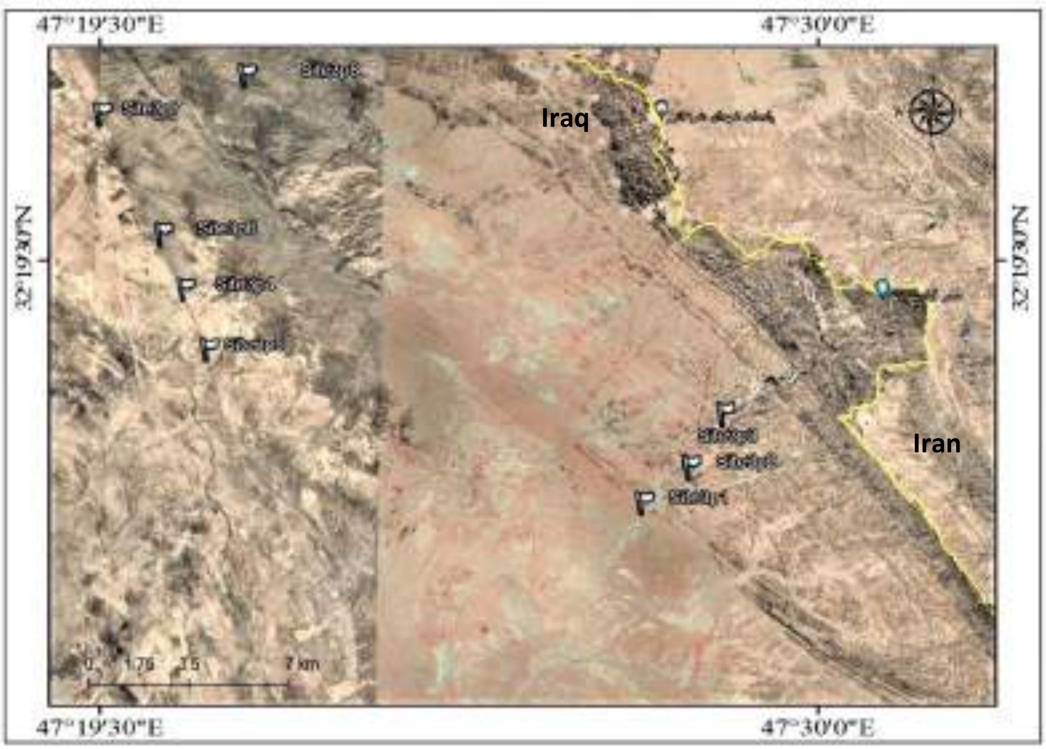


Fig.2.13 Sample location site3

Fig.2.14 Sample location site4

2.7 Lab. Work

Laboratory tests by selection samples from each site with depths vary from (0.10 – 1.5)m. The laboratory test based on American Society for Testing and Materials (ASTM) Table 2.4:

Table: 2.4 The soil classification test which used in the study

Type of Test	Standard
Classification tests (Grain size analysis) - Sieve analysis test - Hydrometer Test	ASTM D-422
Chemical tests - Acidity of soil or water (pH) - Electrical Conductivity (EC) - Conductivity Factor (CF) - Total dissolved solids (TDS)	BS 1377-1990

- **The used equipments** / The lab. test has been done using the following equipment and tools Fig. 2.15.

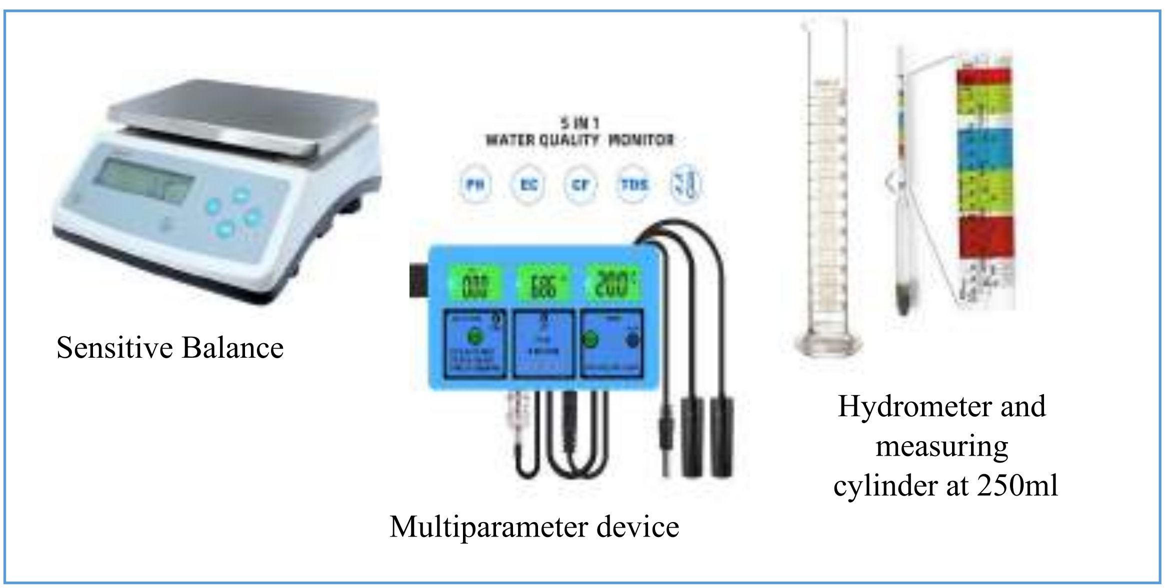


Fig.2.15 The used equipments

- **Soil Samples /** The soil samples are collected from soil of the four sites, at range (15-20) samples and depth (0.3-1.5) m for each site (Fig.2.16). Also, a hand auger has been used to get subsurface samples (Fig.2.17).

Fig.2.16 Soil samples

Fig.2.17 Collecting subsurface soil

Mechanical classification of particle size: including sieve analysis test Fig.2.18, and Hydrometer test Fig.2.19. The Hydrometer Test is categories cohesive soil based on ternary diagram (chapter four).

Fig.2.18 Sieve analysis test

Fig.2.19 Hydrometer test

- **Chemical test /**

Fig.2.20 Chemical test

- **Microscopic study** / The microscopic test has been achieved using digital microscope (Figs.2.21 and 2.22) and Table 2.5. The mineralogy of soil grains and gypsum grains is observed in many samples of study area.

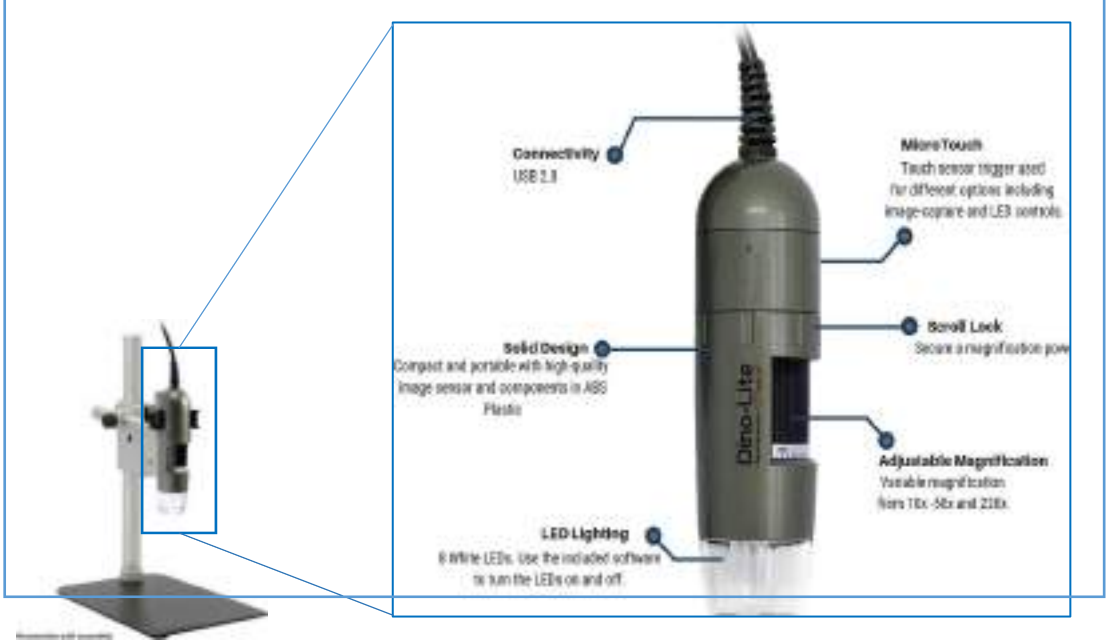


Fig.2.21 Digital microscope (DINO- Capture 2.0)

Fig.2.22 Microscopic study

Table: 2.5 General specifications of the microscope (Amato, *et al*.,2012)

Magnification Characteristic	Standard (10x~50x, 220x)
Connection Type	USB 2.0
LEDs	White (8)
Image Save Formats (Windows)	BMP, GIF, PNG, JPG, TIF, RAS, PNM, TGA, PCX, MNG, WBMP, JP2,JPC, PGX
Video Formats	WMV, FLV, SWF
Operating System	Windows XP, Vista, 7/8/10, Mac OS 10.5+

2.8 Particle size classification

In a general sense, texture of soil refers to its surface appearance. Soil texture is influenced by the size of the individual particles present in it, this classification divided soils into gravel, sand, silt, and clay categories on the basis of particle size (Howarth, 1996). The designing WHS it's important to evaluate how much water can be infiltrated and how much will be runoff. Soil texture test is one of the major parameters controlling on WHS. Therefore, these projects highlight the importance of soil texture, composition, and infiltration (Prinz, 1996).

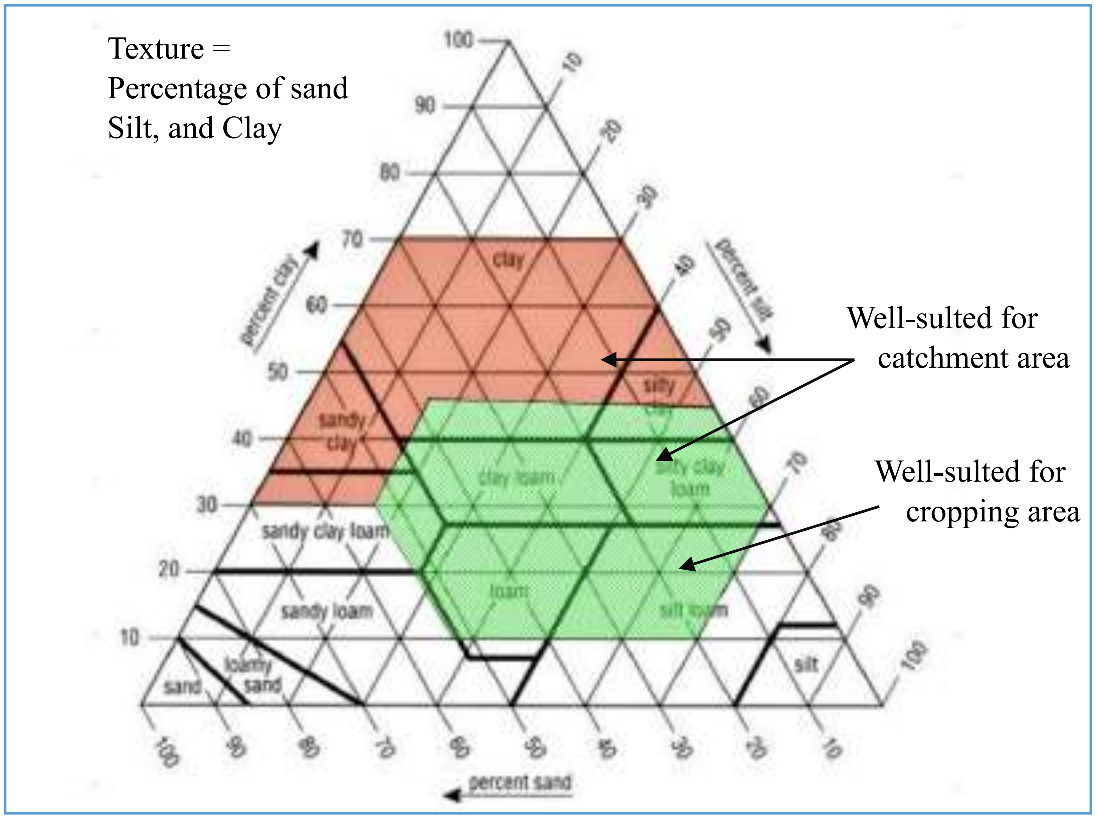


Fig.2.23 Classification of soil for WH components modified after (Prinz, 1996)

These classification systems were achieved relies on nature of soils and their specific properties the area at infiltration rate 5 mm/h or less deemed a perfect location for harvesting rainwater (Eger, 1986).

2.9 Assessment of the previous projects in the study area

The previous and new projects were developed depending on previous studies, Field work, and drone survey (Details in chapter five). The previous projects were classified as: suggested and constructed projects.

2.9.1 The previous projects

The location of previous projects in the study area (suggested and constructed) can be explained (Fig.2.24).

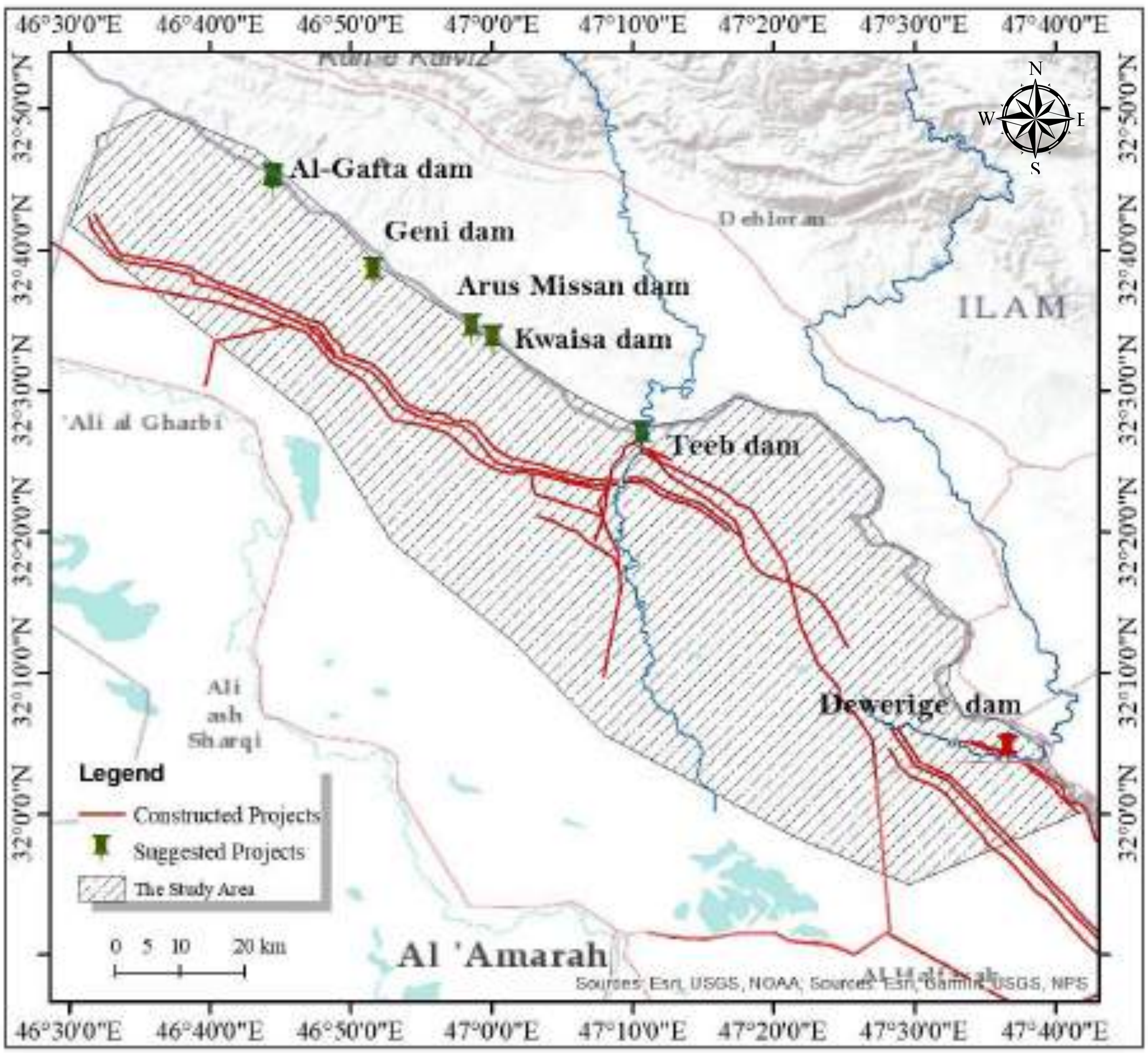


Fig.2.24 Location of previous study

I. **Suggested project /** These projects including construct small dams in Ali-Al-Garbi city next to Iranian bolder to benefit from the flood water. These dams are:

- Al-Gafta dam.
- Geni dam.
- Arus Missan dam.
- Kuissa dam.
- Teeb dam.

ll. Constructed projects

- **Dewerige dam**

Dewerige dam is a small concrete dam located in southeastern part of Missan province, south of Iraq. The coordinates of dam axes are (E746239.862, N3551456.909) - (E746256, N3550931). The length of dam is 512m with total storage capacity about 1,870,000m^3 (Ministry of water resource, 2009).

- **The old canal project**

is an artificial channel located parallel to the Iraqi – Iranian bolder. The channel has been observed during the field work and analyzed using satellite image and drone image to understand the importance and engineering properties of it. This channel was divided into three sites based on its extent: Ali-Al-Garbi, bend, and Al-sheib parts and studied in detail in chapter four. In general, the assessment of previous projects deals with sustainability procedure which classified the project as: degenerative, generative, and regenerative (Mang, 2020):

Degenerative investment projects / described as a project that aims to achieve one goal or one product. It does not generate profits during its operation and the maintenance cost is very high. It builds but doesn't work for several reasons.

The generative investment project is operating and making profits. The profits cover maintenance costs during the life of the project. The project serves one or more goals. The regenerative project is defined as operating and making profits project. Its serves more than one purpose It does not need maintenance at all and can be developed in the future.

2.9.2 Drone techniques used in the study

Two types of drones have been used in this study, Global drone GD89 pro and DJI (Fig.2.25 and 2.26). General specification of these types shown in Table 2.6.

Fig.2.25 The used Drone type I

Fig.2.26 The used Drone type II

Table: 2.6 General properties of the used drones ((Ivanciu and Alexandru, 2020), (Lan and Lee, 2022):

The drone type	Key specification
Type I	- Item Name: GLOBAL DRONE GD89 Pro Drones with HD Camera and Wi-Fi with One Key Take Off vs Air 2. - Function: Electric adjustment 90° camera, forward looking obstacle avoidance, altitude function, and 4k camera, go up/down, forward/backward, turn left/right. left/right side flying, 3 speed adjustment, 360° flip, headless mode, one key take off/landing, trajectory flight, one-key return. - Camera: 4K modular camera - Battery: 3.7V/1200 mAh for drone,3.7V/350mAh for remote control, modular design, can show the battery voltage. - Flying time: About 12-15 minutes. - Control distance: 100m. - FPV distance: 50m. - Model Number: GD 89 pro. - Brand Name: Global Drone.
Type II	- Brand:DJI - Model name: DJI Mini 2 - Color: Gray - Video Capture Resolution: 4K HD - Effective Still: 12 MP - Connectivity Technology: USB - Included Components: Spare Propellers (Pair) ×3, RC Cable (Lightning connector) ×1, Spare Control Sticks (Pair) ×1, Gimbal Protector × 1, Remote Controller x 1, Aircraft x 1, Shoulder Bag × 1, Type-C Cable × 1, Propeller Holder × 1, DJI 18W USB Charger ×1, RC Cable (USB-C connector) ×1, Two-Way Charging Hub ×1, Spare Screw × 18, Screwdriver × 1, DJI Mavic Mini 2 Intelligent Flight Battery × 3, RC Cable (Micro USB connector) ×1Spare Propellers (Pair) ×3, RC Cable (Lightning connector) ×1, Spare Control Sticks (Pair) ×1, Gimbal Protector × 1, Remote Controller x 1, Aircraft x 1, Shoulder Bag × 1, Type-C Cable × 1, Propeller Hold… - POWERFUL PERFORMANCE: with a max battery life of 31 minutes.

2.10 Questionnaire

A questionnaire is a powerful research tool called Self-Administered Questionnaire "SAQ", which comprises of many questions dealing with a specific subject and collecting the answers (Gault, 1907). Fig.2.29 explains the procedures used in this study (Details are given in chapter four and appendixes.

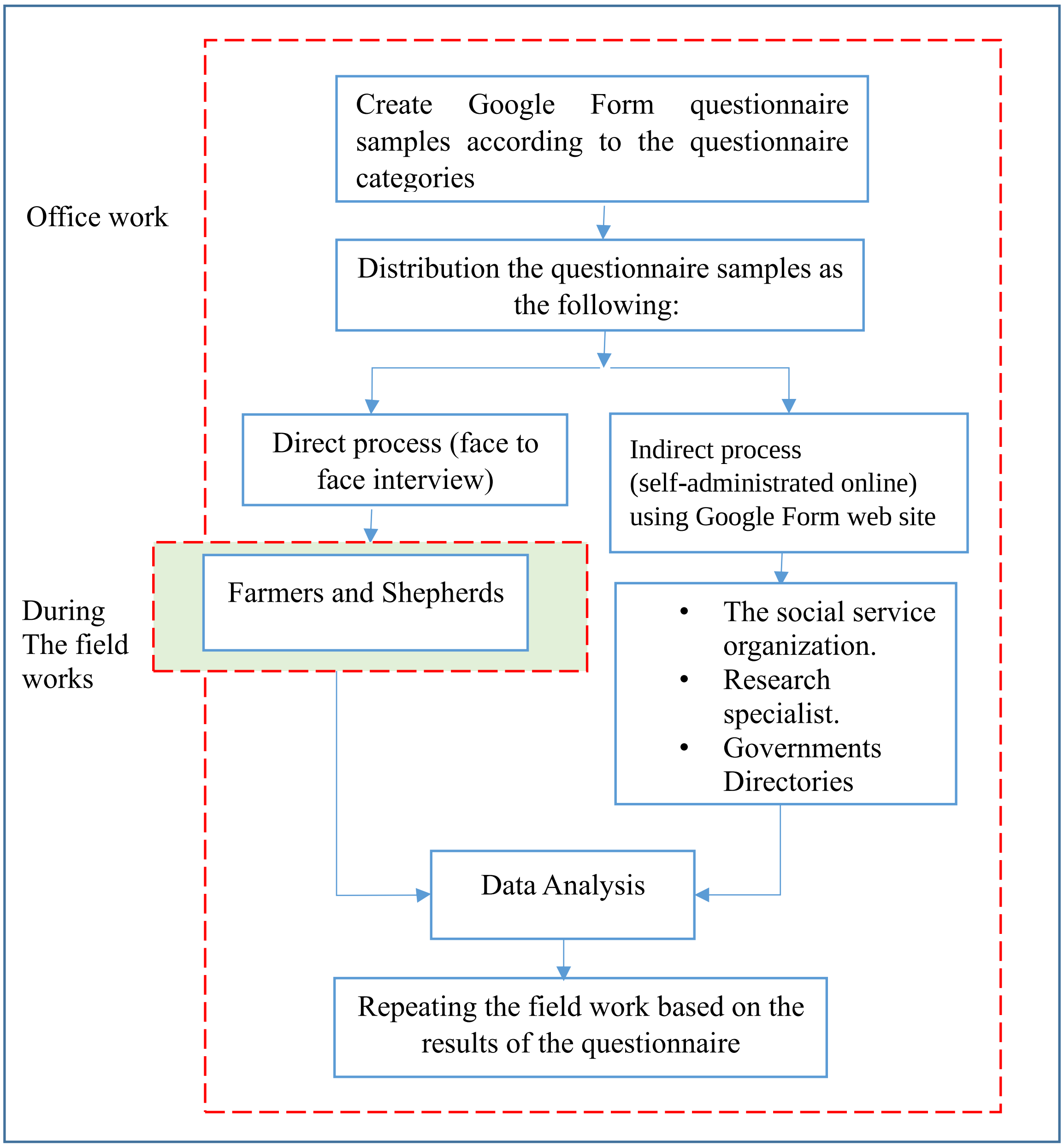


Fig.2.29 Questionnaire methodology in the study

2.10.1 Questionnaire categories

Five community categories which interested water harvesting, were divided as the following Table 2.7:

Table 2.7 The questionnaire forms in the study

Form NO.	Category	responders NO.
1	Governmental directories that interested to WH system including: - water resources directorate - the general commission for groundwater - the directorate of maintaining irrigation and drainage projects. - the directorate of agriculture. - the directorate of the environment - Missan oil company	14
2	Social service organizations	5
3	Research specialists	97
4	Farmers opinion	50
5	Shepherds' opinion	25

2.10.2 The questionnaire design in this study

The type of questionnaire would base a lot on the aim or purpose of the research. The research hypothesis assumes that the eastern desert of Missan is a suitable site to construct the WH project. One of powerful tool that has been used in water harvesting projects is questionnaire, to get the optimum results (Fig.2.30) (Oweis and Hachum, 2012).

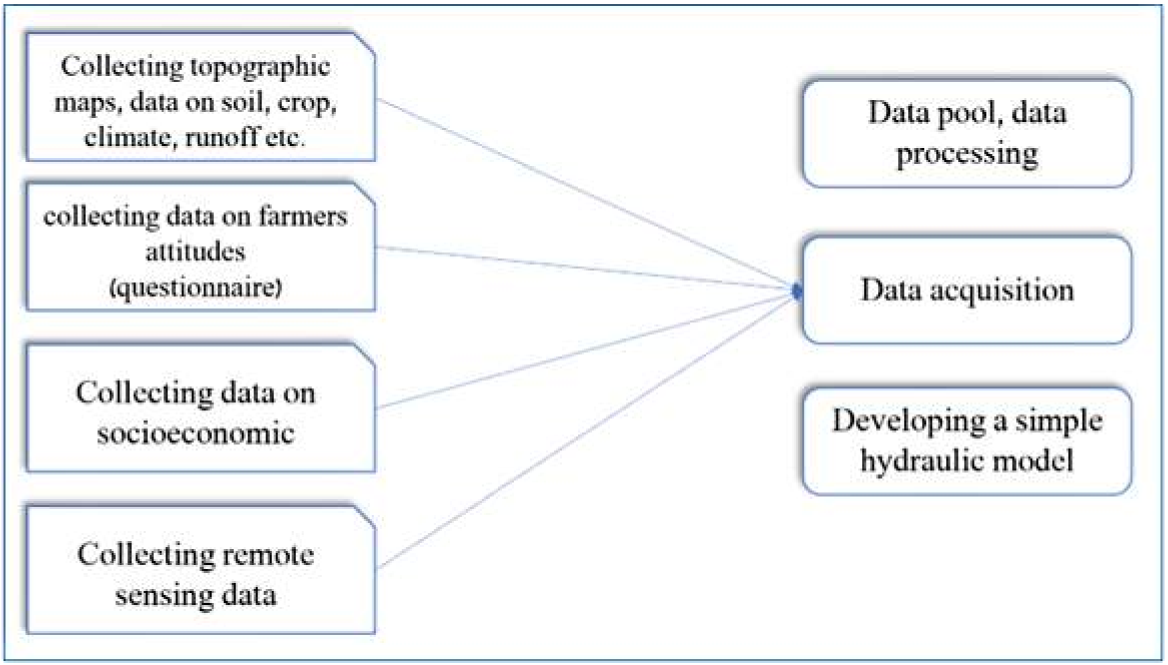


Fig.2.27 The outline of water harvesting procedure (Oweis and Hachum, 2012)

Chapter Three

Remote Sensing Results

CHAPTER THREE
REMOTE SENSING RESULTS

3.1 Introduction

This chapter covered the results of digital image processing and analytical hierarchy process (chapter two).

3.2 Image enhancements / deals with the influence of radiometric, spatial, and spectral filters in the used satellite imagery Figs.3.1, 3.2, 3.3, 3.4, and 3.5. The red arrows discover the extent and detail of the old canal.

- **Radiometric enhancement (histogram equalization) enhancement)**

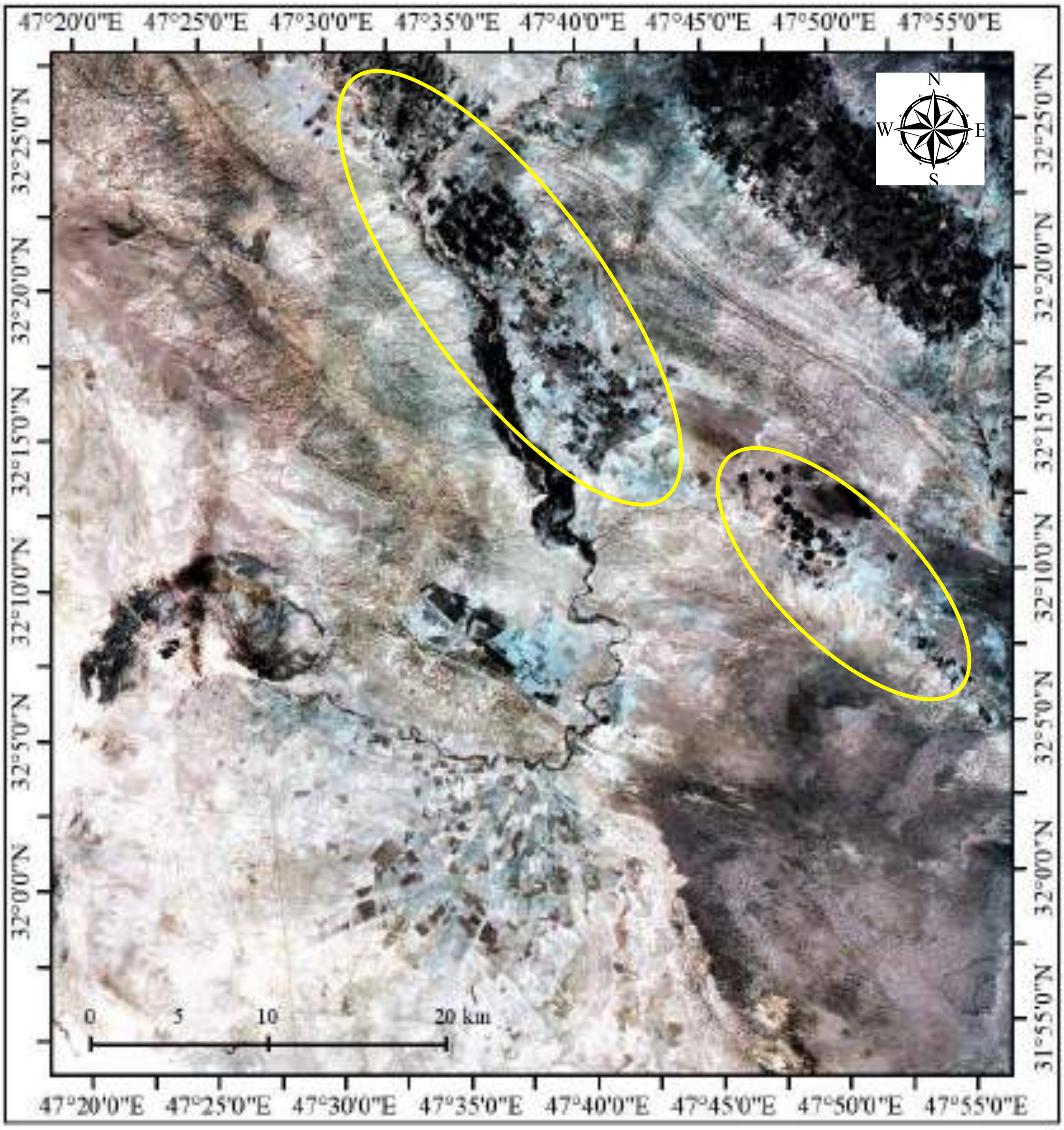


Fig. 3.1 Radiometric enhancement applied in Sentinel -2A (8,6, and 11 bands) GBR, the examples of water harvesting projects in adjacent areas

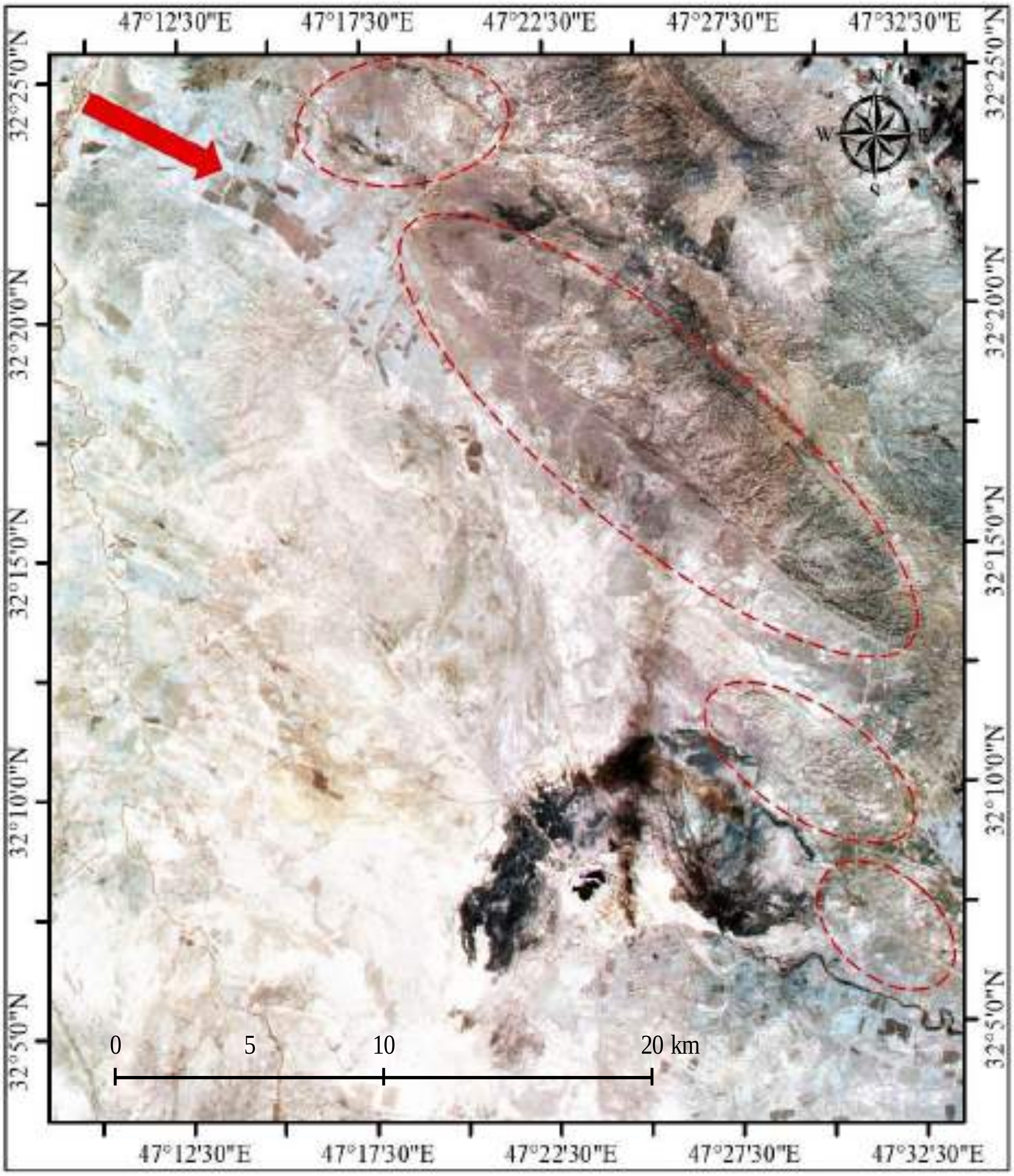


Fig.3.2 The four sites (ellipsoid shape) using Histogram filter (8.6, and 11 bands) GBR sentinal2 A imagery

The histogram equalized method applied on image Figs. 3.1 and 3.2 shows all individual pixels in the image, thus increasing the contrast and clarity of features in images. As is clear in the above figure, the distinctive geological structures appear in the study area, perhaps the most important of which are folds such as the Bazrgan and Abu Grab folds (red circles with an oval shape Fig.3.2.

- **Spatial enhancement (adaptive filter)**

Adaptive filter increasing the spatial resolution and clarity of feature by improving contrast in an image as shown in Fig.2.9, This technique showed river channels, branches, and drainage basins clearly visible, as well as isolate the wetlands covered with vegetation from desertification lands, in addition to geological structures such as folds and linear patterns.

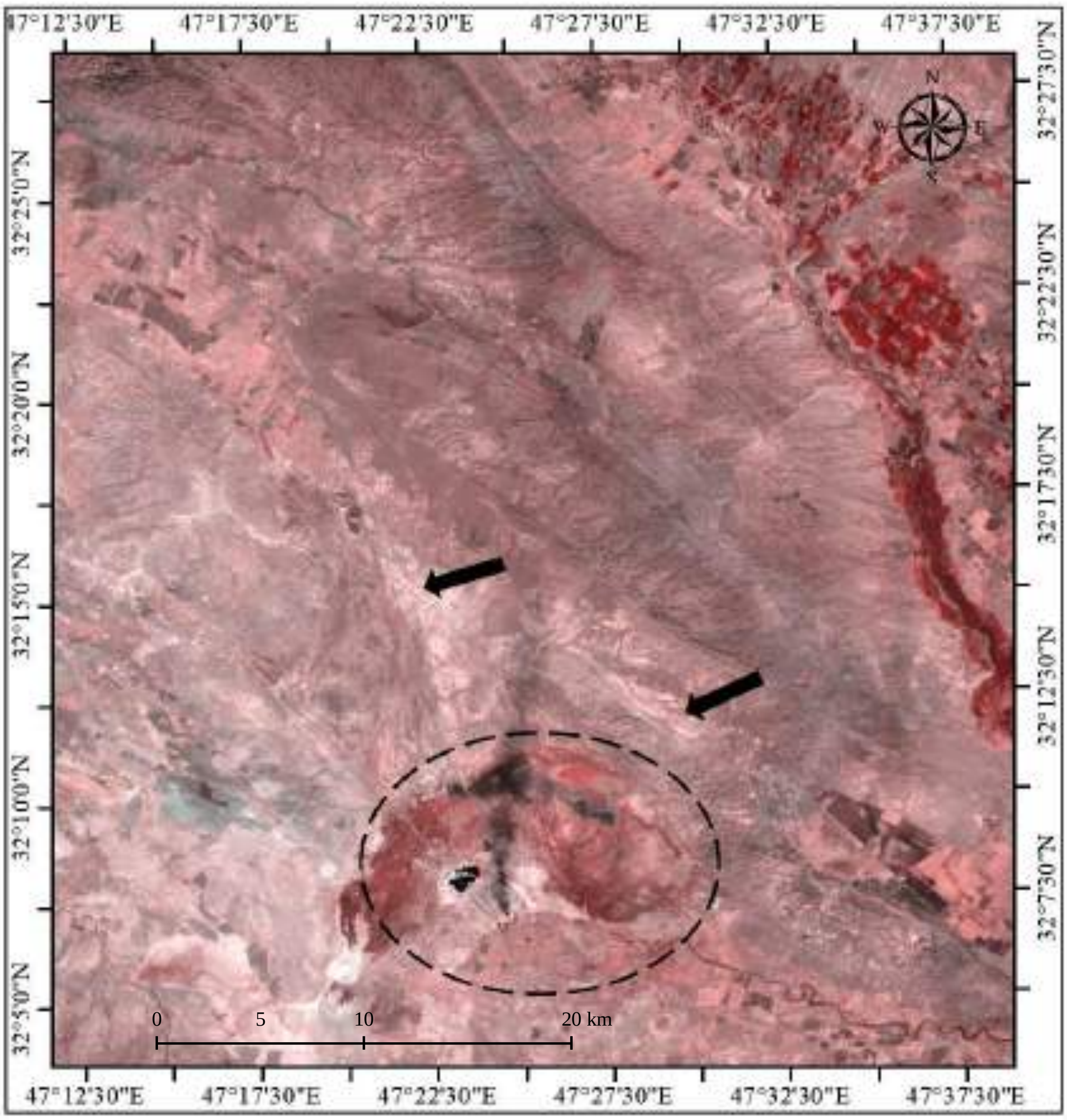


Fig.3.3 Adaptive Filter (4, 5 and 7 bands) BGR technique in the study area (sentinal2 imagery)

The black arrows refer to the colour contrast, while the black circle with an oval shape shows the flooded area.

- **Spectral enhancements (Layer stacking)**

The spectral bands 8, 10, and 12 have been used to apply the layer-stacking filter. Fig.3.4 explains the cropping area in Ali-Al-Garbi city and the old canal extent (blue arrows) and the water line comes from Iranian territory (sites of Ali-Al-Garbi dams). The flooded area, the four sites, and the colour contrast are detected in Fig.3.5.

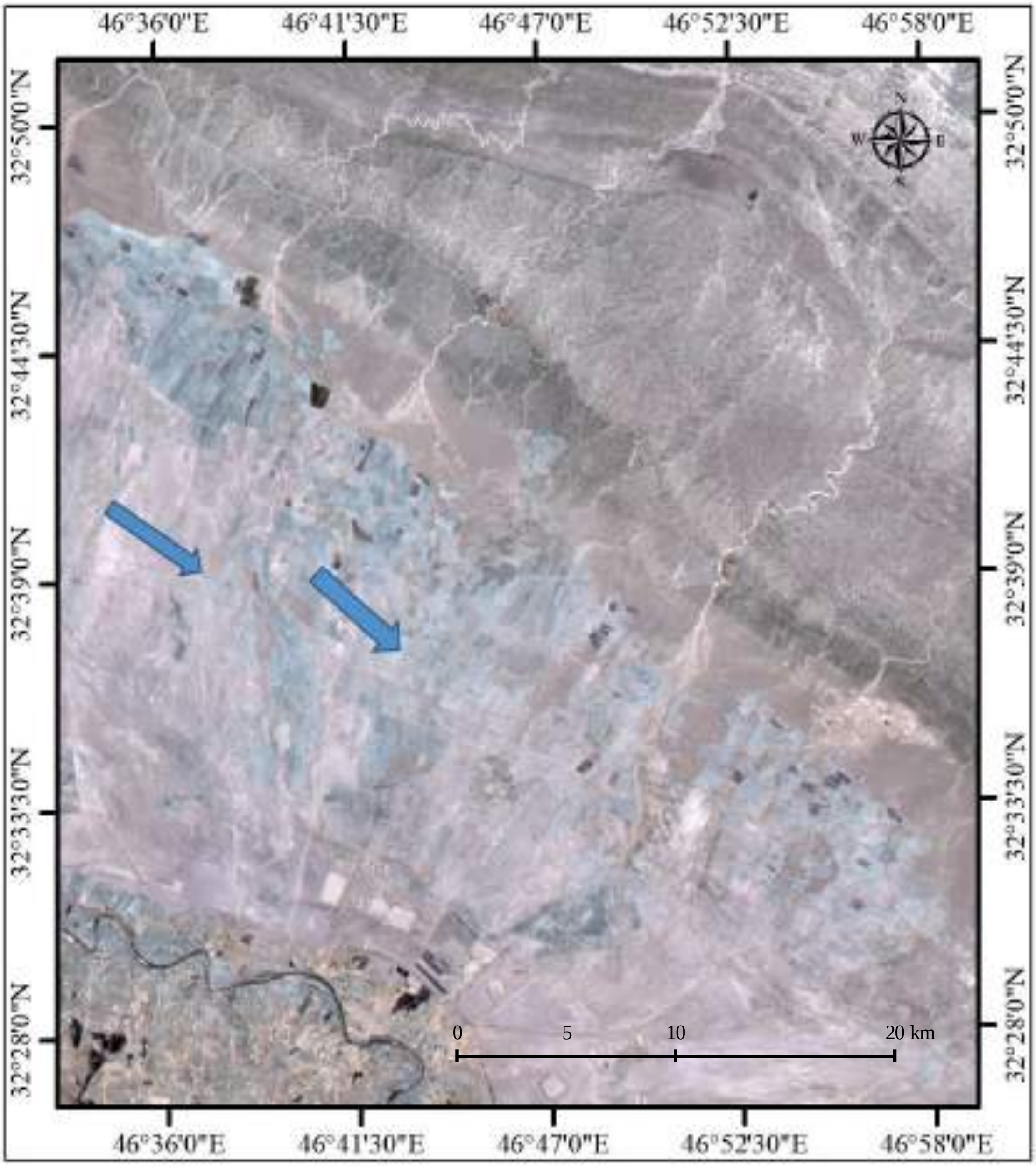


Fig.3.4 Layer stacking (8,10, and 12) GBR (bands combinations)

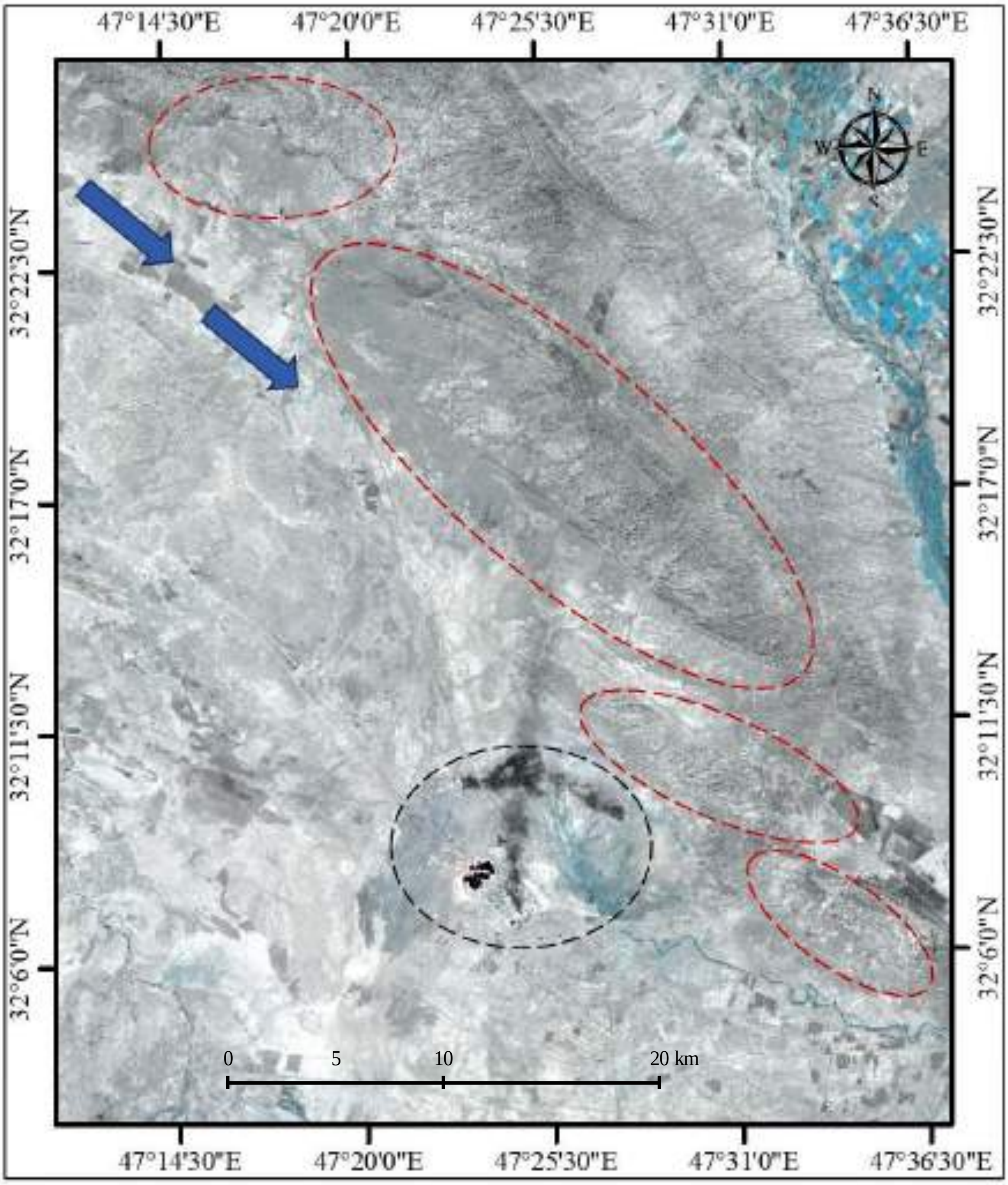


Fig.3.5 Layer stacking with (8,10, and 12) GBR bands combination (Sentinal2 imagery) The four selected locations are illustrated in addition to the flooding area.

3.3. The result of analytical hierarchy process

The components of AHP in the study are illustrated in Fig.3.6. Calculation and the result of the analytical method (AHP) have been inserted as steps:

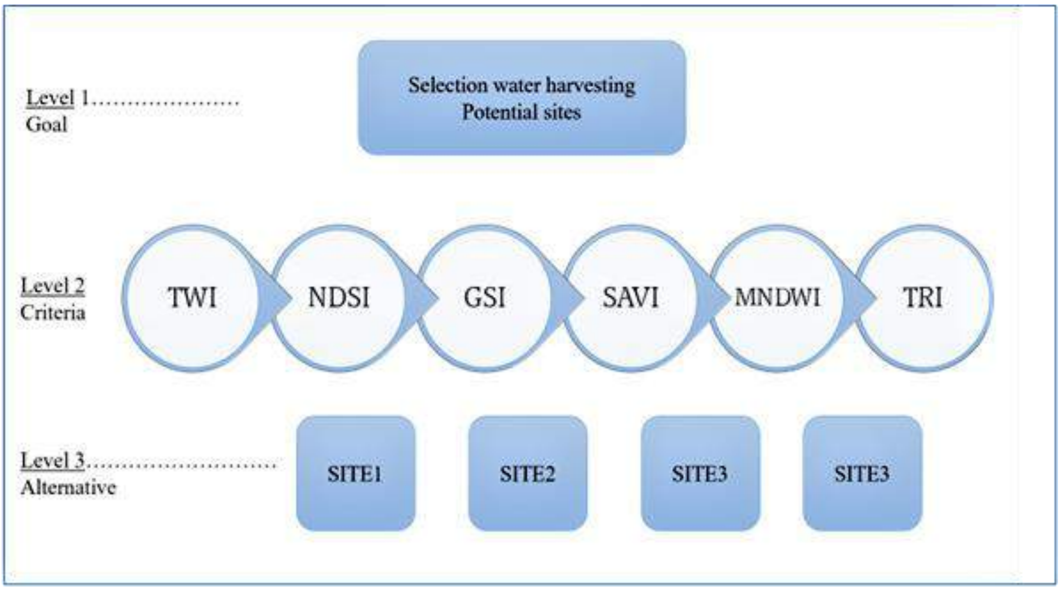


Fig. 3.6 The components of Analytic Process Hierarchy

A. Set up a matrix that is n*n, where n is the number of criteria and the grey cell represent equally important criteria table: 3.1

Table: 3.1 matrix set up

Criteria	TWI	NDSI	TRI	MNDWI	SAVI	GSI
TWI						
NDSI						
TRI						
MNDWI						
SAVI						
GSI						

B. Making pairwise comparison of each criterion according to their rank (Saaty, 1980):

a) 1 indicates that criteria A and B have the same importance.
b) 3 refers to that A is intermediate in importance compared to B.
c) 5 means that A is highly important compared to B.
d) 7 this value means criteria A has been demonstrated to be much more important than B.
e) 9 shows that A has been demonstrated to be much more important than B.

The matrix of pairwise comparison comprises of pairs of factors that are compared with each other so as to determine the most important factor table: 3.2.

Table:3.2 matrix of factors

Criteria	TWI	NDSI	TRI	MNDWI	SAVI	GSI
TWI	1	2	3	4	5	6
NDSI	0.5	1	1.5	2	2.5	3
TRI	0.333	0.66	1	1.3	1.6	2
MNDWI	0.25	0.5	0.7	1	1.25	1.5
SAVI	0.2	0.4	0.6	0.8	1	1.2
GSI	0.2	0.4	0.6	0.8	1	1

C. Adding sum to each column, table: 3.3

Table 3.3 sum of each column

Criteria	TWI	NDSI	TRI	MNDWI	SAVI	GSI
TWI	1	2	3	4	5	6
NDSI	0.5	1	1.5	2	2.5	3
TRI	0.333	0.66	1	1.3	1.6	2
MNDWI	0.25	0.5	0.7	1	1.25	1.5
SAVI	0.2	0.4	0.6	0.8	1	1.2
GSI	0.2	0.4	0.6	0.8	1	1
Sum ∑	2.483	4.96	7.4	9.9	12.35	12.35

D. Normalize the pairwise matrix, table: 3.4

Table 3.4 normalize the pairwise

Criteria	TWI	NDSI	TRI	MNDWI	SAVI	GSI
TWI	0.402	0.403	0.405	0.404	0.404	0.485
NDSI	0.201	0.201	0.202	0.202	0.202	0.242
TRI	0.134	0.133	0.135	0.131	0.129	0.161
MNDWI	0.100	0.100	0.094	0.101	0.101	0.121
SAVI	0.080	0.080	0.081	0.080	0.080	0.097
GSI	0.080	0.080	0.081	0.080	0.080	0.080

E. Criteria weight can be calculated by computing the average of each a row in the normalized matrix, this average is called " criteria weight", table: 3.5.

Table:3.5 Criteria weight calculation

Criteria	TWI	NDSI	TRI	MNDWI	SAVI	GSI	weight
TWI	0.402	0.403	0.405	0.404	0.404	0.485	0.41
NDSI	0.201	0.201	0.202	0.202	0.202	0.242	0.20
TRI	0.134	0.133	0.135	0.131	0.129	0.161	0.13
MNDWI	0.100	0.100	0.094	0.101	0.101	0.121	0.10
SAVI	0.080	0.080	0.081	0.080	0.080	0.097	0.08
GSI	0.080	0.080	0.081	0.080	0.080	0.080	0.08

F. Calculate consistency matrix by tables 3.6, 3.7, 3.8:

Table 3.6 multiply each criteria value by it weight, table: 3.6

Criteria	TWI	NDSI	TRI	MNDWI	SAVI	GSI
TWI	0.417	0.417	0.412	0.413	0.417	0.485
NDSI	0.208	0.208	0.206	0.206	0.208	0.242
TRI	0.139	0.137	0.137	0.134	0.133	0.161
MNDWI	0.104	0.104	0.096	0.103	0.104	0.121
SAVI	0.083	0.083	0.082	0.082	0.083	0.097
GSI	0.083	0.083	0.082	0.082	0.083	0.080

Table 3.7 Computing criteria weight sum

Criteria	TWI	NDSI	TRI	MNDWI	SAVI	GSI	CWS
TWI	0.417	0.417	0.412	0.413	0.417	0.485	2.563
NDSI	0.208	0.208	0.206	0.206	0.208	0.242	1.281
TRI	0.139	0.137	0.137	0.134	0.133	0.161	0.844
MNDWI	0.104	0.104	0.096	0.103	0.104	0.121	0.634
SAVI	0.083	0.083	0.082	0.082	0.083	0.097	0.512
GSI	0.083	0.083	0.082	0.082	0.083	0.080	0.496

Table: 3.8 Calculation ratio of WSC/WC

Criteria	Criteria weight sum	Criteria weight	Ratio WSC/WC
TWI	2.563	0.41	6.251
NDSI	1.281	0.20	6.405
TRI	0.844	0.13	6.49
MNDWI	0.634	0.10	6.34
SAVI	0.512	0.08	6.4
GSI	0.496	0.08	6.4

i. Calculate consistency ratio / which can be calculated by finding the average of ratios ((Saaty, 1980), ((Saaty, 1984):

- λ_{max} = (6.251 + 6.405 + 6.49 +6.34 + 6.4 + 6.4) / 6
- λ_{max} = 6.381

ii. Calculate consistency index (C.I), where n is the number of criteria in the study:

- **C.I** = (λ_{max} -n)/ (n-1)
- **C.I** = (6.381 – 6) / (6-1)
- **C.I** = 0.07
- Consistency ratio = Consistency index (C.I) / Random index
- Random consistency index can be obtained using standard values table 3.3:

Table: 3.3 the average random consistency indices (RI) for various type of N (Saaty, 1980):

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0.0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.54	1.56	1.57	1.59

Where:
N= criteria number
RI= random consistency index

Consistency ratio = Consistency index (C.I) / Random index

Consistency ratio = 0.07 / 1.24

Consistency ratio = 0.05

If the value of the consistency ratio is less than (0.10, standard consistency ratio), then the criteria weights are acceptable (Saaty,1984), (Malczewski, 1999), and (Saaty and Vargas, 2001), whereas if the value is more than (0.10), then pair-wise comparisons have to be re-estimate. Since the consistency ratio is (0.05), less than the standard consistency ratio. Therefore, a pair-wise comparison is possible.

3.4 Application of analytic hierarchy process in GIS

3.4.1 Site selection

According to the agricultural plan of 2021 Fig.3.7, obtained by the directorate of irrigation and maintaining projects of Missan. The potential sites for water harvesting were selected Fig.3.8 and table 3.5.

Fig. 3.7 The agricultural Map of plain modified after (directorate of irrigation and maintaining projects of Missan)

Fig. 3.8 Water harvesting selected sites

Table: 3.5 illustrates the surface area of the selected sites.

water harvesting proposed sites	Area in km²
Site1	12.3
Site2	27.3
Site3	203
Site4	194

3.4.2 Methodology

The methodology adopted in the present study is schematically (Fig.3.9) and described in the following steps:

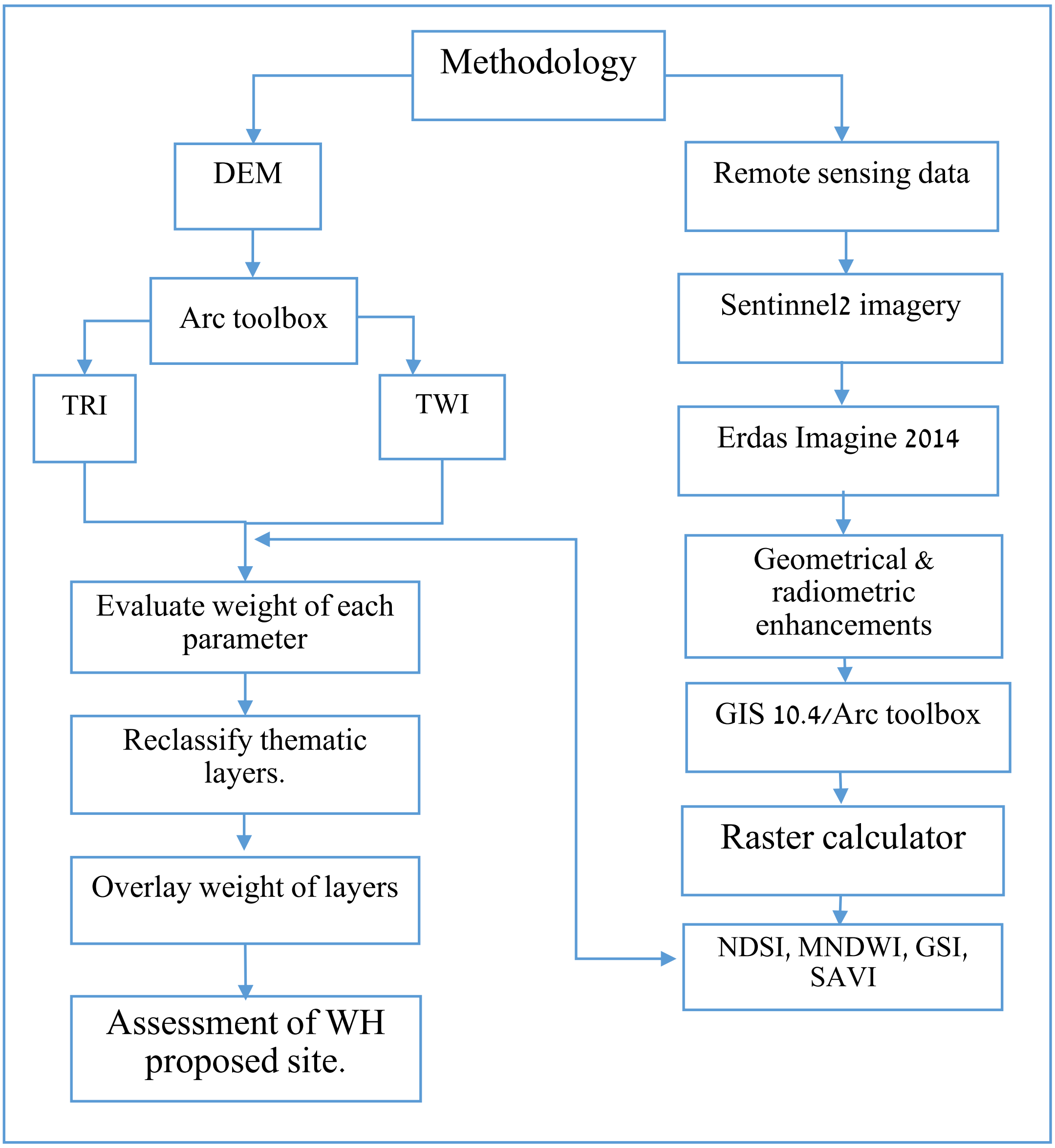


Fig. 3.9 The AHP Procedure of the study

3.4.3 The parameters rating

The six factors have been evaluated (table3.1). Depend on percentage weight “criteria weight” table:3.5, the classes rank is estimated according to its effect on the study, and multiple by criteria weight to calculate the final weightage of classes.

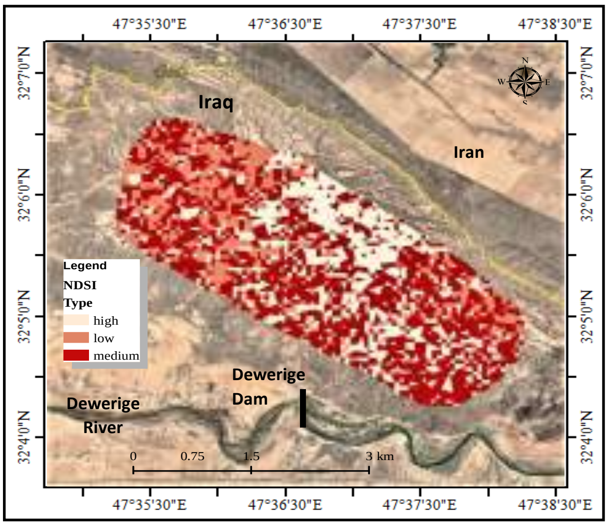
Table: 3.5 rating of used criteria which used is AHP

Criteria	Weight	Rank	Overall
TWI			
high	41%	3	123
medium		2	82
low		1	41
NDSI			
high	20%	3	20
medium		2	40
low		1	60
TRI			
high	13%	3	13
moderate		2	26
low		1	39
MNDWI			
high	10%	3	30
medium		2	20
low		1	10
GSI			
high	8%	3	8
medium		2	16
low		1	24
SAVI			
high	8%	3	24
medium		2	16
low		1	8

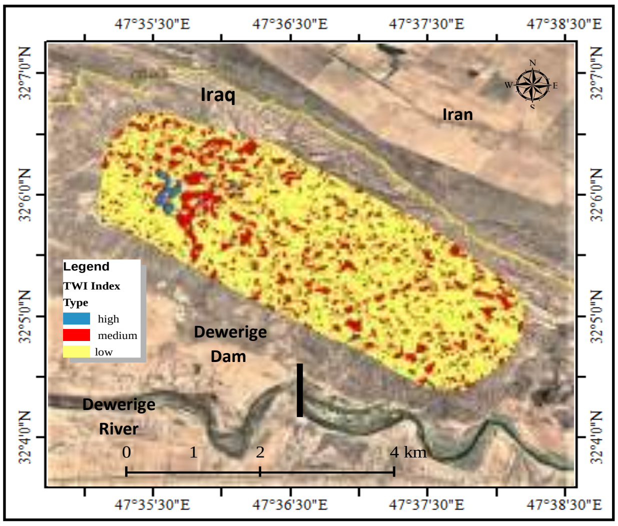
3.4.4 Creating thematic layers

According to the matrix of pairwise comparison and the final rating of each subclass in selected parameters, thematic layers of AHP have been created Figs.3.10, 3.11, 3.12, and 3.14.

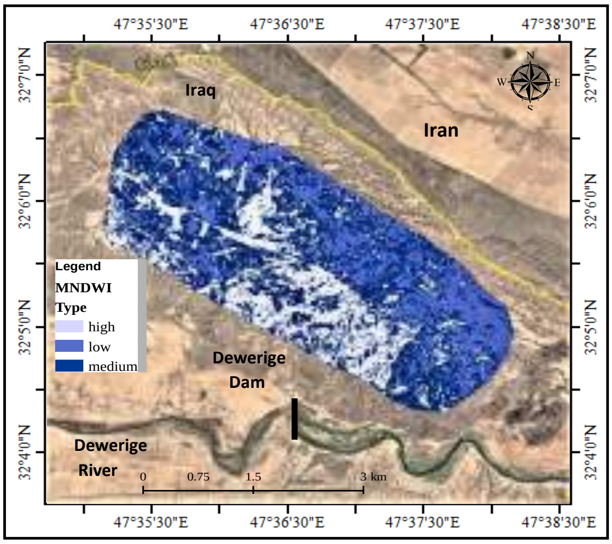
Thematic layer of each parameter / **Site1**



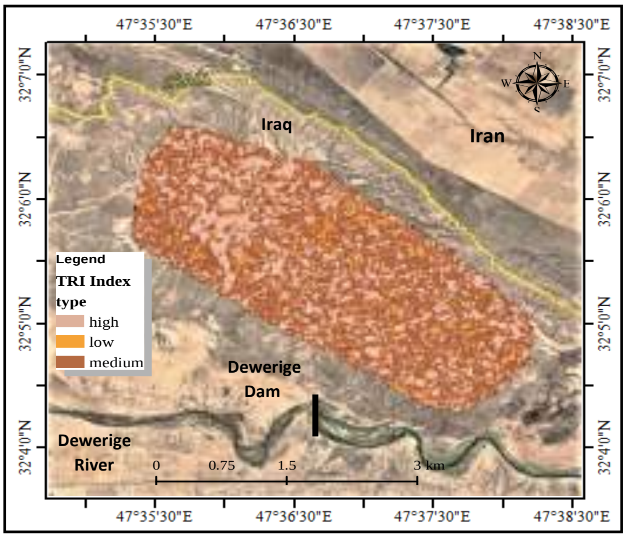
a. NDSI



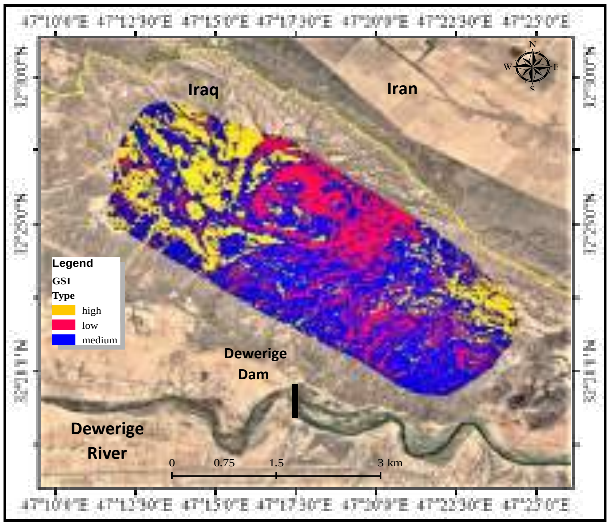
b. TWI



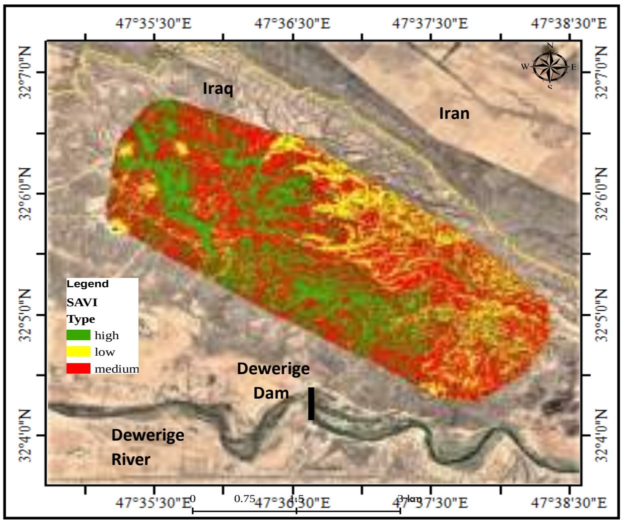
c. MNDWI



d. TRI



e. GSI

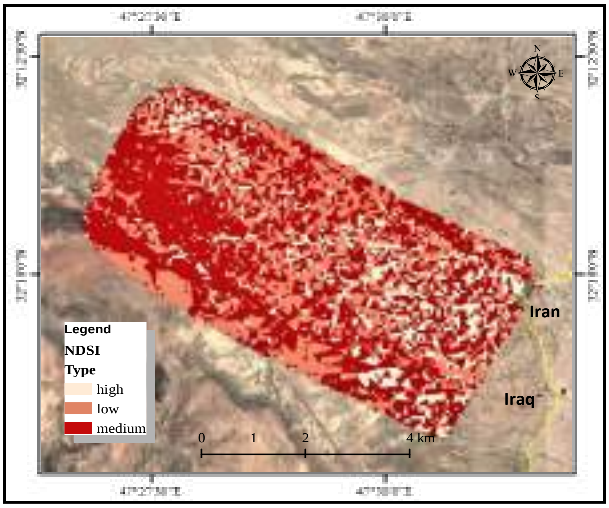


f. SAVI

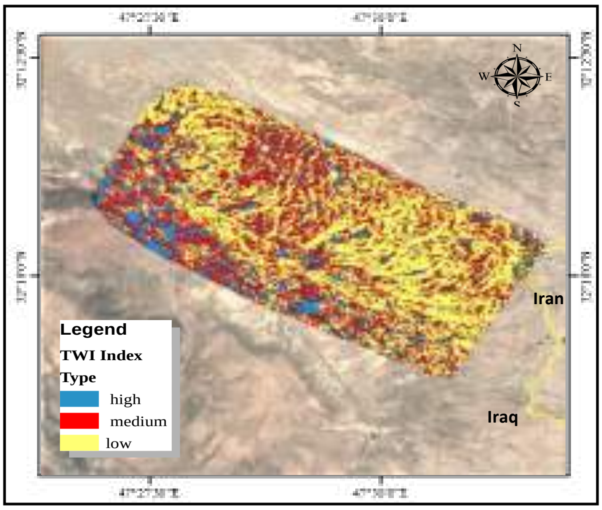
Fig.3.10 (a, b, c, d, e, and f) The Result of applied indices of AHP in site1

The site suitability analysis involve consideration of many parameters influencing the performance of the structure under consideration, in this study, AHP approach has been applied for decision making. The adapted parameters such as TWI, NDSI, MNDWI, TRI, GSI, and SAVI. Each parameter was reclassified into three subclasses (low, medium, and high). In site1 the results of creating thematic layers was explained in Fig.3.10. The normalized difference sand index raster (a) gives an idea about soil type in site1. Most type of soil range from medium – low sand reflectance, therefore the area is suitable to be catchment area. The high values of topographic wetness index (b) concentrated in north-western of site1, this mean that location in high suitability for WHS.. Topography and soil types are the most factor controlling in subtility of WH projects. The other factors TRI, MNDWI, GSI, and SAVI are additional factors utilized to make the decision-making be accurate, At the same time these factors are important environmental parameters.

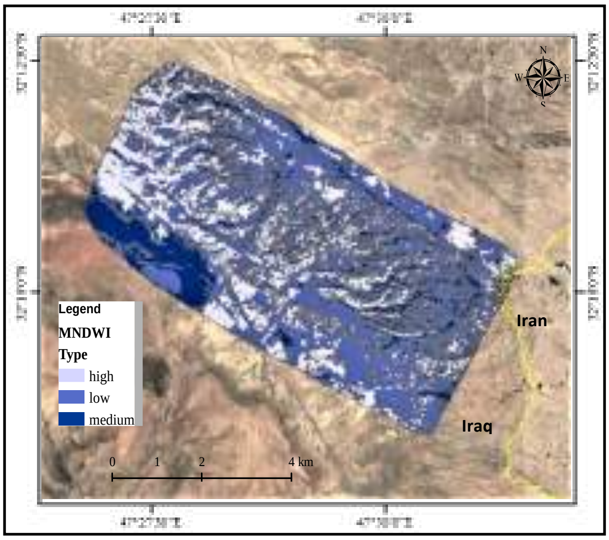
Thematic layer of each parameter / **Site2**



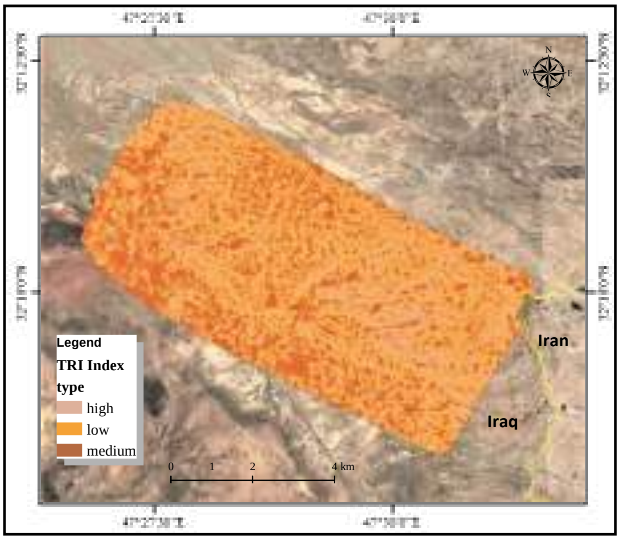
a. NDSI



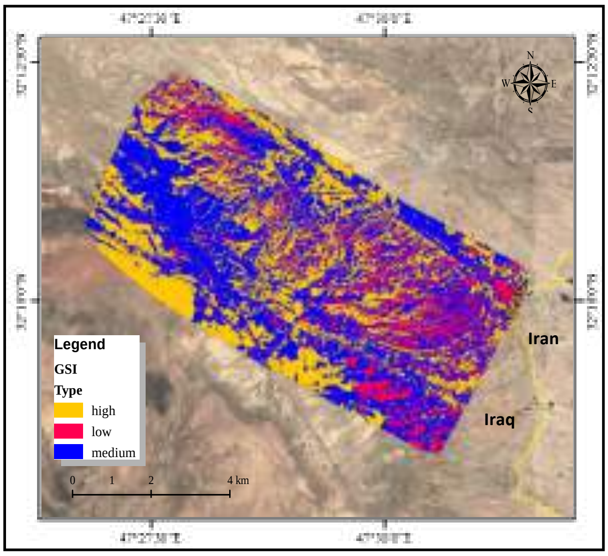
b. TWI



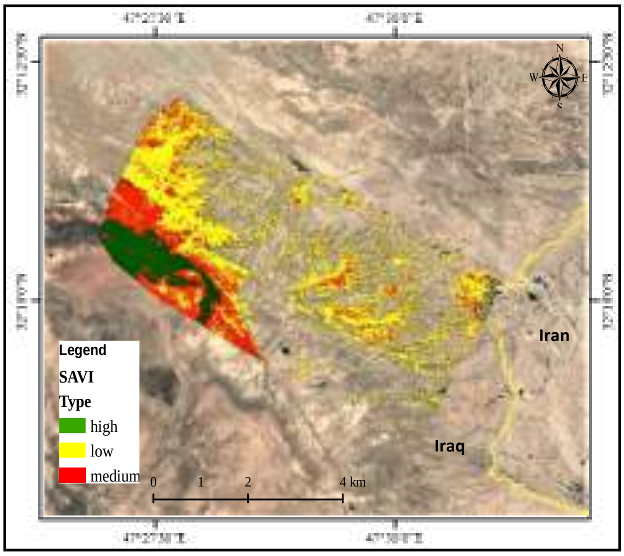
c. MNDWI



d. TRI



e. GSI

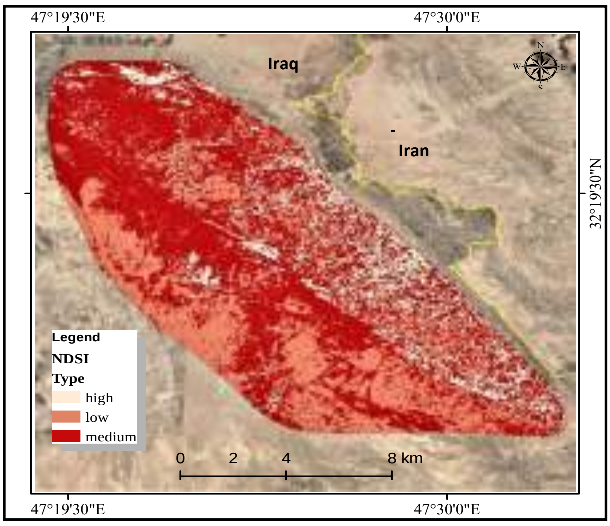


f. SAVI

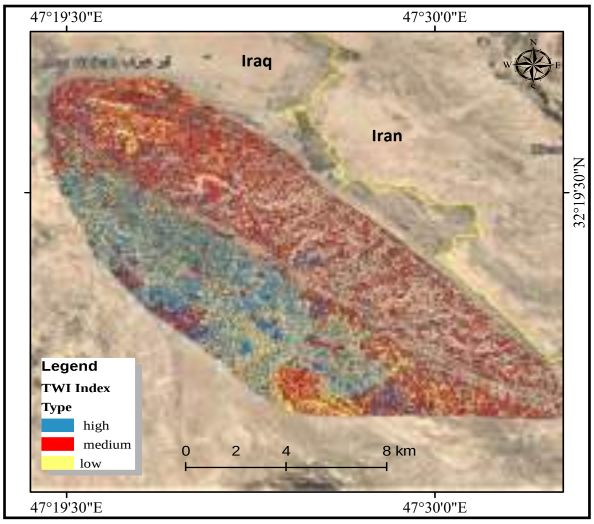
Fig.3.11 (a, b, c, d, e, and f) The Result of applied indices of AHP in site2

While site2 the results of creating thematic layers was explained in Fig.3.11. The normalized difference sand index raster (a) gives an idea about soil type in site1. Soil type range is medium sand reflectance in most position in site2, therefore the area is suitable to be catchment area. The high values of topographic wetness index (b) concentrated in western position of site2, this mean that location in high suitability for WHS. Topography and soil types are the most factor controlling in subtility of WH projects. The other factors TRI, MNDWI, GSI, and SAVI are additional factors utilized to make the decision-making be accurate, At the same time these factors are important environmental parameters.

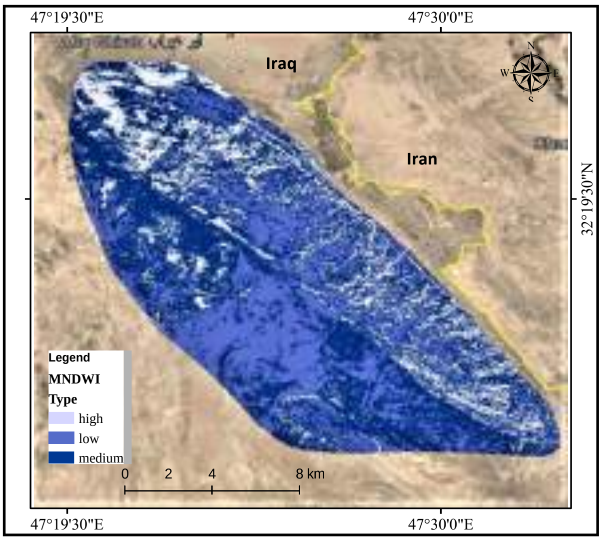
Thematic layer of each parameter / **Site 3**



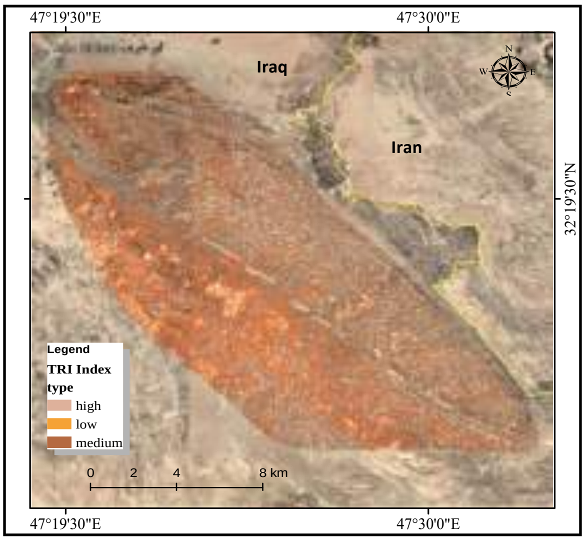
a. NDSI



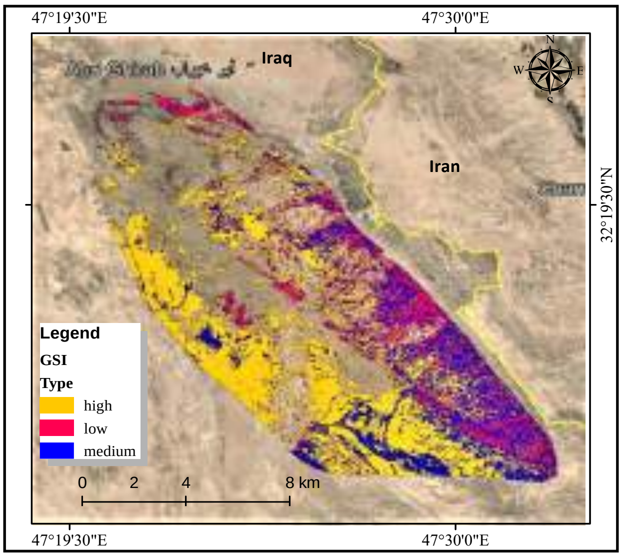
b. TWI



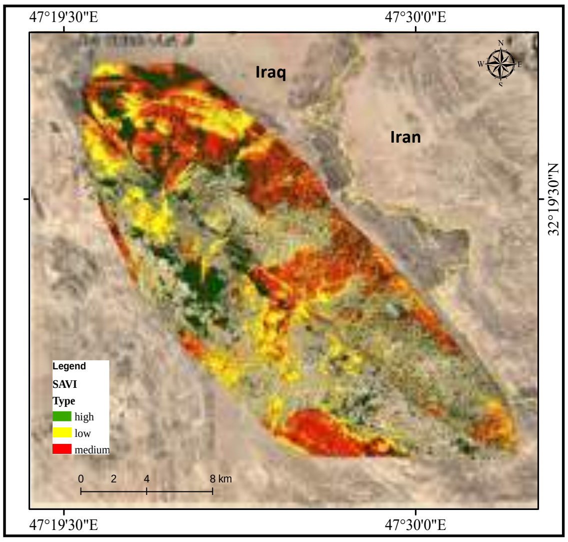
c. MNDWI



d. TRI



e. GSI

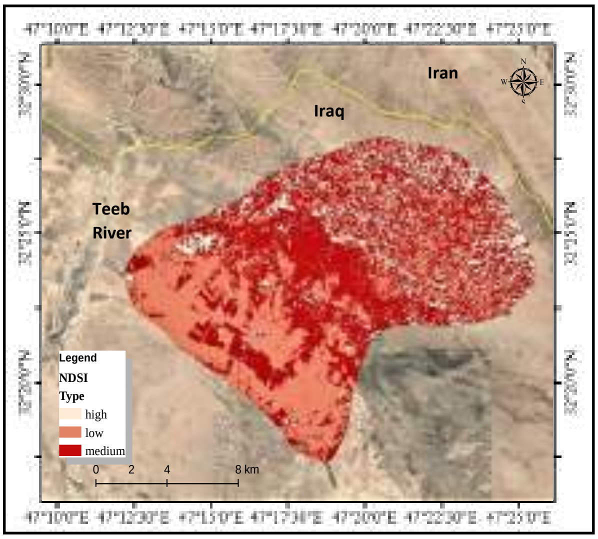


f. SAVI

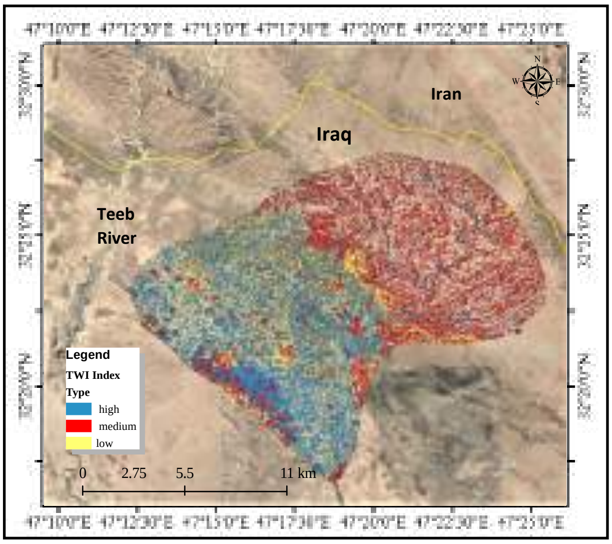
Fig.3.12 (a, b, c, d, e, and f) The Result of applied indices of AHP in site3

In site3 the results of creating thematic layers was explained in Fig.3.12. The normalized difference sand index raster (a) gives an idea about soil type in site3. Most type of soil is medium sand reflectance; therefore, the area is suitable to be catchment area. The high values of topographic wetness index (b) concentrated in northwestern of site1, this mean that location in high suitability for WHS. Topography and soil types are the most factor controlling in subtility of WH projects. The other factors TRI, MNDWI, GSI, and SAVI are additional factors utilized to make the decision-making be accurate, At the same time these factors are important environmental parameters.

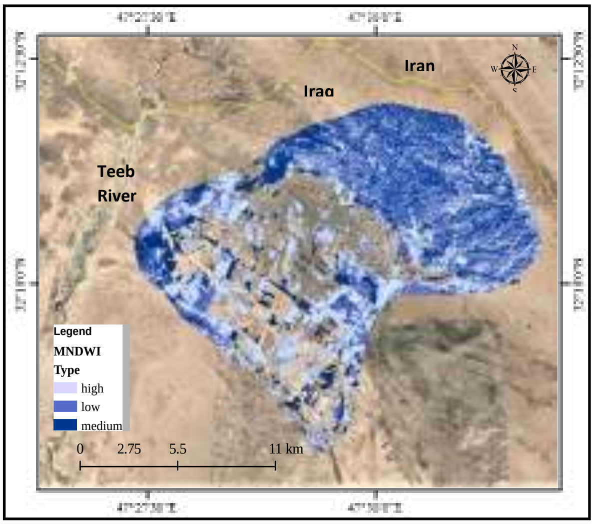
Thematic layer of each parameter / **Site 4**



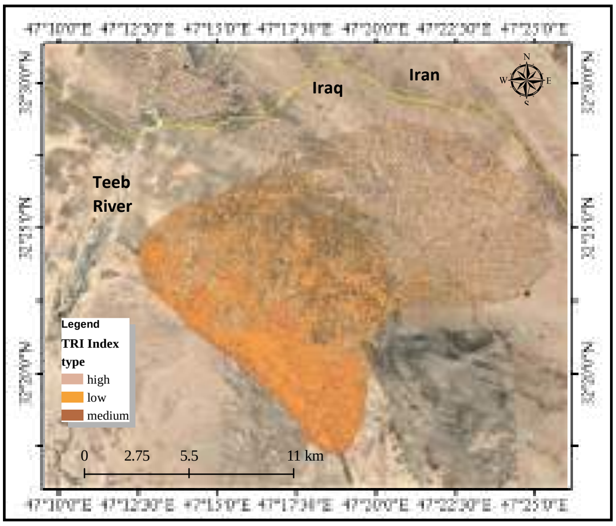
a. NDSI



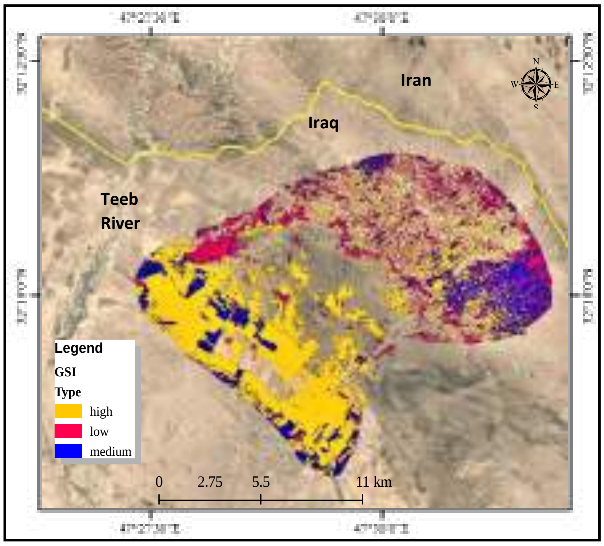
b. TWI



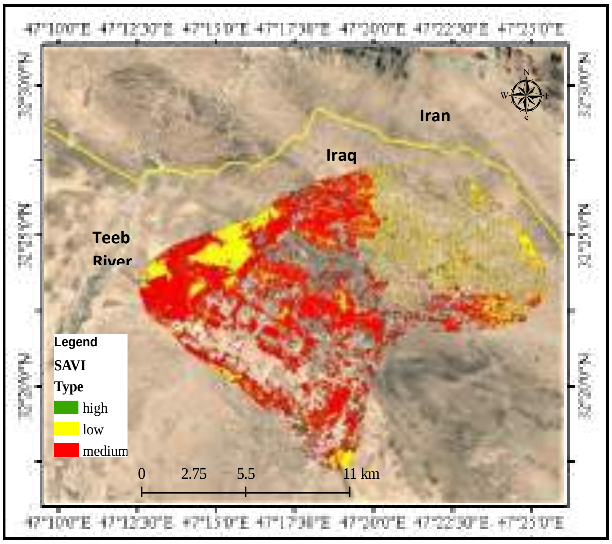
c. MNDWI



d. TRI



e. GSI



f. SAVI

Fig.3.13 (a, b, c, d, e, and f) The Result of applied indices of AHP in site4

In site4 the results of creating thematic layers was explained in Fig.3.13. The normalized difference sand index raster (a) gives an idea about soil type in site1. Most type of soil range from medium – low sand reflectance, therefore the area is suitable to be catchment area. The high values of topographic wetness index (b) concentrated in northwestern of site1, this mean that location in high suitability for WHS. Topography and soil types are the most factor controlling in subtility of WH projects. The other factors TRI, MNDWI, GSI, and SAVI are additional factors utilized to make the decision-making be accurate, In the same time these factors are important environmental parameters

3.5 The suitability of water harvesting potential sites

The volume of storage yield in water harvesting techniques is based on several factors: Rainfall, vegetation, texture of soil, slope of the area etc. (Lewis, 1995).The appropriate sites to apply water harvesting techniques have been identified in the study area using the analytical hierarchy process (explained in detail in chapter three).There is no certain design recommended for all sites and covers all different needs. The perfect storage system must be the least cost, minimum seepage and evaporation, and simple construction and maintenance. The figures below explain the results of applying AHP is the study Figs.3.14, 3.15, 3.16, and 3.17.

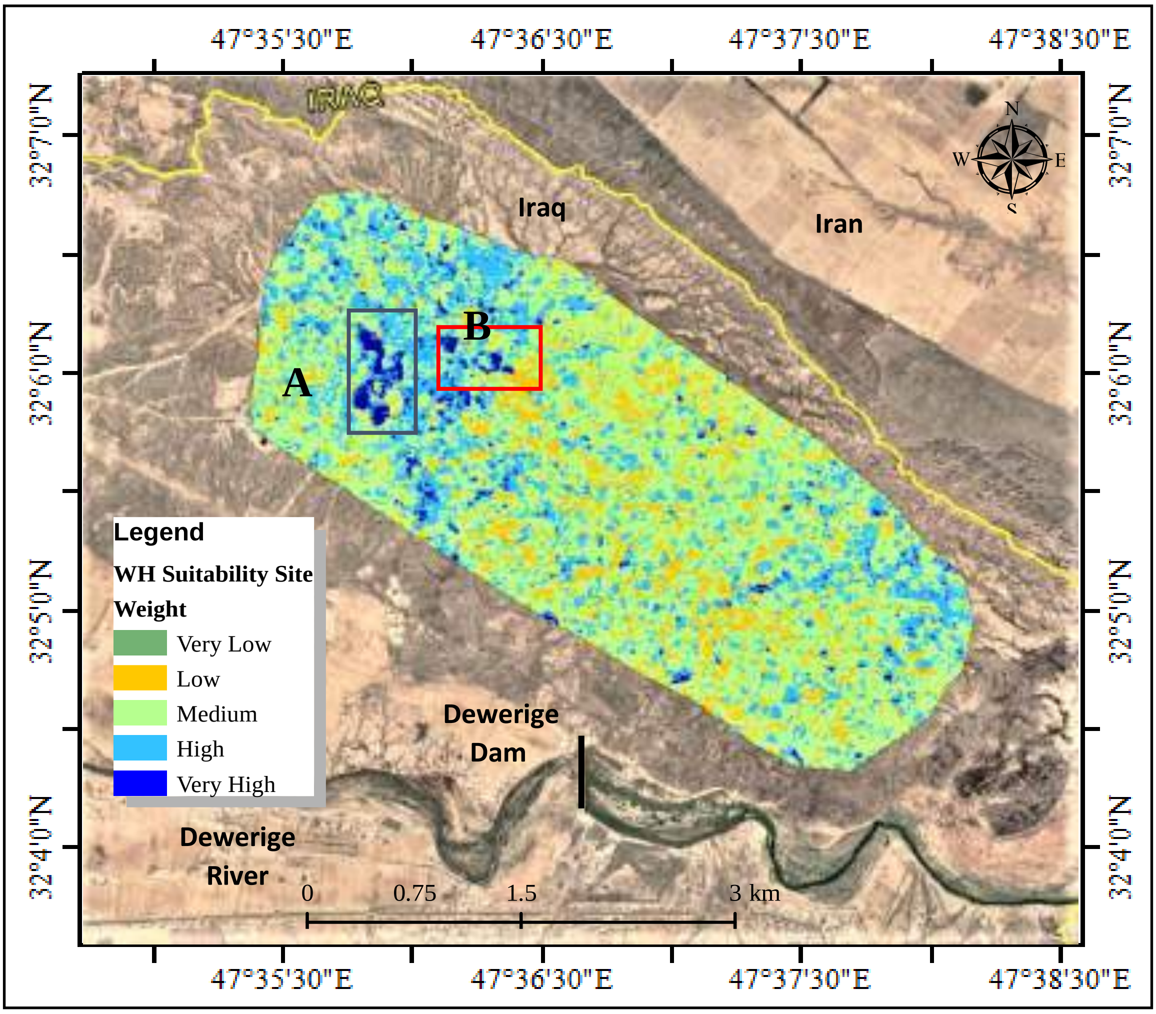


Fig. 3.14 Final map of WH suitability site1

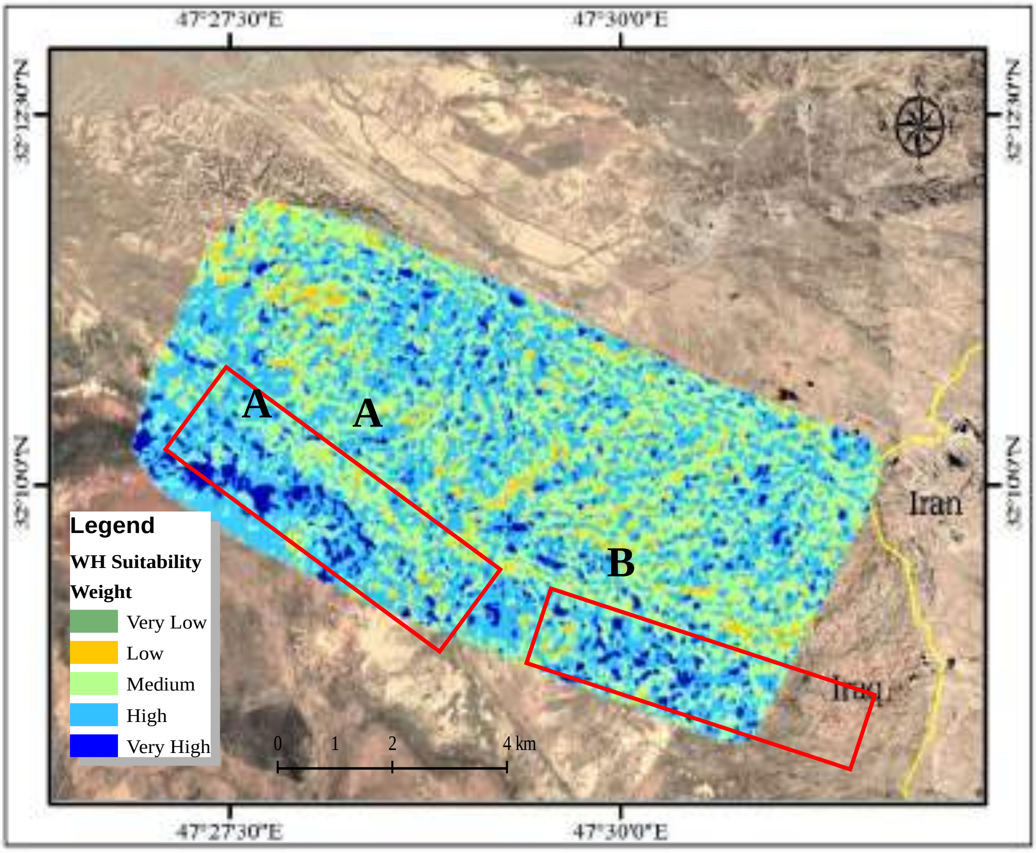


Fig. 3.15 Final map of WH suitability site1

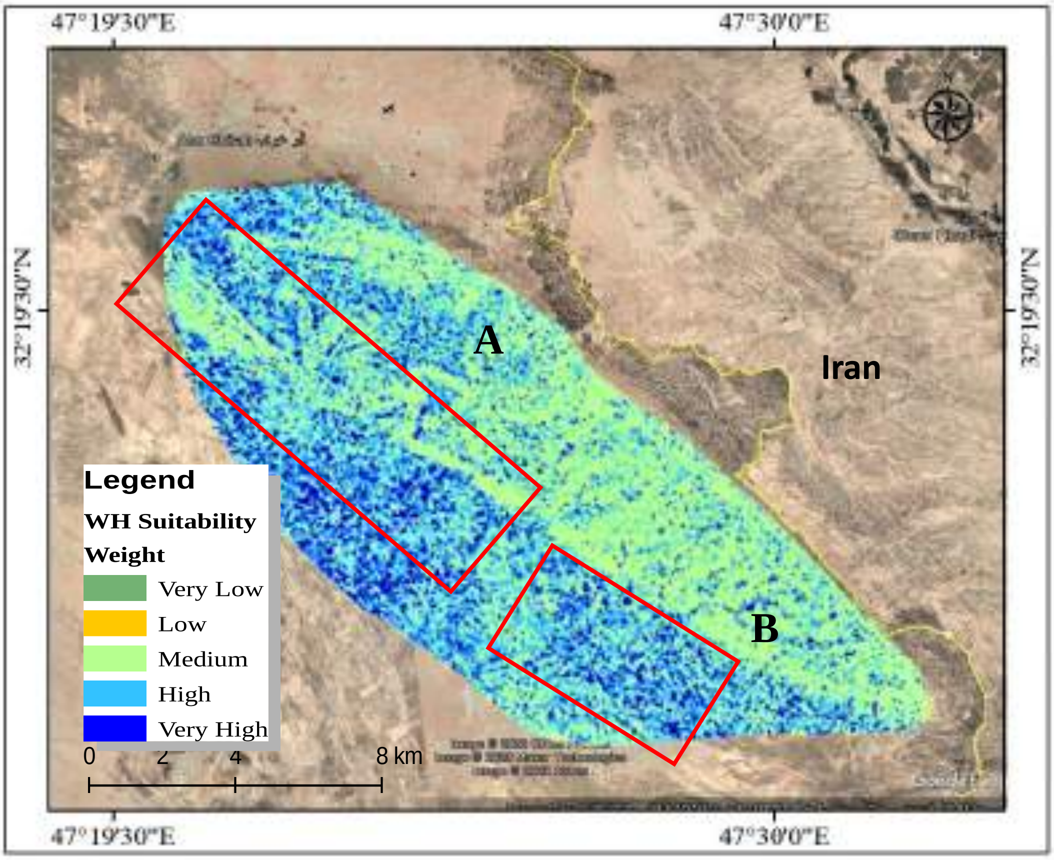


Fig. 3.16 Final map of WH suitability site1

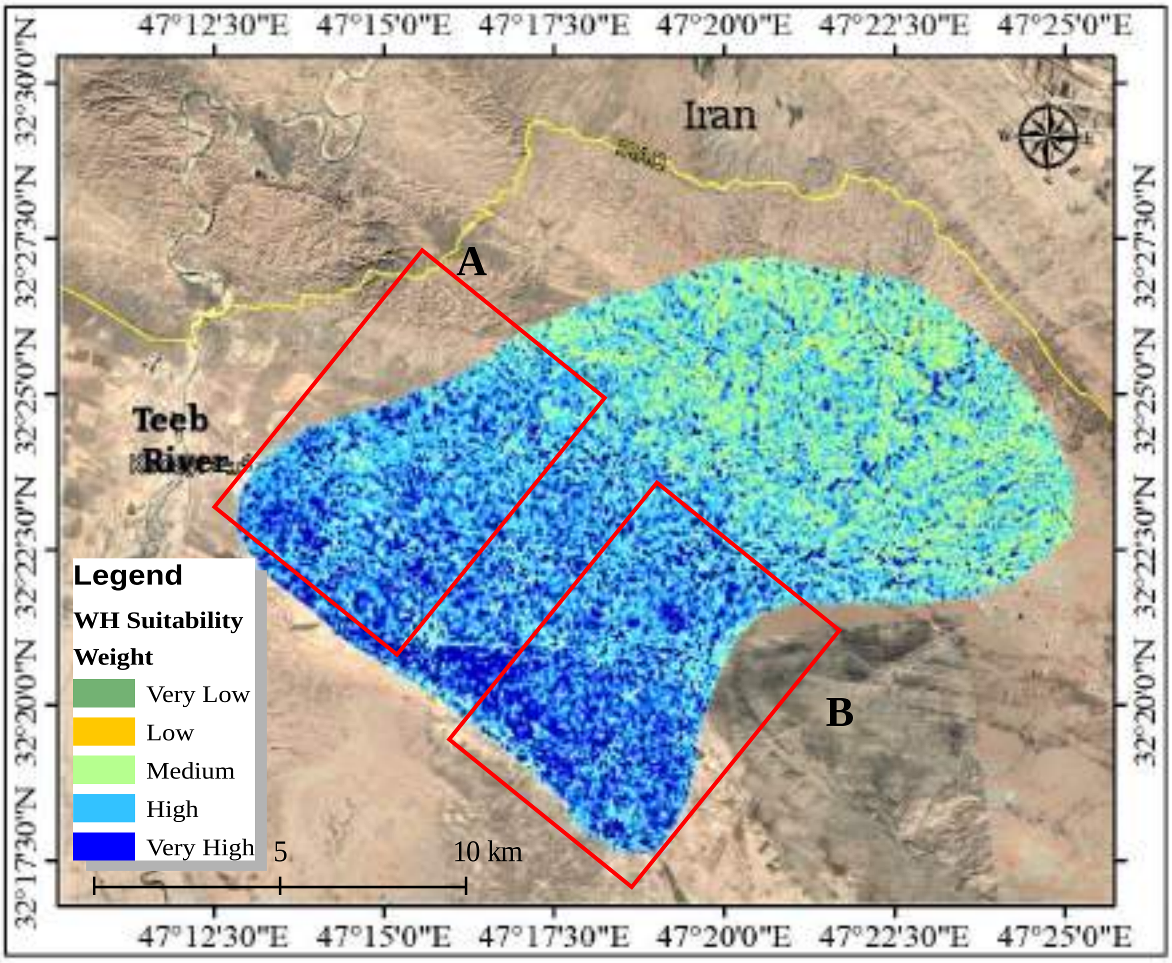


Fig. 3.17 Final map of WH suitability site1

According to the result of AHP for research problem, the chosen sites were classified into five subclasses in term of water harvesting suitability: very low, low, medium, high, and very high. The chosen areas (site1, site2, site3, and site4) are including large areas. The recommended water harvesting area must be neither large to avoid water loss nor small area. Therefore, only the very high suitability subclass has been selected and adopted as a perfect area to construct water harvesting projects. Also, choosing the suitable project to the area based on the geological properties that mentioned before. Table 3.5 shows the position of suggested water harvesting projects and properties of the four sites.

Table 3.5 the positions properties of very high subclasses suitability

Potential Sites	Slope average	Coordinates system
Site1		
Position A	0.9 - 2.5	7446690.09E – 3554171.4N
Position B	1.3 – 2.2	745185.40E – 3554460.97N
Site2		
Position A	1.1 – 4.2	732283.10 E- 3561807.73 N
Position B	4.3 – 1.3	736933.51 E 3560615.80 N
Site3		
Position A	4.9 – 1.3	733521.50 E 3567183.88 N
Position B	2.3 – 0.7	721484.46 E 3576958.25 N
Site4		708707.06 E 3588026.65 N
Position A	1.6 – 0.4	715867.13 E 3580470.68 N
Position B	3.9 – 0.7	

Chapter Four

Water Harvesting Systems

CHAPTER FOUR
WATER HARVESTING SYSTEMS

4.1 Introduction

The flow chart (Fig.4.1) showing the adopted strategy in this chapter to explain water harvesting systems in the study area.

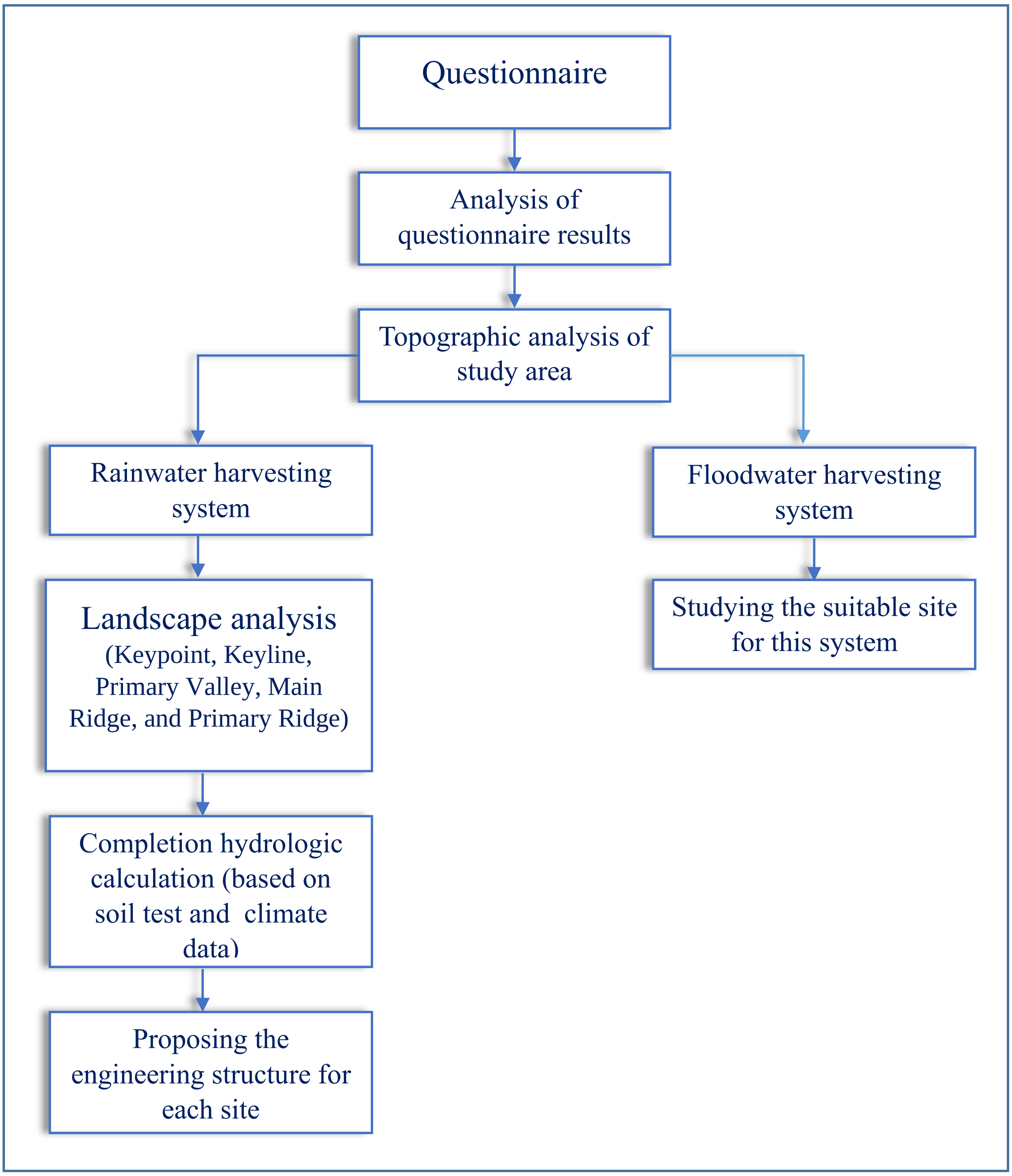


Fig.4.1 Water harvesting systems methodology

4.2 The questionnaire result

In this part of the chapter, the result is offering and analysing open-ended, closed-ended, multiple-choice questions. To the category sample: form no.1, form no.2, form no.3, form no.4, and form no.5. The questionnaire responses would display in tables: 4.1, 4.2, 4.3, 4.4, and 4.5.

I. Government Institutions (form no.1)

Table 4.1 the result of Government Institutions questionnaire

NO.	Question	Answer		Notices'
		Yes	No	
Q1	Is there any water harvesting project that was previously achieved in Missan Governorate?	35.7%	64.3%	-
Q2	Do you have future studies on water harvesting projects?	50%	50%	No answer
Q3	Do you know about similar projects?	35.7%	64.3%	No answer
Q4	If the answer is yes, what is the project name and where is it located?			Dewerige dam in Missan, Al-Shahabi and Bedra dam Al-Abiath dam in Al-Nagaf Al-Al-Garbi projects north Missan., Water harvesting in Wased.
Q5	Do you suggest setting up a water harvesting project in Teeb area, east of Missan?	92.9%	7.1%	-
Q6	What are the obstacles facing these projects?			14.3% evaporation 7.1% soil erosion 28.6%administrative obstacles 14.3% social obstacles 35.7% silt accumulation
Q7	Do you have suggestions about water harvesting?	35.7%	64.3%	
Q8	If the answer is yes, what are these suggestions?			- Investing in the rain and torrential waters east of Missan. - Climate data analysis for 30 consecutive years

				- Using water harvesting projects to recharge groundwater. - Studying the valleys located on the eastern side of Missan.
Q9	If the water harvesting project succeeds in the region, do you think it encourages the establishment of development projects (schools, health centers, youth centers)?	92.9%	7.1%	-
Q10	Do you think that water harvesting projects encourage agricultural, commercial and tourism investment in the area?	85.7%	14.3%	-
Q11	If the answer is yes, what are your suggestions?			- Establishing modern villages - Establishing parks and geological sites - Establishing natural reserves

II. Social Service Organizations (form no.2)

Table 4.2 The result of Social Service Organizations questionnaire

NO.	Question	Answer		Notices'
		Yes	No	
Q1	Does your organization have any activity related to water?	100%	0%	-
Q2	If the answer is yes, in which city was this activity?			Missan, Baghdad, Basrah, Duhuk, Sulimanya, Diwanya
Q3	Did your organization support or finance any water harvesting project in Missan?	0%	100%	-
Q4	If the answer is yes, in which city was this that support?	-	-	No answer
Q5	Do you support fundraising for the implementation of these projects?	60%	40%	-
Q6	Have you witnessed conflicts or problems between the community of farmers and fishermen, or shepherds caused by the scarcity of water?	80%	20%	-

Q7	Can you participate in raising awareness among the farmers and shepherds community to help implement these projects?	100%	0%	-
Q8	Do you have suggestions about the project?	40%	60%	-
Q9	If the answer is yes, what are these suggestions?			- Encouraging water harvesting projects in various regions of Iraq - Constructing many small dams to exploit the water and groundwater recharge
Q10	Do you have the desire to contact governmental or international institutions to support the project?	80%	20%	-

III. **Research Specialists (form no.3)**

Table 4.3 The result of Research Specialists questionnaire

NO.	Question	Answer		Notices'
		Yes	No	
Q1	Do you think that water harvesting techniques are useful to overcome the drought in Iraq?	83%	16.3%	-
Q2	If the answer is yes, what are the reasons?			- Administrative corruption - Lack of rainfall and poor utilization of it - Lack of modern techniques to combat desertification. - Modern technologies must be used to avoid wasting water - Lack of water harvesting projects in Missan. - Missan is not suitable for water harvesting projects.
Q3	Do you think that these technologies may reduce desertification in the future?	89.1%	10.9%	-
Q4	Did you contribute to preparing a study on water harvesting techniques?	81.7%	18.3%	-

Q5	If the answer is yes, mention the name of the study.	-	-	name of the area was not mentioned
Q6	Is water harvesting techniques useful for studying climatic changes?	95.6%	4.4%	According to the knowledge of the researchers.
Q7	Do you have any suggestions about water harvesting?	36.6%	63.4%	-
Q8	If the answer is yes, what are these suggestions?			- Establishing a center for water harvesting projects - Support the re-stores of the marshes - The use of modern technology to face the water crisis - Construction of subsurface dams - The exploitation of dry valleys during the flooding.
Q9	Do you think that water harvesting projects encourage agricultural investment and tourism?	89.2%	10.8%	-
Q10	If the answer is yes, what are these suggestions?			- Encourage investment to use modern irrigation technologies - Establishing modern villages - Drilling wells for ground water - Establishing tourist centers and research centers - Using modern irrigation technologies.

IV. **Shepherds Opinion (face to face interview) form no.4**

Table 4.4 The result of Shepherds Opinion questionnaire

NO.	Question	Answer		Notices'
		Yes	No	
Q1	Is there any influence of water scarcity on the shepherds' life and the situation of livestock in the area? How is that?	100%	0%	-
Q2	If drinking water is available in sufficient quantities, does this help in life stability?	98%	2%	-

Q3	In the case of designated lands for grazing, does this limit overgrazing and thus control desertification?	70%	30%	-
Q4	Does overgrazing cases affect the increase in feed prices?	40%	60%	-
Q5	In the case of establishing water harvesting projects, will this reflect positively on your animals?	80%	20%	-
Q6	Is there a relationship between the availability of good water quality and diseases prevalent among animals?	95%	5%	-
Q7	Has the idea of the water harvesting project been explained or clarified to you before?	0%	100%	-
Q8	If the answer to the question is yes, by whom?	-	-	No answer
Q9	If the local authorities asked you to cooperate with them to help, would you agree?	70%	30%	-
Q10	Do you consider designating land for grazing as a solution that helps reduce conflicts in the area?	80%	20%	-

V. Farmers Opinion (face to face interview) form no.5

Table 4.5 The result of Farmers Opinion questionnaire

NO.	Question	Answer		Notices'
		Yes	No	
Q1	Missan eastern desert is subjected to the flooding risk, is there any effect of the flooding on your farm? And general life?	70%	30%	-
Q2	Did you use a specific technique to harvest rainwater and use it for irrigation?	100%	0%	-
Q3	What is your source of water for irrigation?	-	-	- 30% Teeb River - 70% (rainfall+wells+others)

Q4	Do you pay any money to get water for irrigation?	80%	20%	-
Q5	If case the increasing amount of water you use for irrigation, will this affect the variety and quantity of crops?	100%	0%	-
Q6	In case of the water harvesting projects contribute to solving the water crisis, will this encourage farmers to turn to agriculture? And not to leave their lands for going to government jobs?	70%	30%	Administrative corruption
Q7	There are wild plants in the area that are used as traditional treatments. Can they be invested in a way that provides a financial return for the people in this area?	95%	5%	Did not matter.
Q8	Have concerned authorities established water harvesting projects in your land?	0%	100%	-
Q9	Has the idea of the water harvesting project been explained or clarified to you before?	0%	100%	-
Q10	If the answer to the question is yes, by whom?	-	-	No answer
Q11	If the local authorities asked you to cooperate with them to help, would you agree?	60%	40%	The subject needs more explanation
Q12	Does water scarcity cause conflicts and problems in the area?	100%	0%	Conflicts over grazing lands

4.3 Analysing the questionnaire results

The questionnaire results have been summarized and discussed in tables: 4.6, 4.7, and 4.8.

Table 4.6 Compared key findings between the questionnaire samples:

	The key findings	Government Institutions	Research Specialists	Social Service Organizations	Shepherds Opinion	Farmers Opinion
1	The availability of accurate technical data about water harvesting projects	-	-	-	-	-
2	Presence of specialized institutions in water harvesting (to spread awareness or implementation)	-	-	-	-	-
3	The presence of government organizations concerned with water studies or water harvesting	-	-	-	-	-
4	The availability of a research center specifically concerned with the issue of water harvesting	-	-	-	-	-
5	The presence of private or governmental companies specialized in water harvesting projects	-	-	-	-	-

Table: 4.7 Compared key findings between governments Institution, research specialists, and social service organizations:

	The key findings	Government Institutions	Research Specialists	Social Service Organizations
1	Preparing a study on water harvesting projects in Missan Governorate	-	21.7%	-
2	Organizing introductory and awareness-raising activities about water harvesting subjects.	-	-	-

Table 4.8 Compared key findings between categories of project beneficiaries:

	The key findings	Shepherds Opinion	Farmers Opinion
1	Water scarcity raises the chance of competition, conflict, and instability in communities in the study area	100%	100%
2	Impact of water harvesting project on conflicts and instability in the area.	100%	100%
3	Explaining the idea of water harvesting projects by government institutions	0%	0%

According to the questionnaire obtained results, in this study:

1. There is no data, experience, or planning to establish water harvesting projects.
2. There are no social service organizations (governmental or private) specialized in spreading awareness regarding water harvesting.
3. There is no future vision for the establishment of pioneering projects in this field.

4.4 Influence of keyline application on overcoming conflicts between farmers and shepherds

One of the major objectives of applying the keyline system is to develop and deepen soil fertility and overcome the risks of soil erosion. For example, this strategy deepens the topsoil by about (10 - 15) cm. In the same way, increase the depth of living soil about (30 - 45) cm. This is done by improving the living conditions of aerobic organisms in the soil from moisture, warmth, and the supply of protein-rich plants. These types of plants are considered the best pastures. The method of obtaining good pastures with fertile soil is summarized: Before flowering, plants rich in protein are harvested, keeping the roots. Because the roots at this stage of the plant's life are at their maximum size. Repeating this process ensures the provision of high-quality pastures with fertile soil protected from erosion by the upper layer. Finally, the application of the keyline strategy can ensure the overcoming of the conflicts between farmers and shepherds.

4.5 Floodwater harvesting in the study area

Based on the previous studies of the study area, the area is at flooding risk and called (submerged land) Fig.4.2. The study area can be classified into three sites according to the source of the flood water (Al-Abadi and Al-Ali, 2016), (Sissakian and Hamid, 2011)

a) Dewerige site / flooding of Dewerige River.
b) Teeb site / flooding of Teeb River.
c) Ali-Al-Garbi site / Torrential waters coming from Iran.

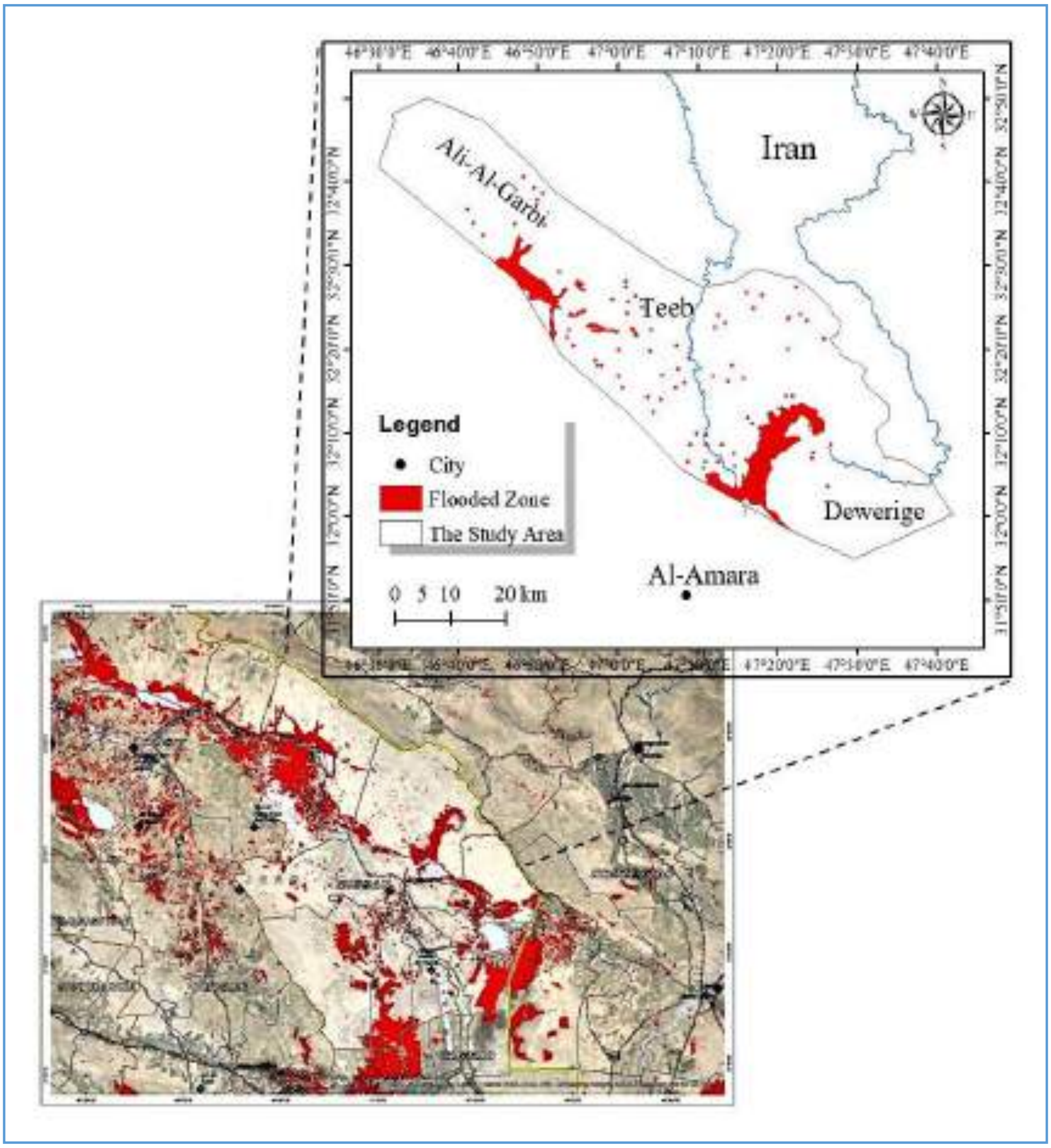


Fig.4.2 Flooding risk in Missan governate shaded in red modified after (UNOSAT, 2013)

There are no stations for measuring and monitoring the rivers levels during certain periods of the flood, therefore the measurements for calculating the amount of water as a floodwater harvesting cannot be achieved.

4.6 Rainwater harvesting method

The landscape classification of the four sites were studied by constructing a topographic map derived by DEM and used depending on keyline principles (Yeomen techniques). The selected sites were classified according to the water lines and topography. The catchment area is computed, and a suitable structure is suggested. Fig.4.3 show the RWH in the study area which is selected based on the agricultural map of Missan Winter 2021.

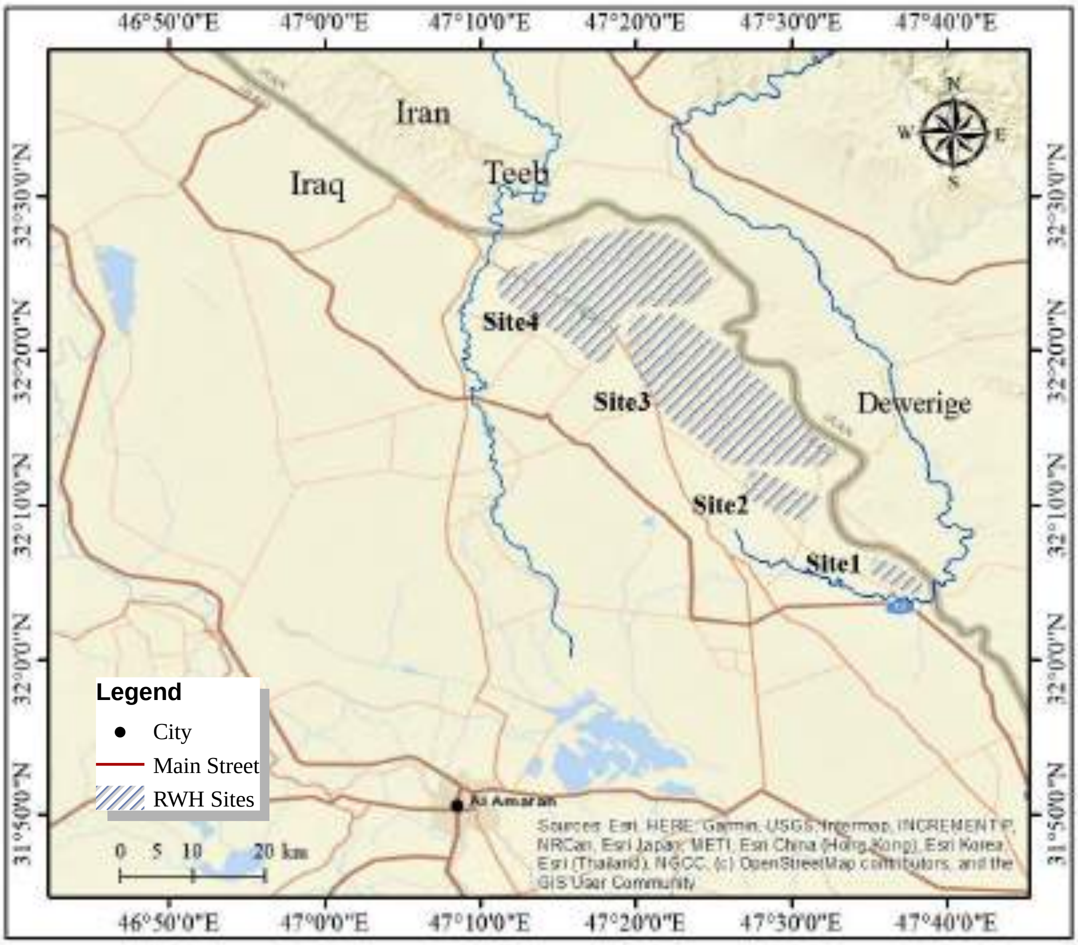


Fig.4.3 Distribution of chosen RWH areas in study area

4.6.1 Rainwater harvesting site1

In site1 (Fig.4.4) the main ridge, primary valley were denoted. Then profiles lines selected through primary valley Fig.(4.6). The results of soil test (Fig.4.5) site1 explains, that the soil is silty clay, and the site is suitable to be catchment area.

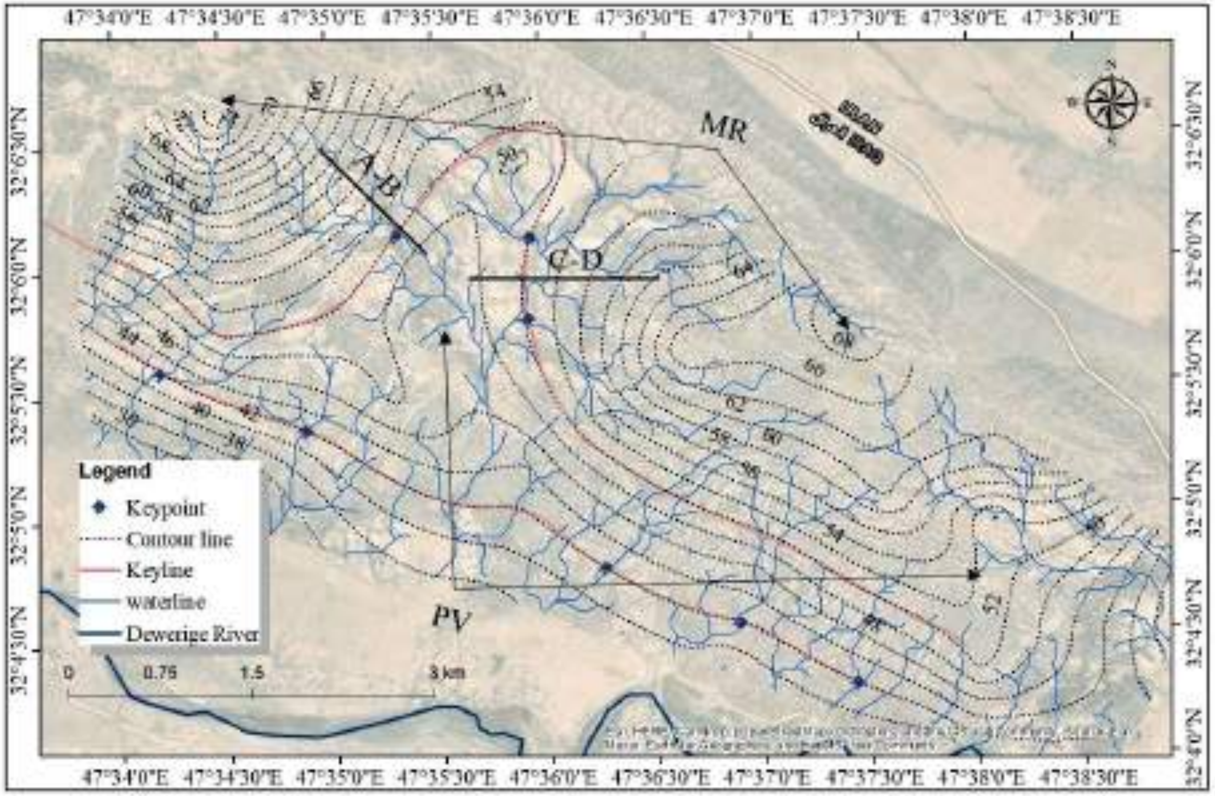


Fig.4.4 Landscape analysis based on Yeomen techniques / **site1**

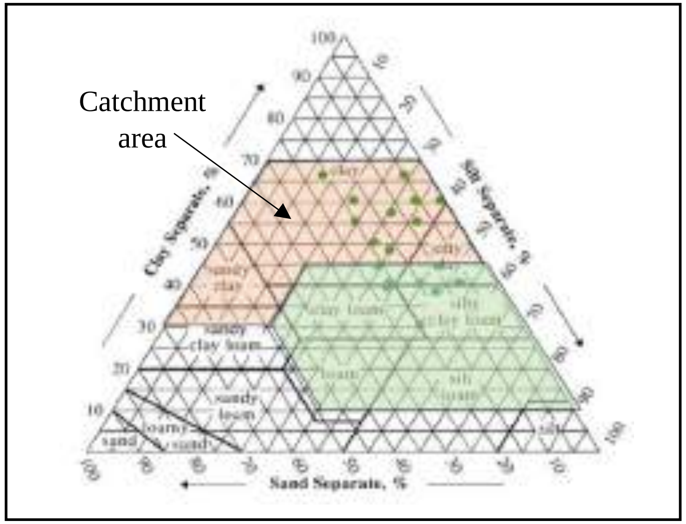


Fig.4.5 soil texture site1

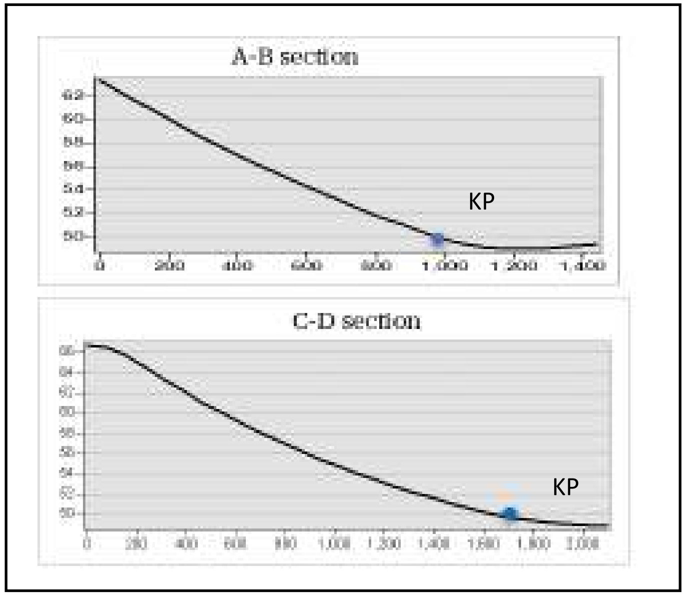


Fig.4.6 Keypoint position

4.6.2 Rainwater harvesting site2

In site2 (Fig.4.7) the main ridge, primary valley were denoted. Then profiles lines selected through primary valley Fig.(4.9). The results of soil test (Fig.4.8) site2 explains, that the soil is sandy clay and site is suitable to be catchment area.

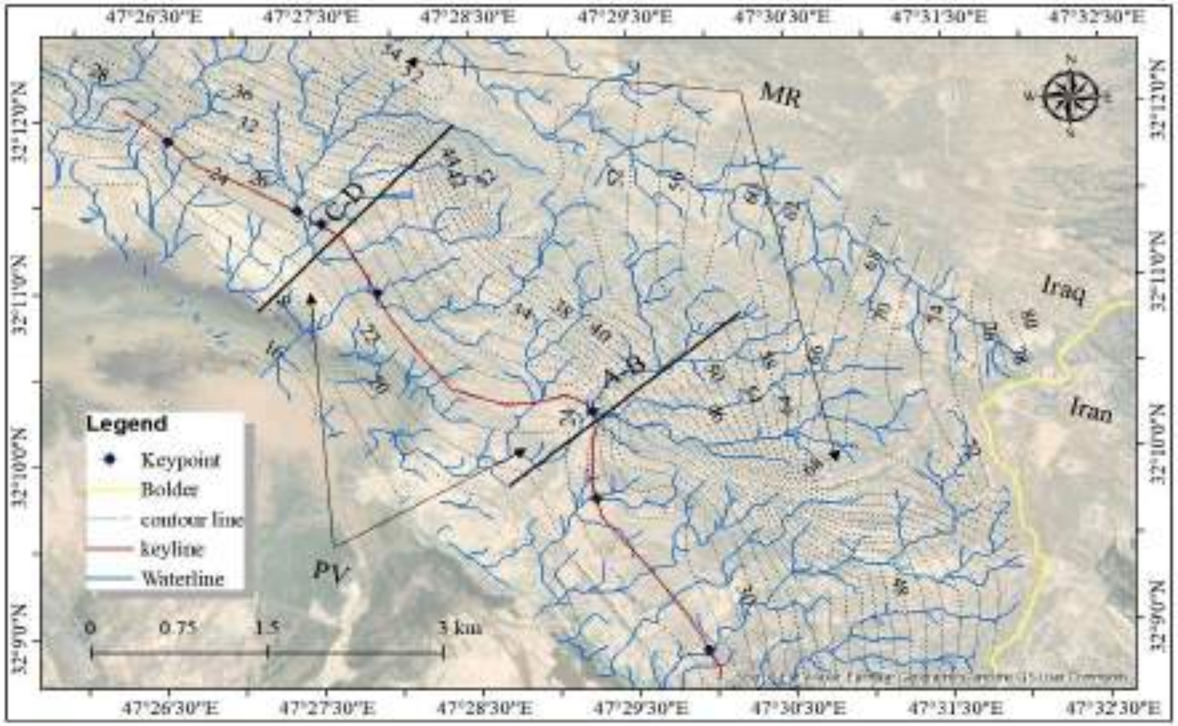


Fig.4.7 Landscape analysis based on Yeomen techniques / **site2**

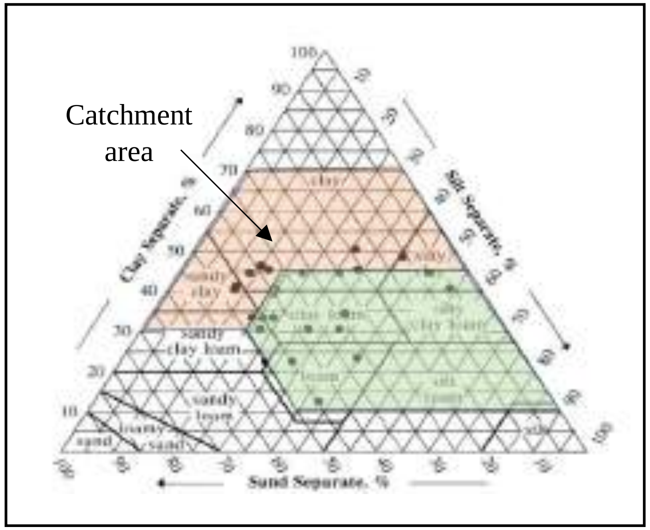


Fig.4.8 Soil texture site2

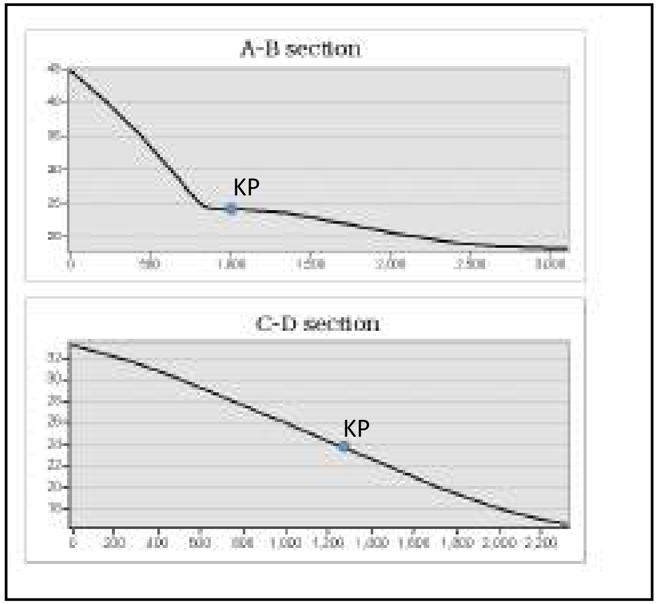


Fig.4.9 Keypoint position

4 .6.3 Rainwater harvesting site3

In site3 (Fig.4.10) the main ridge, primary valley were denoted. Then profiles lines selected through primary valley Fig.(4.12). The results of soil test (Fig.4.11) site3 explains, that the soil is silty clay loam, and the site is suitable to be an application area.

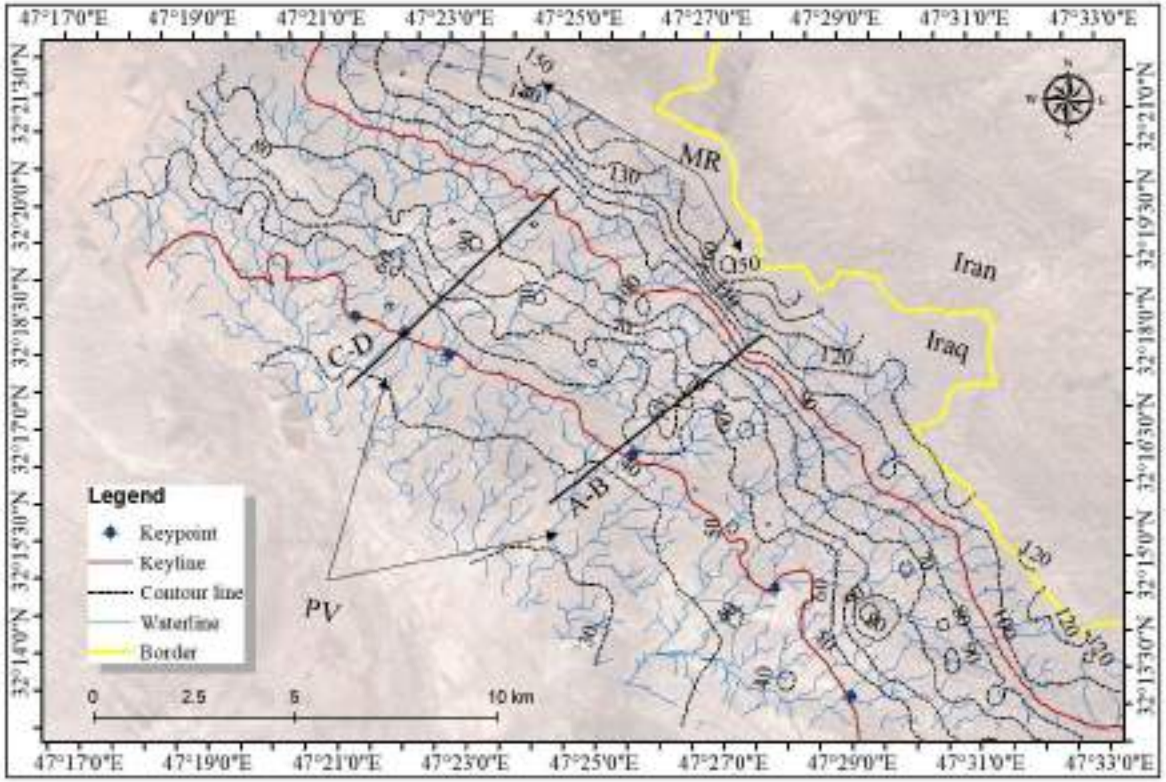


Fig.4.10 Landscape analysis based on Yeomen techniques / **site3**

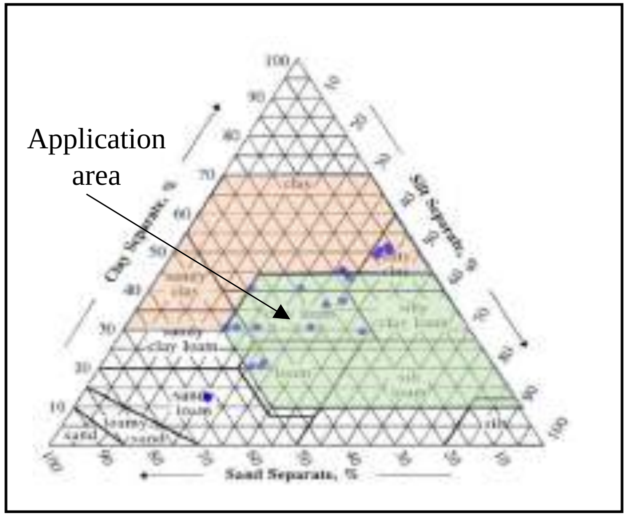


Fig.4.11 Soil texture site3

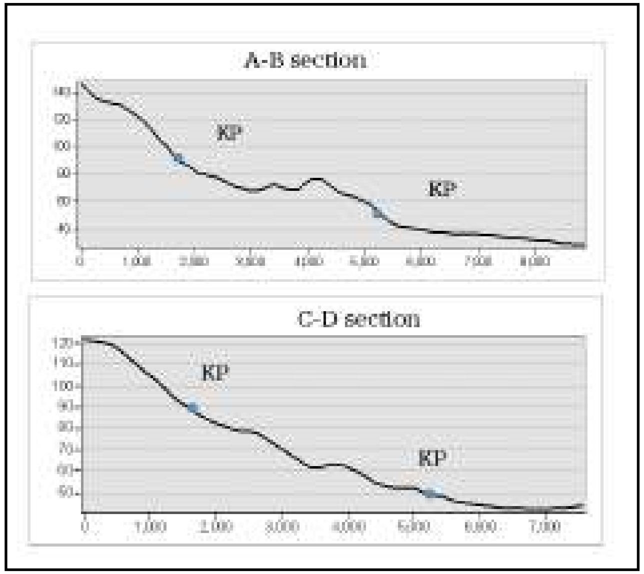


Fig.4.12 Keypoint position

4.6.4 Rainwater harvesting site 4

In site4 (Fig.4.13) the main ridge, primary valley were denoted. Then profiles lines selected through primary valley Fig.(4.15). The results of soil test (Fig.4.15) for site1 explains, that the soil is sandy clay, and the site is suitable to be catchment area.

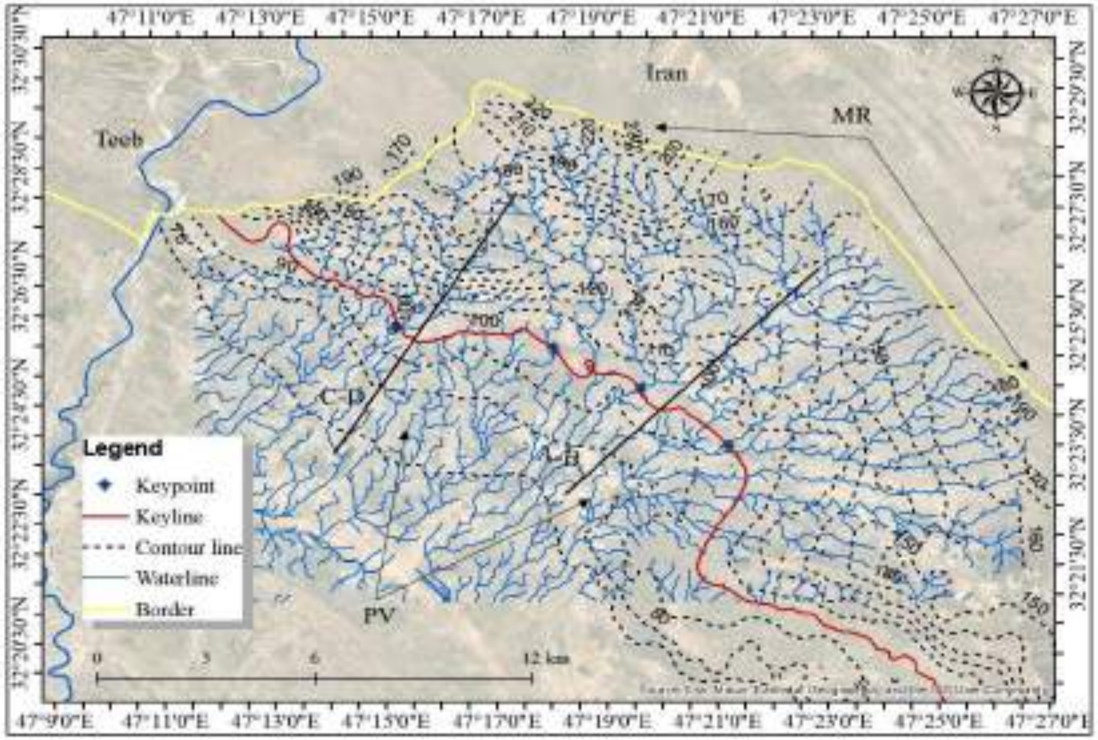


Fig.4.13 Landscape analysis based on Yeomen techniques / **site 4**

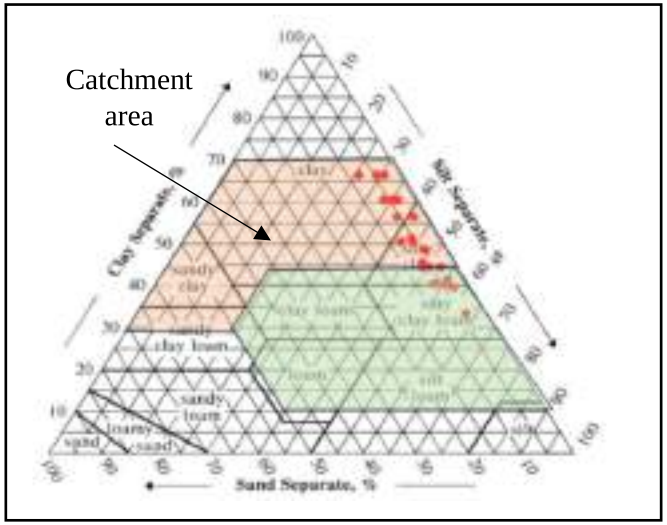


Fig.4.14 Soil texture site4

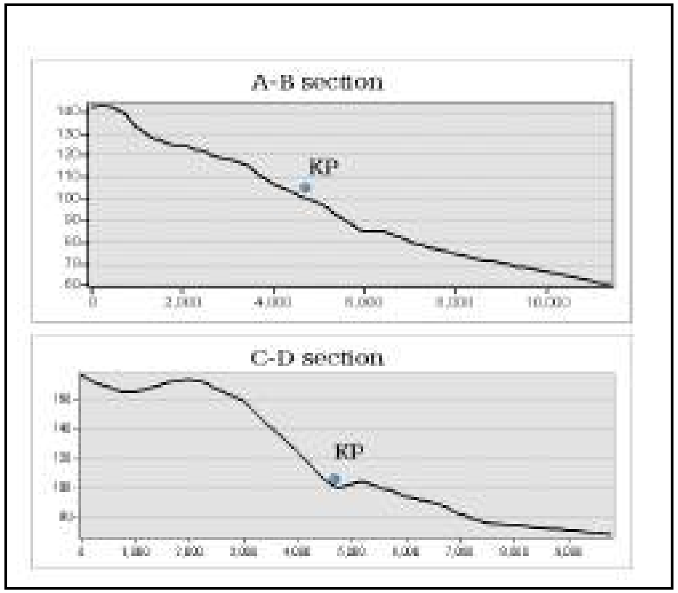


Fig.4.15 Keypoint position

3.7 Calculation of WHS in the area

To classify RWH components in the study area, the area above the keyline is deemed as a catchment area, whereas the area below the keyline is an application area (cropping area). The used annual precipitation in calculations was at normal conditions 200mm and at peak conditions 809mm Table 4.4. Runoff coefficient was determined according to results of soil texture test (Ternary chart).

Table 4.4 The calculations of RWH quantity in the chosen sites

Site1						
Keyline	Rainfall (m)	Area of valley m^2	Rainfall (m^3)	Runoff coefficient	Soil type	Runoff quantity (m^3)
42m	0.2	2019670	403934	0.67	silty clay	270635.78
	0.8	2019670	1615736	0.67		1082543.12
Site2						
24m	0.2	7,370	1474	0.63	sandy clay	928.62
	0.8	7,370	5896	0.63		2523.488
Site3						
100m	0.2	76,200	15240	0.57	silty clay loam	8686.8
	0.8	76,200	60,960	0.57		34747.2
50m	0.2	79000	15800	0.57		9006
	0.8	79000	63200	0.57		36024
Site4						
100m	0.2	124,000	24800	0.67	sandy clay	16616
	0.8	124,000	99200	0.67		66464

3.8 Suggested structures in the study area

Based on the topography and landscape analysis of each WH chosen site, the farm-scale water harvesting structures (details chapter one) has been suggested Figs.4.16, 4.17, 4.18, and 4.19.

- **Site1: Turkey nest tank** / the two sides of embankment make it perfect to site1 to avoid siltation in reservoir Fig. 4.16.

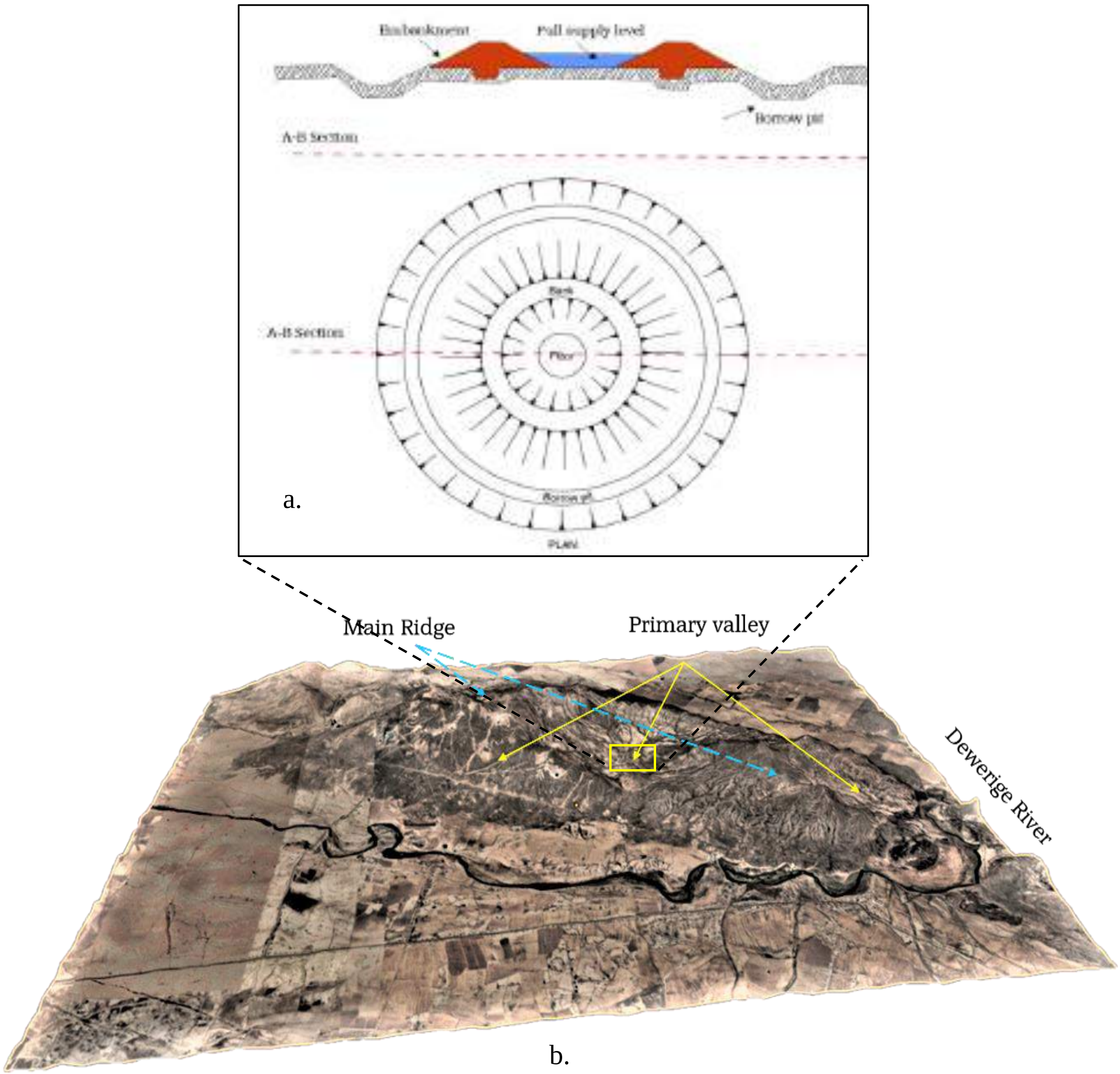
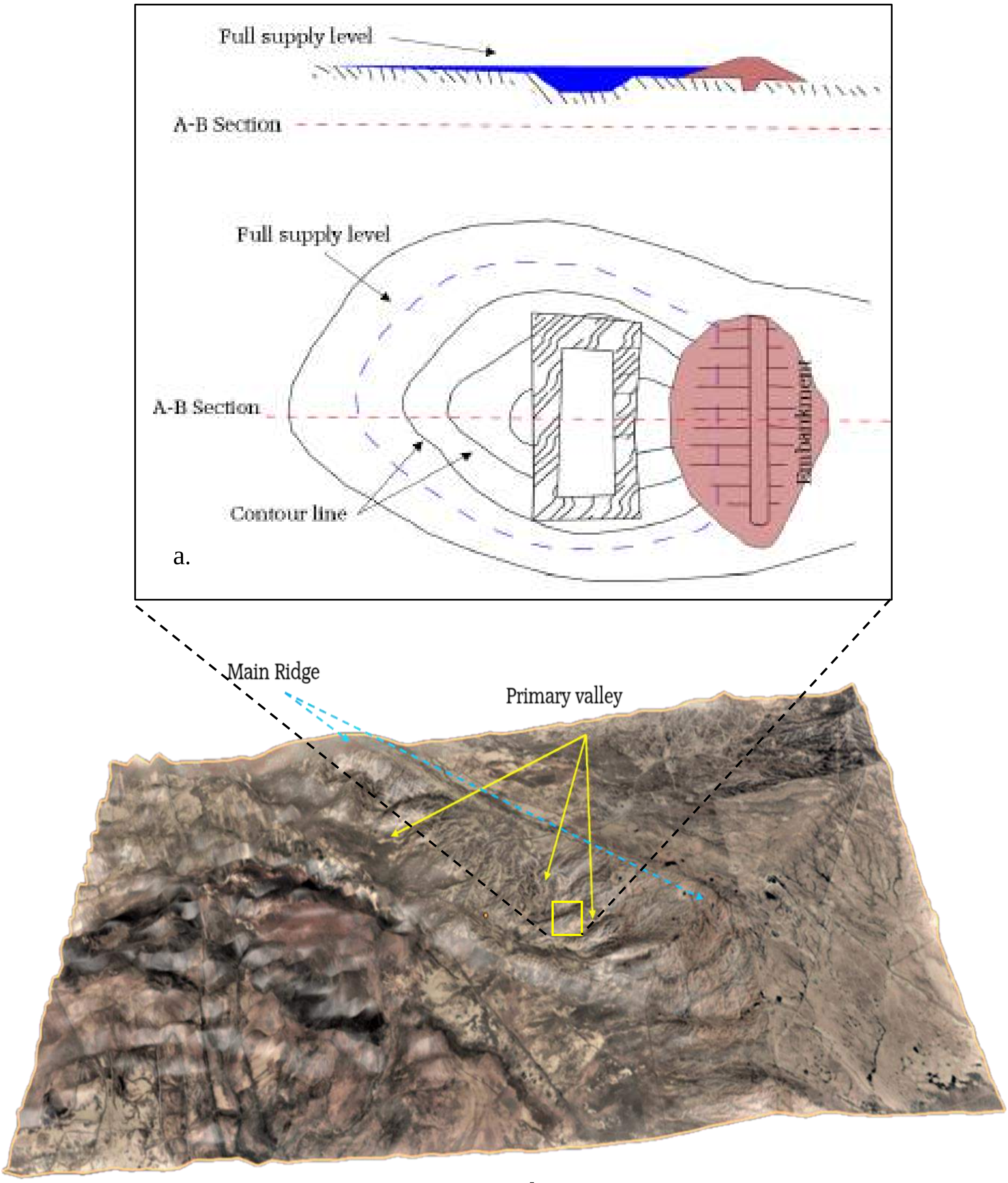


Fig.4.16 a. The suitable farm scale structure
b. Topographic analysis of site1

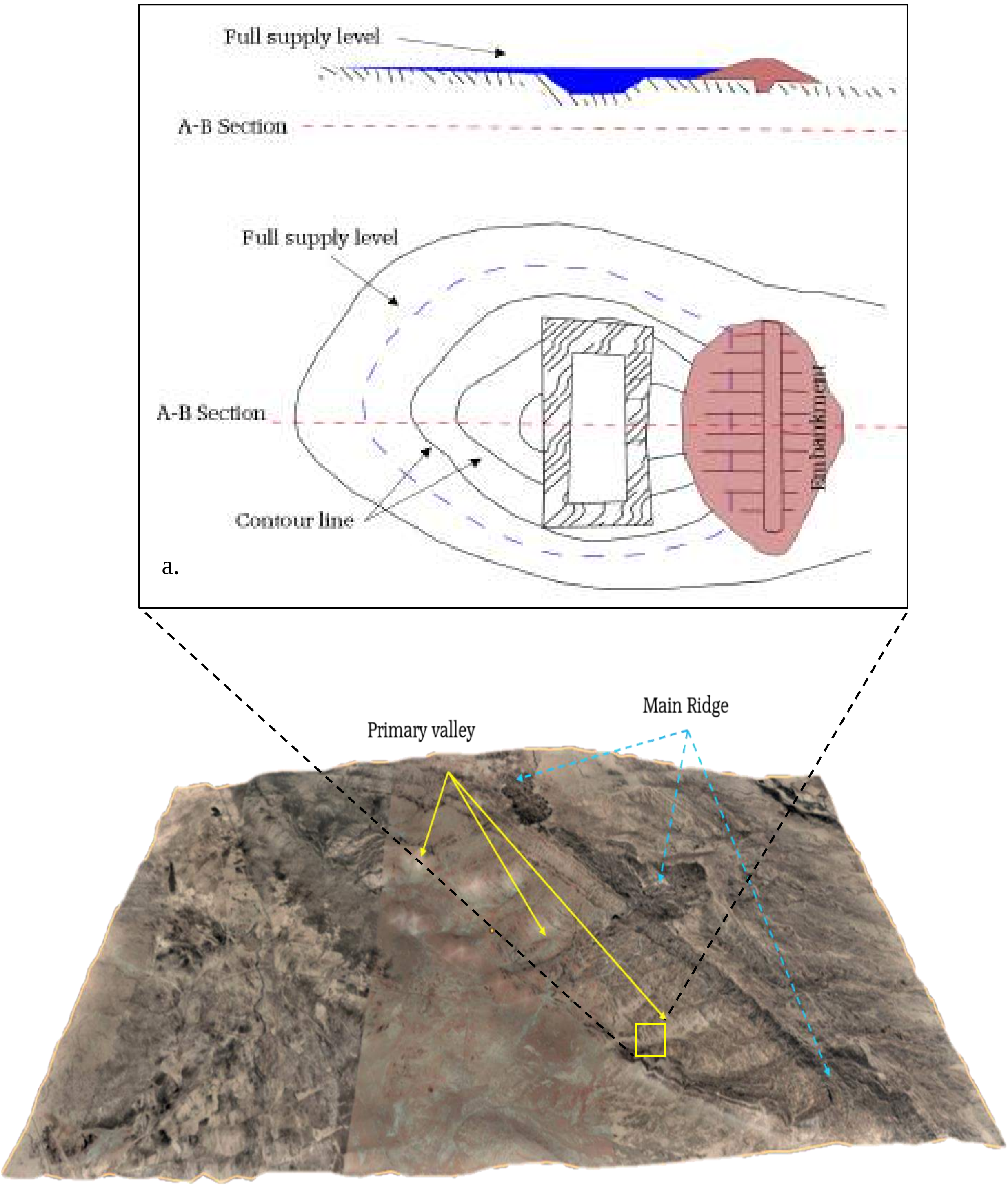
- **Site2 : Gully dam** / is chosen to site3 because the perfect location of these type is narrow valley and represent the biggest economic kind of small dams Fig.4.17.



b.

Fig.4.17 a. The suitable farm scale structure
b. Topographic analysis of site2

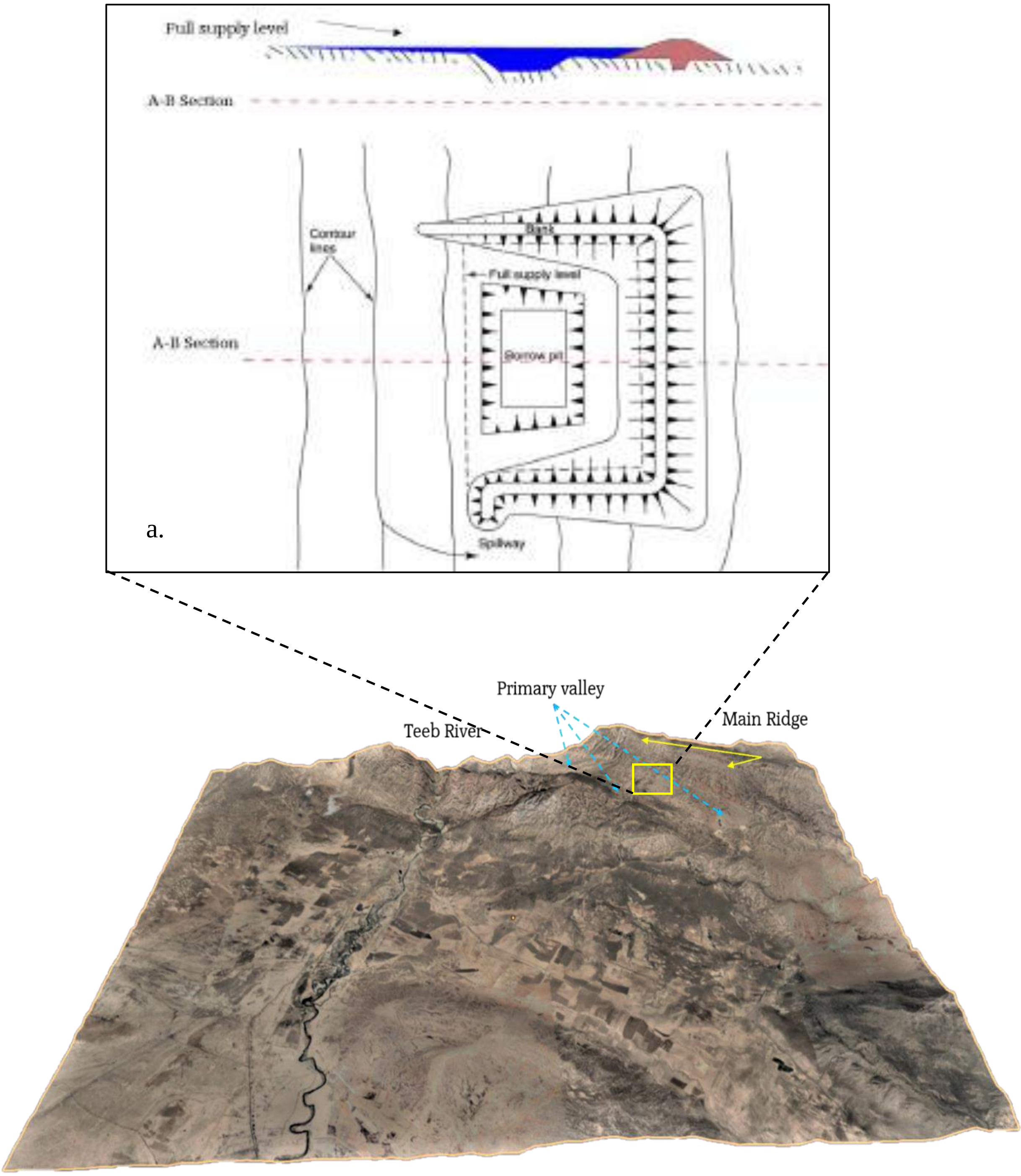
- **Site3 : Gully dam** / is chosen to site3 because the perfect location of these type is narrow valley and represent the biggest economic kind of small dams Fig.4.18.



b.

Fig.4.18 a. The suitable farm scale structure
b. Topographic analysis of site3

- **Site4 : Hillside dam** / is chosen to site4 because its suitable for hillside area at right angle with natural contour for maximum yield. Fig.4.19.



b.

Fig.4.19 a. The suitable farm scale structure
b. Topographic analysis of site2

Chapter Five

Evaluation of previous projects in study area

CHAPTER FIVE
The Assessment of previous water harvesting project in the study area

5.1 Introduction

The procedure used to evaluate the water harvesting projects in the study area can be summarized schematically (Fig. 5.1).

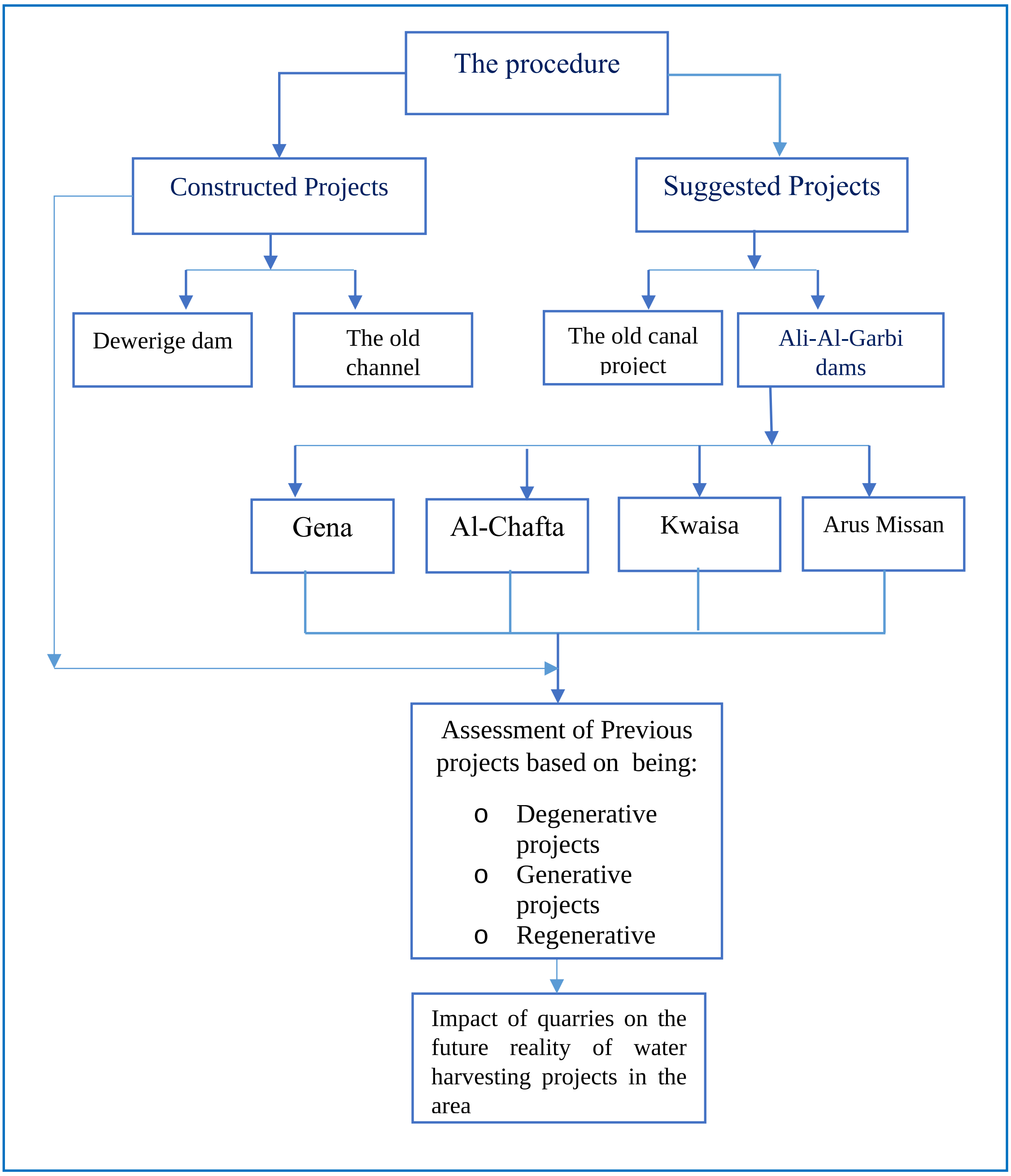


Fig.5.1 The methodology that was adopted in this chapter

5.2 Ethical balance

The basis for initiating the designs of water harvesting projects is these three ethics: earth, people, and future care. It is not limited to this aspect only but applies to all social systems and aspects. These three elements were chosen as the core of ethics for ancient civilizations. For example, water harvesting projects should be designed to serve the economy and the environment of the region without oppressing the farmers or shepherds. The commitment to these ethics guarantees successful projects in the present and safe in the future (Taylor, 2017).

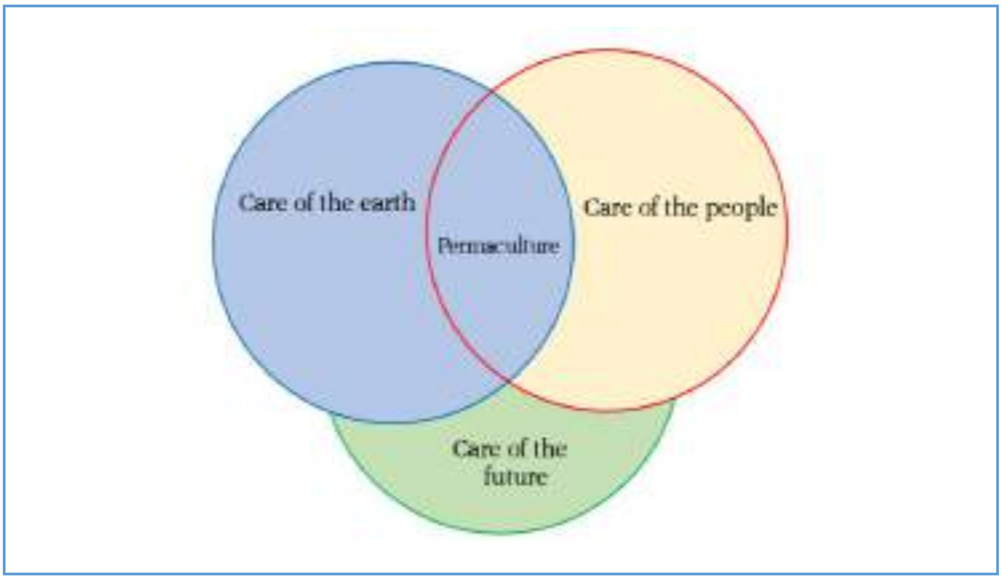


Fig. 5.2 the elements of ethical balance (Taylor, 2017)

5.3 The previous project and structures in the study area

As can be observed, there is no rainwater harvesting projects in the study area. On the contrary, the existing and planned projects are floodwater harvesting projects and can be classified as:

1. **Suggested projects**

Ali Al-Garbi city is situated in the south-eastern of Iraq at 236 km from Baghdad. It lies between longitude 647869.40 E, 3632560.8N and latitude 670174.72 E, 3615244.29 E. To avoid frequently flooding risk in the area, five dam have been proposed (Ministry of water resource, 2021):

The suggested projects in the study area have been shown in Figs.5.3, 5.4, 5.5, and 5.6 with details in Table 5.1:

Table 5.1 General properties of proposed dams in the study area (Ministry of water resource, 2021)

The dams	Properties
Kwaisa	- Located within Ali-Al-Garbi city. - 501m far from Iraqi Iranian border. - Elevations of dam site rang from (90 – 101) m. - Type of soil in the site is silty sand.
Arus Missan	- Located within Ali-Al-Garbi city. - 650 m far from Iraqi Iranian border. - Elevations of dam site rang from (98 – 102) m. - Type of soil in the site is silty sand
Geni	- Located within Ali-Al-Garbi city. - 1293m far from Iraqi Iranian border. - Elevations of dam site rang from (65– 72) m. - Type of soil in the site is silty sand.
Al-Gafta	- Located within Ali-Al-Garbi city. - 1487m far from Iraqi Iranian border. - Elevations of dam site rang from (86– 112) m. - Type of soil in the site is silty sand.
Teeb	- Located within Teeb area. - 1445m far from Iraqi Iranian border. - Elevations of dam site rang from (56 – 69) m. - Type of soil in the site is coarse sand to gravely sand.

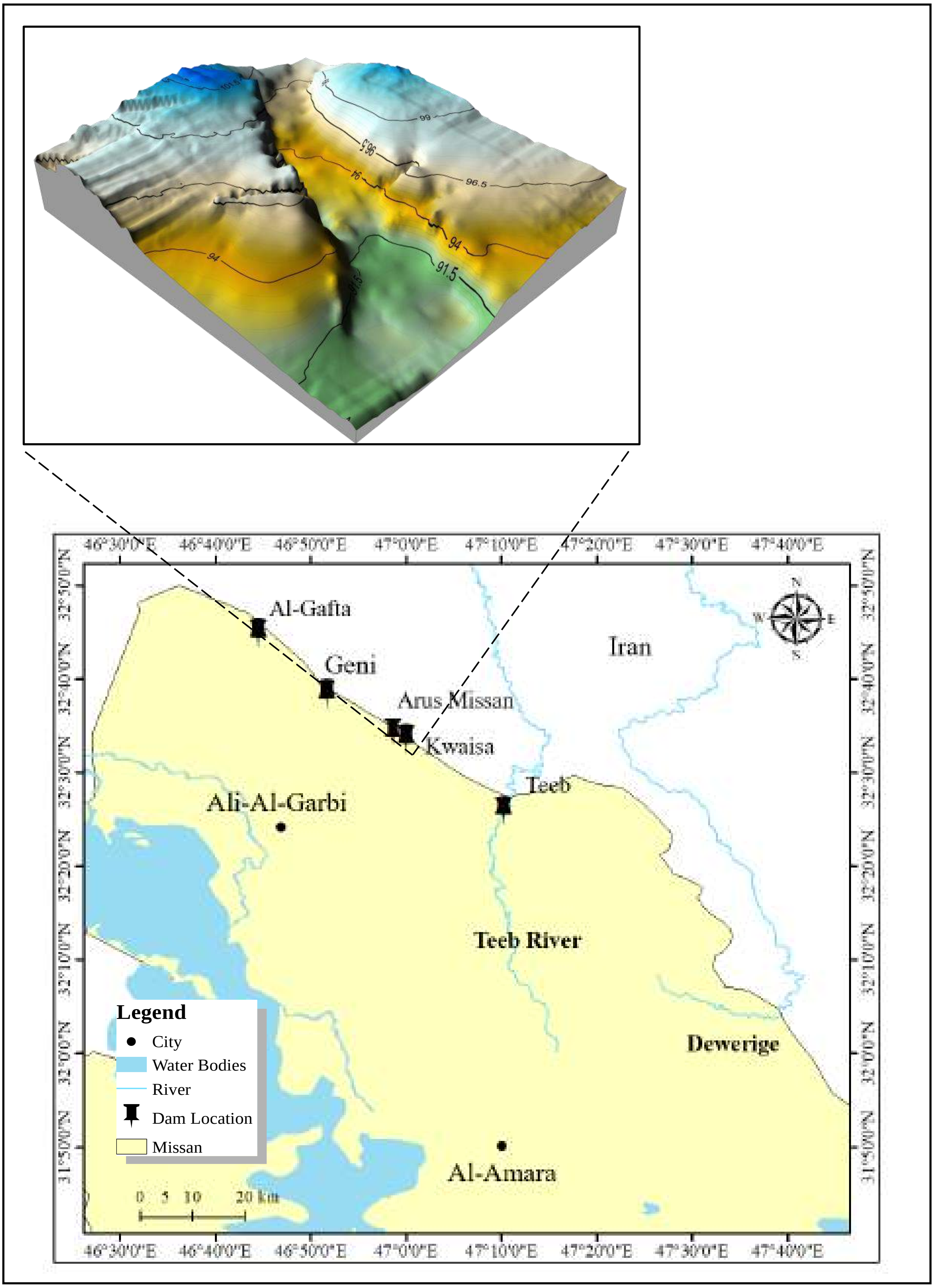


Fig.5.3 Location of Kwisa dam

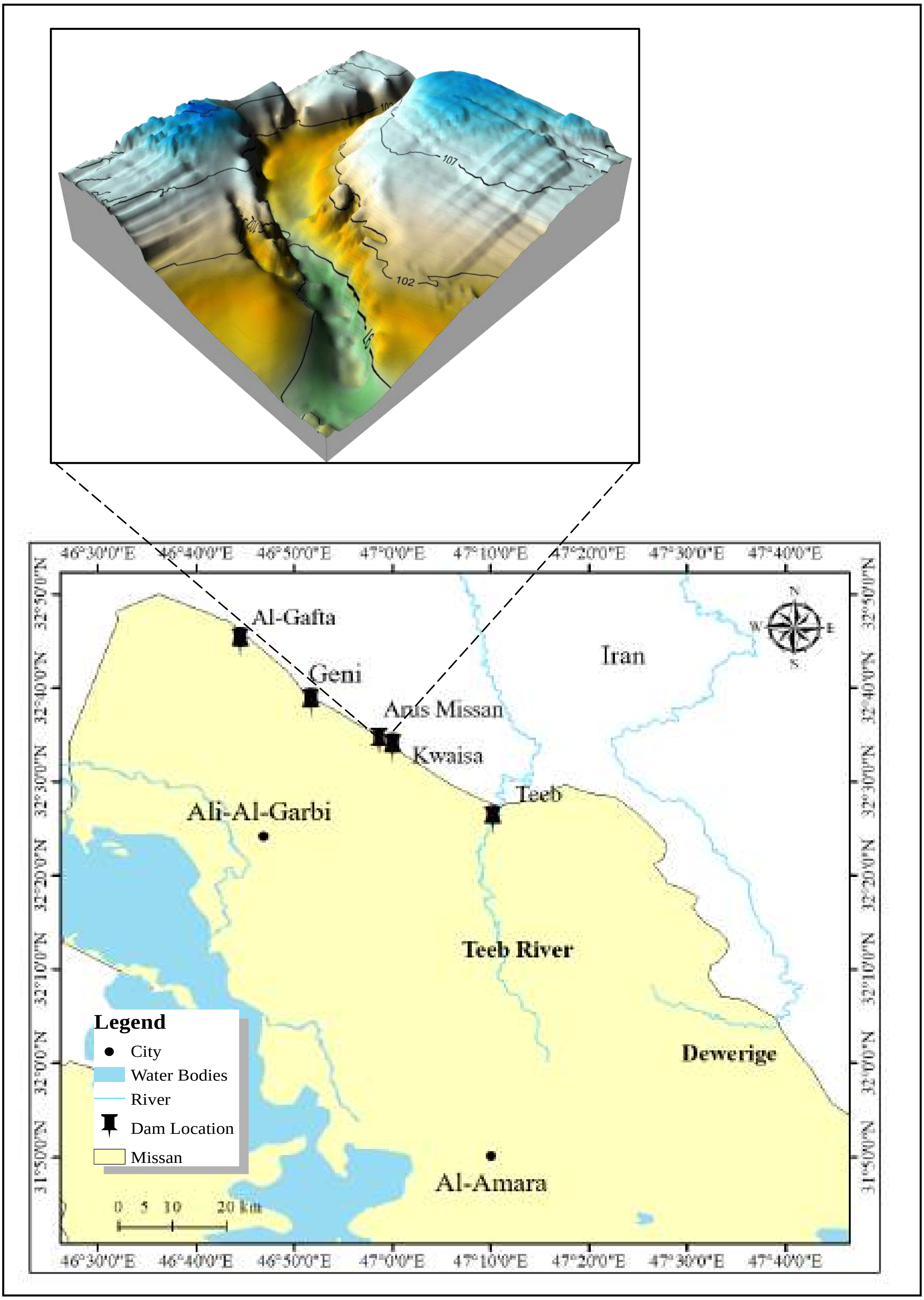


Fig.5.4 Location of Arus Missan dam

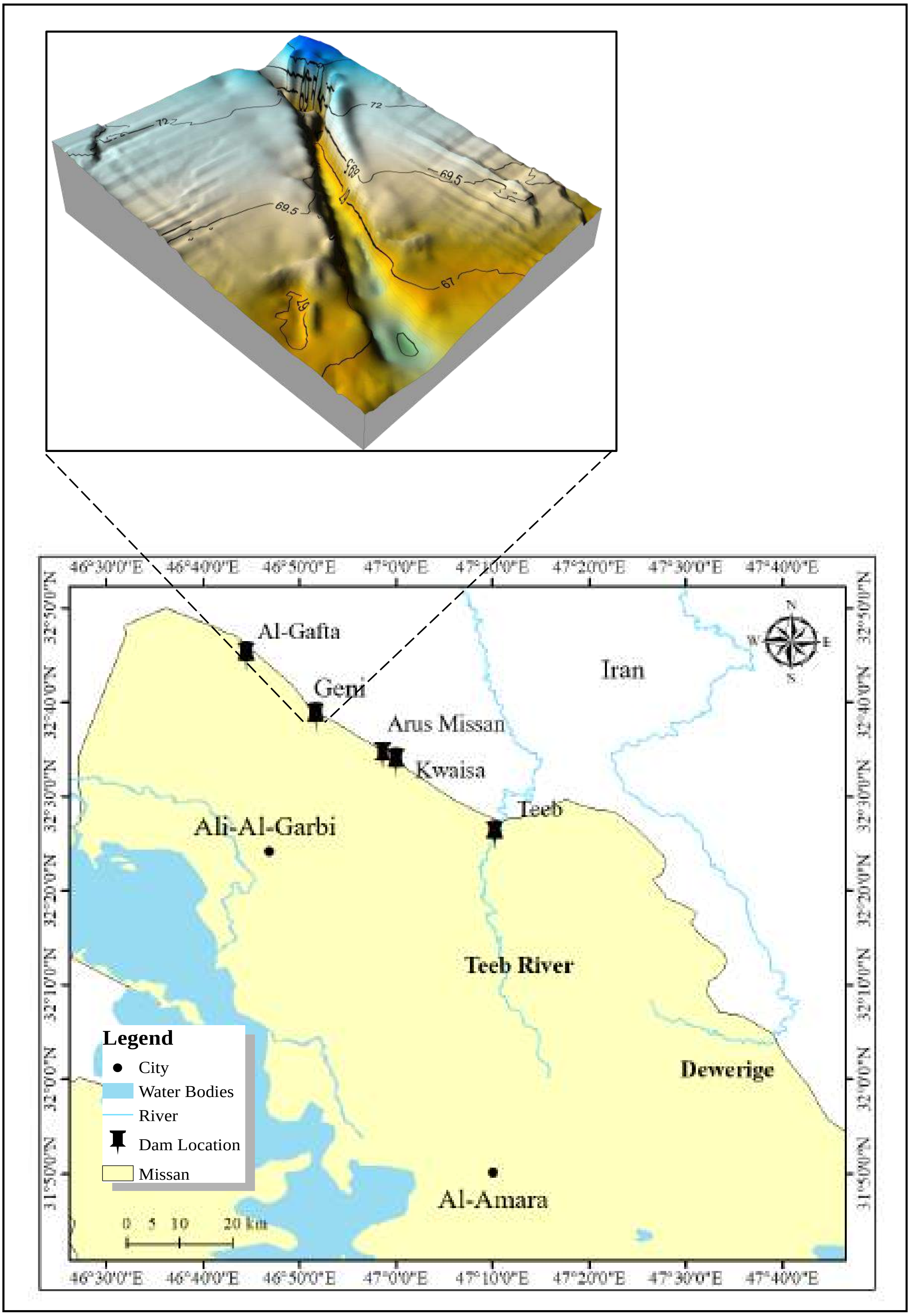


Fig.5.5 Location of Geni dam

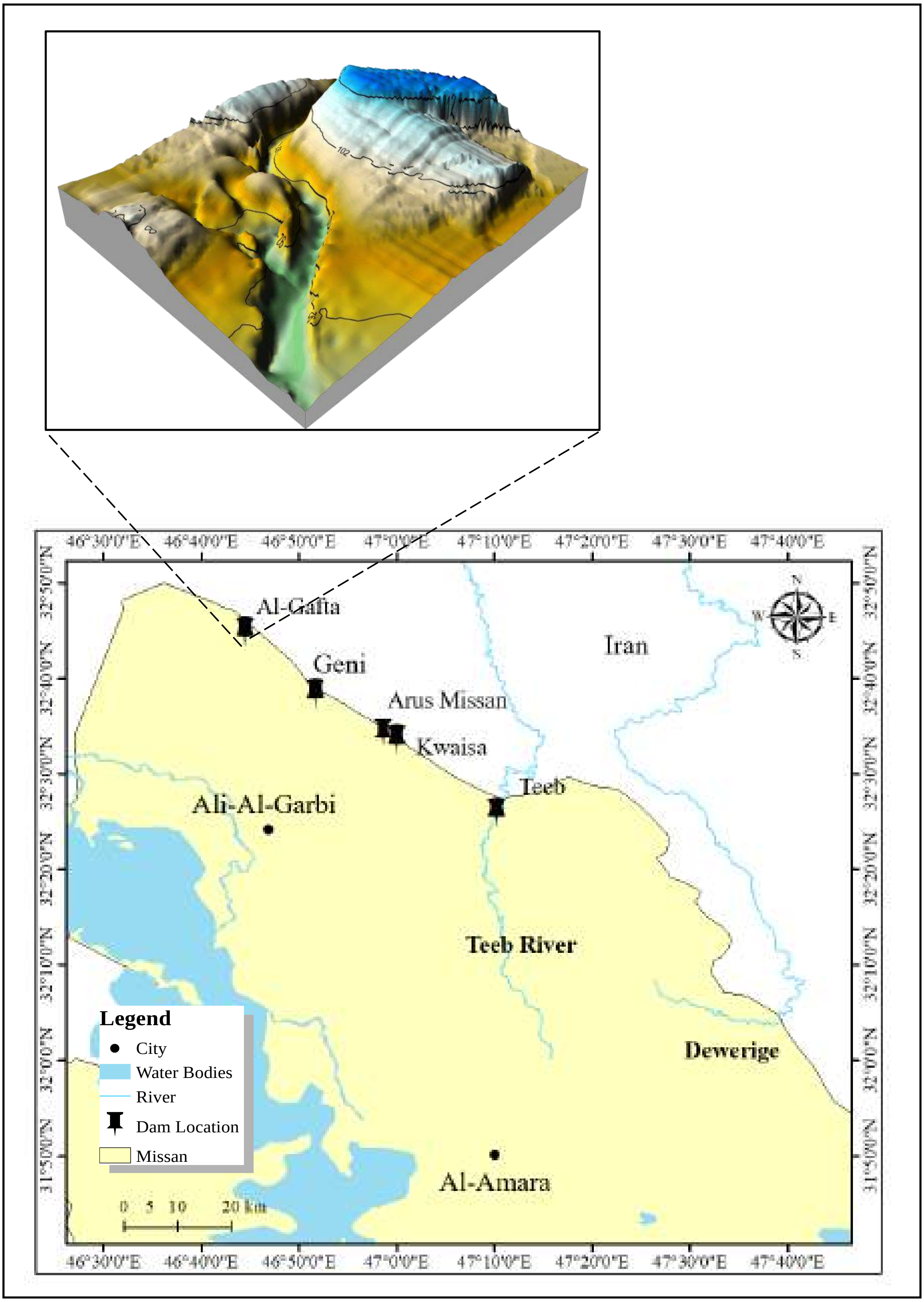


Fig.5.6 Location of Al-Gafta dam

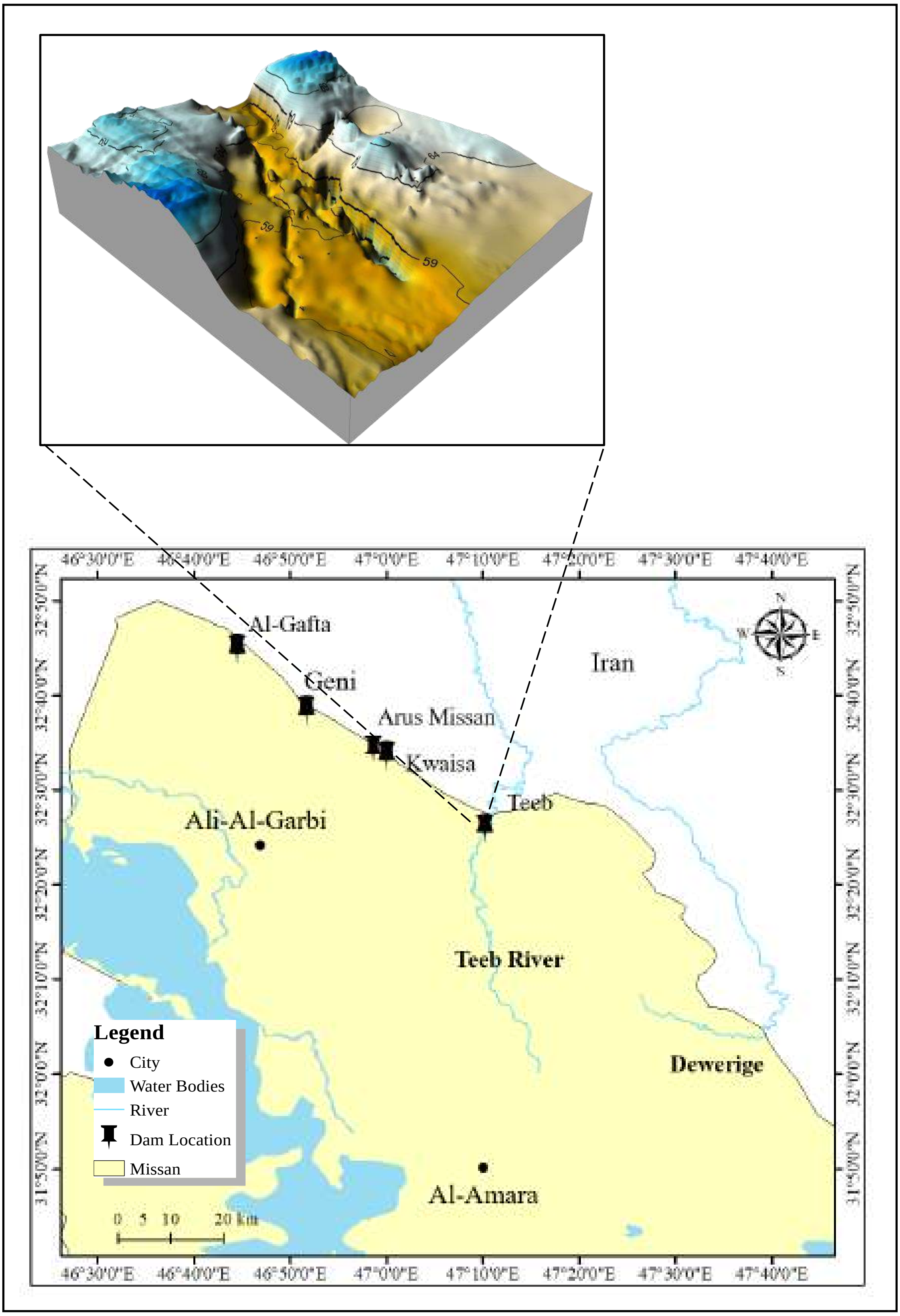


Fig.5.7 Location of Teeb dam

2. Constructed projects:

A. Dewerige dam

Dewerige dam located in southeastern part of Missan province, south of Iraq Fig.5.8.The coordinates of dam axes are (E746239.862, N3551456.909) - (E746256, N3550931). The general engineering specifications of dam explains in Table 5.2 and the main geological problems in Dewerige dam and reservoir illustrated in Figs.5.10, 5.11, 5.12, and 5.13 (Al-Sudani, 2018):

Fig. 5.8 Dewerige dam in Missan

Table: 5.2 General properties of Dewerige dam

Dam type	Gravity small dam (weir)
Dam length	512m
Total storage capacity	1,870,000$m.3$
Operation date	2013 – 2015
Cost	11.370.675.100 IQD
Purpose	Dewerige dam is a multi-purposes dam, used for flooding control, water storage for irrigation projects and recharge groundwater.

The observed geotechnical problem in this dam (Al-Sudani, 2018):

1.Dispersive soils / are soils that have a high content of sodium, which causes soil particles to repel each other and become easily dispersed when wet. This can lead to soil erosion, poor water drainage, and reduced soil fertility. Dispersive soils are common in arid and semi-arid regions (Figs.5.9 and 5.10).

Fig.5.9 Grooves and gullies dispersive soil in left shoulder

Fig. 5.10 Dispersive soil destroyed structure / abridge (Al-Sudani, 2018)

2.Siltation problem / the amount of siltation in the dam reservoir was like the initial calculations of siltation in 2009. Siltation decreasing the economic live time of the dam from 50year to 24 years for one year only, that is very dangerous and threatens completely bury to the reservoir in the next few years Fig.5.11.

Fig. 5.11 Siltation problem in dam reservoir (Al-Sudani, 2018)

3.Sulfate attack / the concrete of dam body exposed to sulfates in down steam side, by the action of high salinity ratio in water of Dewerige dam Figs.5.12 and 5.13.

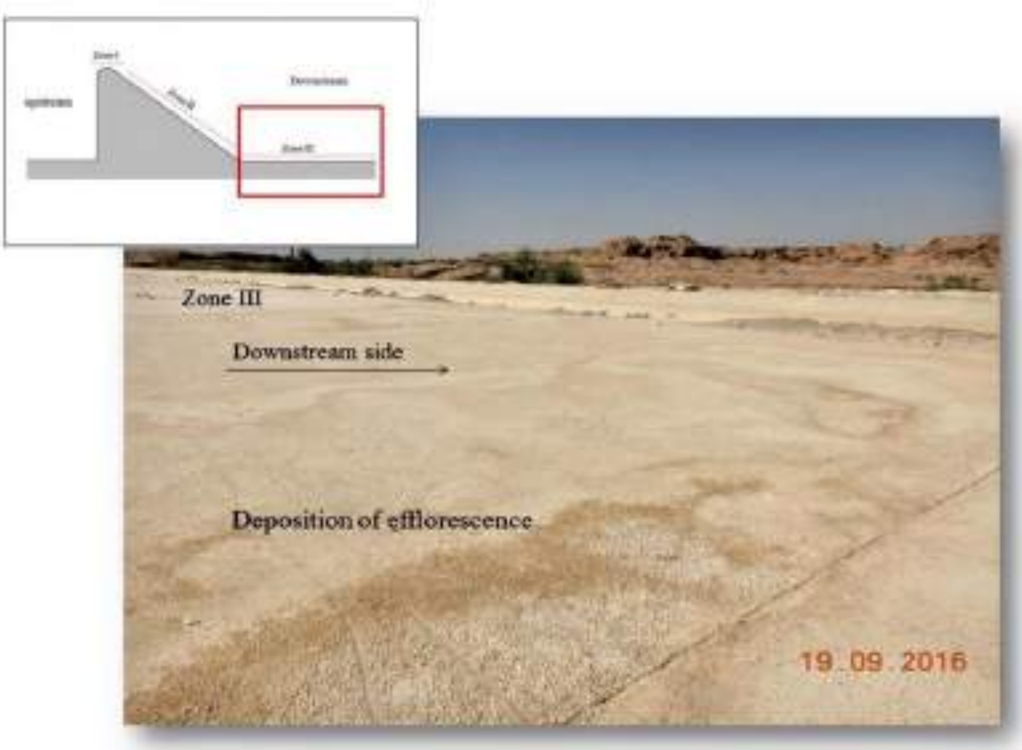


Fig. 5.12 Sulfates attack in dam body (Al-Sudani, 2018)

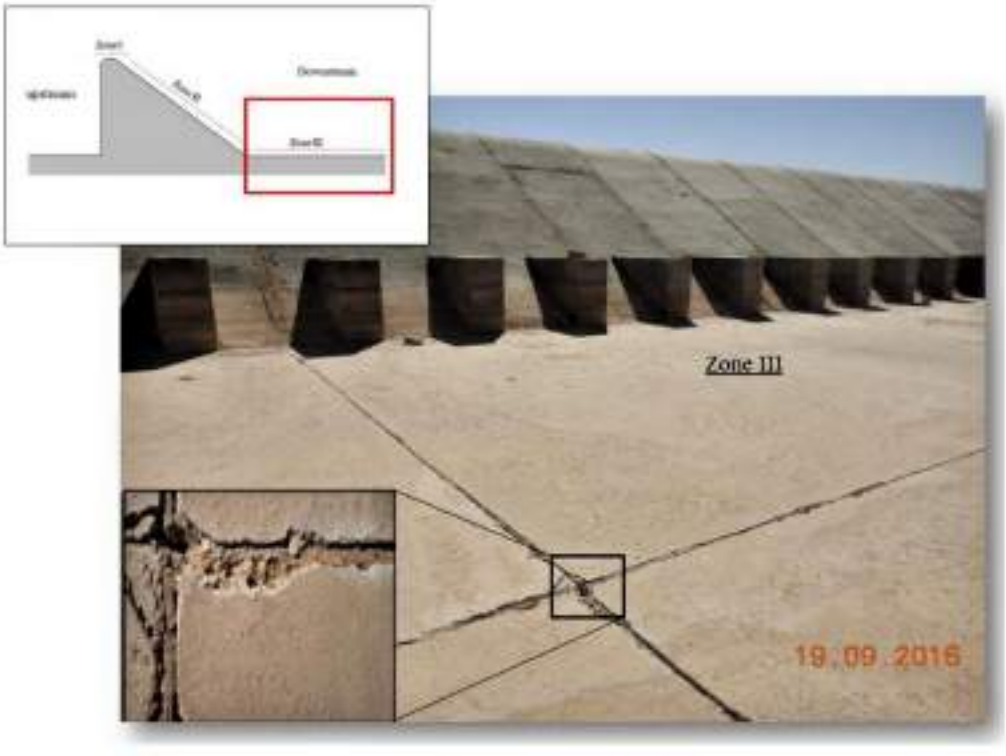


Fig. 5.13 Sulfates attack in dam body (Al-Sudani, 2018)

B. The old canal project

During studying the area through aerial photographs, a group of water channels has been observed extending parallel to the borders, as well as the contour lines of the area. In the fieldwork, more details were discovered about these channels, including they contain parallel paths and silt traps next to Teeb River. These canals extend on both sides of the Teeb River and represent the remnants of an important water harvesting and flood control project. The trees planted in the system can be seen, which indicates that it is a defense line established to combat sand encroachment in the area. The project has been thought it was established during the seventies of the last century with the project of the socialist village of Al-Teeb and it still exists now. The extension of the project was redrawn using Google Earth (Fig.5.14).

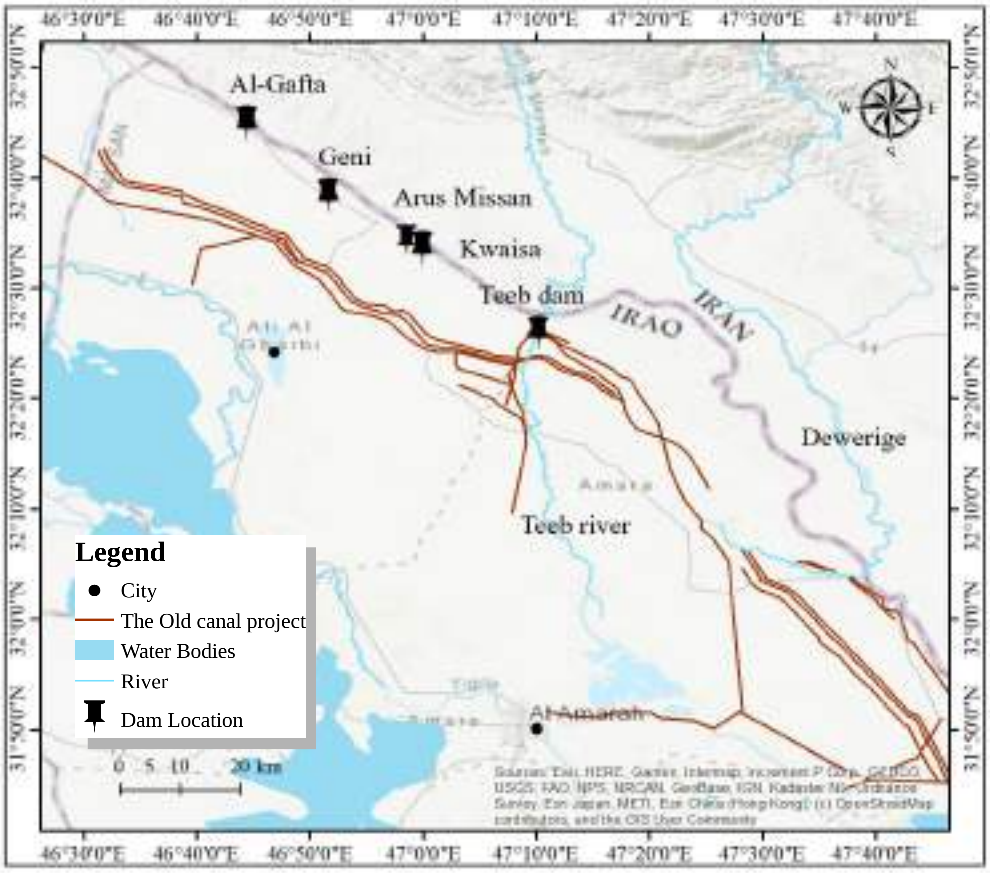


Fig. 5.14 The old project extent in the study area

5.4 Analysis of the old project topography

The length of the canal project is about 300 km along the eastern side of the Missan (Figs.5.15, 5.18, and 5.19). A set of cross-sections were taken to analyze the topographical aspect of the project (Figs.5.16 and 5.17).

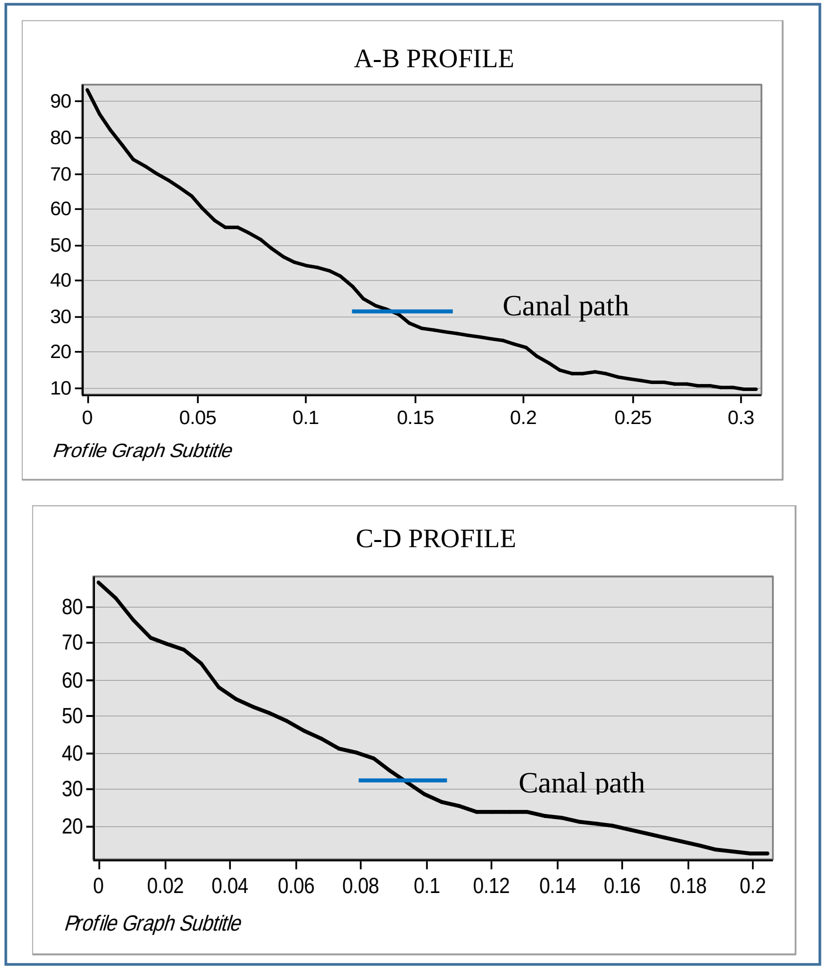


Fig. 5.16 Slope analysis of canal path

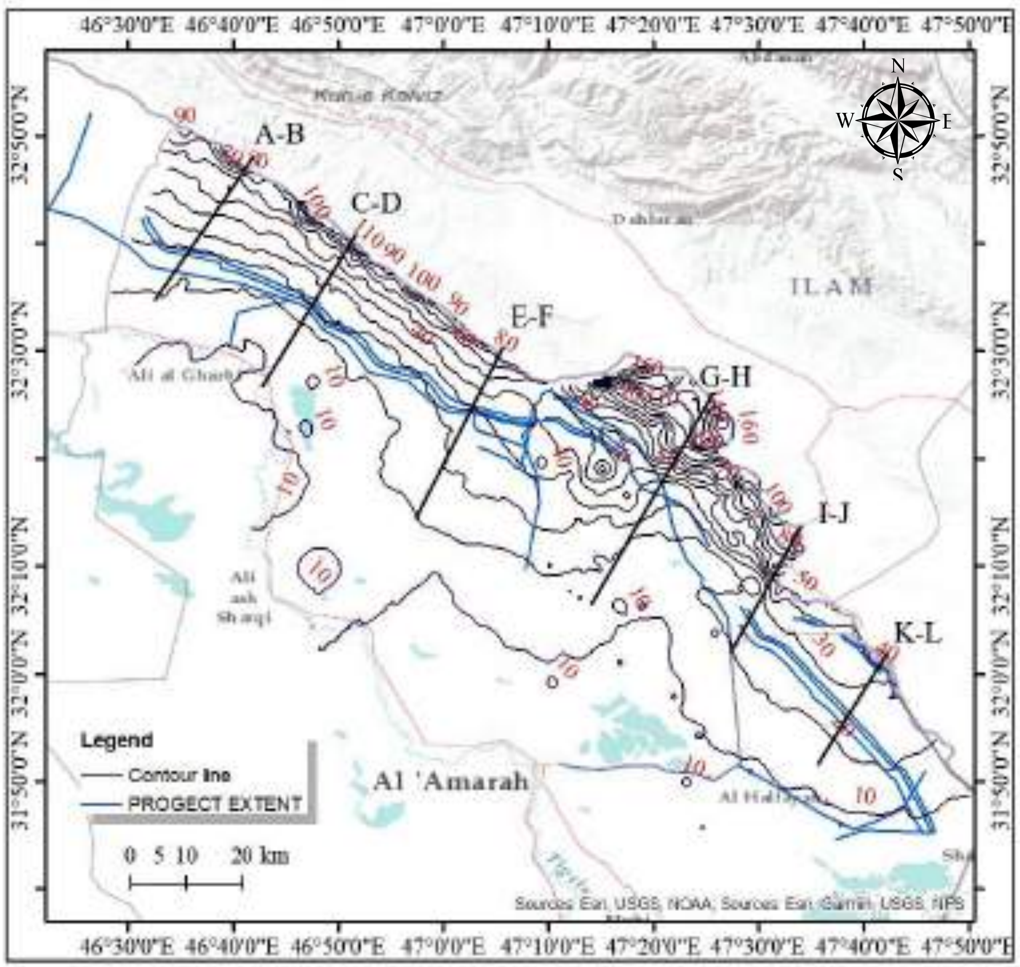


Fig. 5.15 Topography of canal location

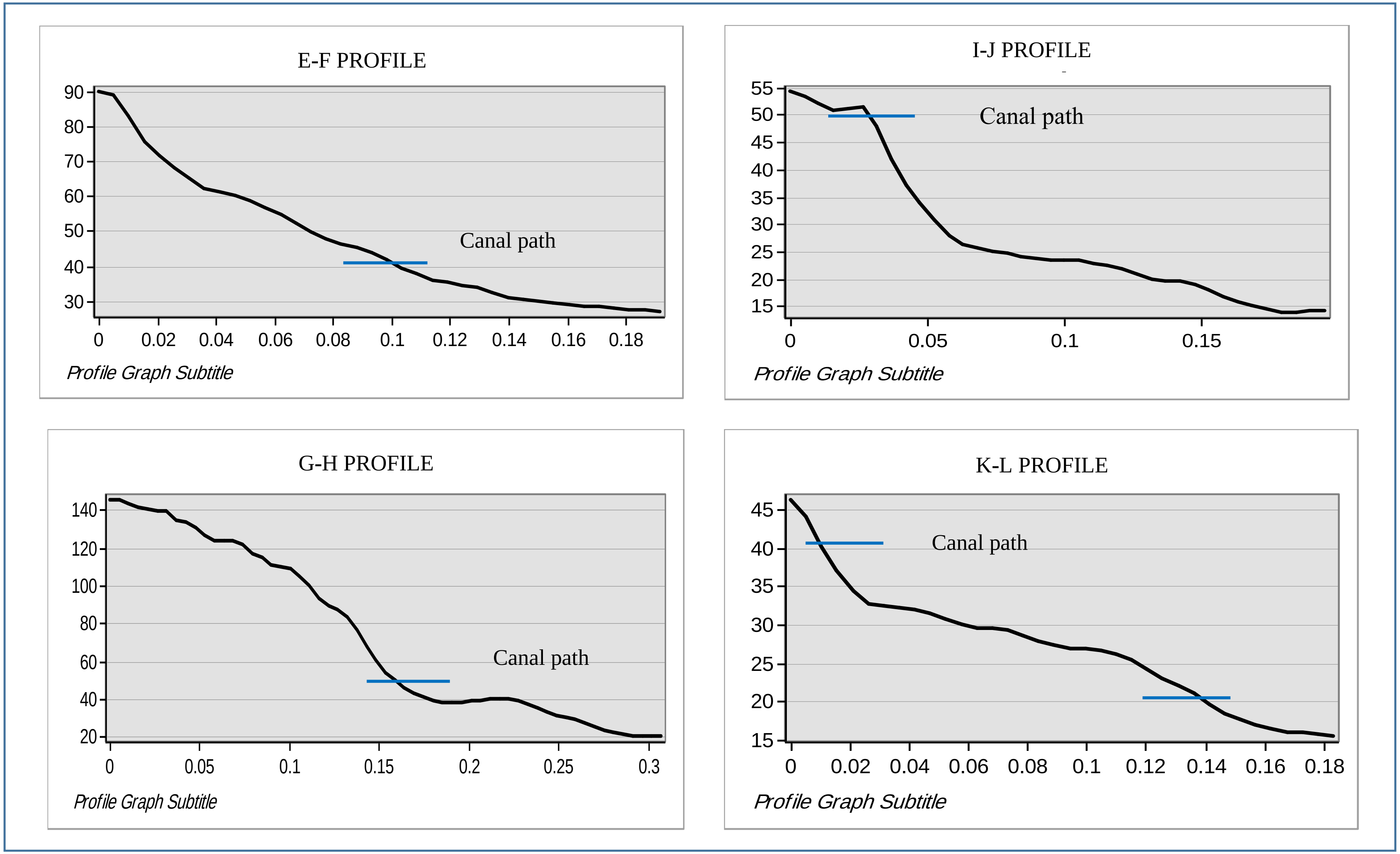


Fig. 5.17 Topographic analysis of canal path

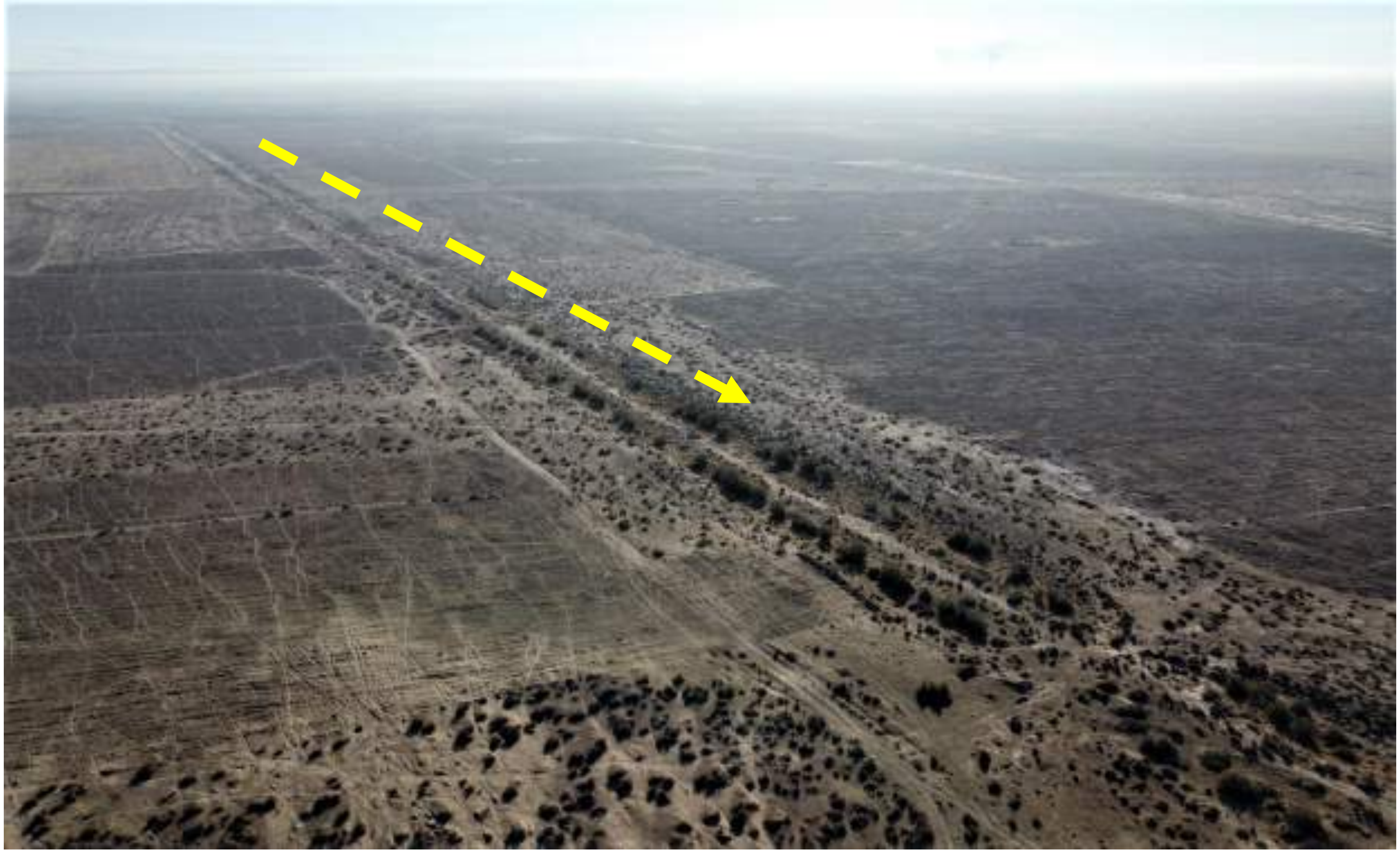


Fig.5.18 The canal extent by photogrammetry

Fig.5.19 The canal extent by photogrammetry

5.5 The Assessment of projects

The engineering projects have been classified into degenerative, generative, and regenerative. According to this principle, the previous projects in the study area have been assessment table 5.3.

Table 5.3 summarized the assessment of projects in study area

Project name	The condition	W.H.S type	Main problems	Ethical balance	Assessment of projects
Dewerige dam	Constructed	RWH & FWH	Siltation. Dispersive soil. Piping. Sulfates attack.	does not fulfill the conditions	Degenerative
Teeb dam	Suggested	RWH & FWH	This site is expected to be exposed to siltation and dispersed soil (that recommended in the final geotechnical report to Teeb dam)	does not fulfill the conditions	Degenerative
Arus Missan dam	Suggested	FWH	This site is expected to be exposed to siltation and erodible soil (Ali-Al-Garbi dams is located in sandy soil next to high slope and flooded area)	does not fulfill the conditions	Degenerative
Kuasa dam	Suggested	FWH	This site is expected to be exposed to siltation and erodible soil (Ali-Al-Garbi dams is located in sandy soil next to high slope and flooded area)	does not fulfill the conditions	Degenerative

AL-Chafta dam	Suggested	FWH	This site is expected to be exposed to siltation and erodible soil (Ali-Al-Garbi dams is located in sandy soil next to high slope and flooded area)	does not fulfill the conditions	Degenerative
Gana dam	Suggested	FWH	This site is expected to be exposed to siltation and erodible soil (Ali-Al-Garbi dams is located in sandy soil next to high slope and flooded area)	does not fulfill the conditions	Degenerative
The old project	Constructed	RWH & FWH	Its spate irrigation project, provided by silt trap to avoid siltation problem. The canal is extending along the eastern part of Missan about 300 km length.	fulfill the conditions	Regenerative

5.6 Impact of quarries on water harvesting areas

5.6.1 Definition of quarry

A quarry is a place where large amounts of stone, rock, sand, gravel, or other minerals are extracted from the earth. These materials are typically used in construction or landscaping projects. Quarries are also known by other names around the world: 'surface mine', ‘pit’, 'open pit', or 'opencast mine' (Fig.5.20). Within the UK, the largest quantity of mineral extracted by quarrying is used for construction and known as "aggregates" (Brown, *et al*., 2011).

A.

B.

Fig.5.20 The two main type of quarries, A. Subsurface quarry or mine Surface mine or open pit.

5.6.2 Characteristic of a good quarry

The primary objectives of good quarry design are the safe, efficient, and profitable extraction of the maximum usable material from the available land whilst causing the minimum environmental disturbance and resulting in beneficial final restoration and land use (Chesnutt, 1999). The essential balance and interaction between these objectives are illustrated in Fig.5.21.

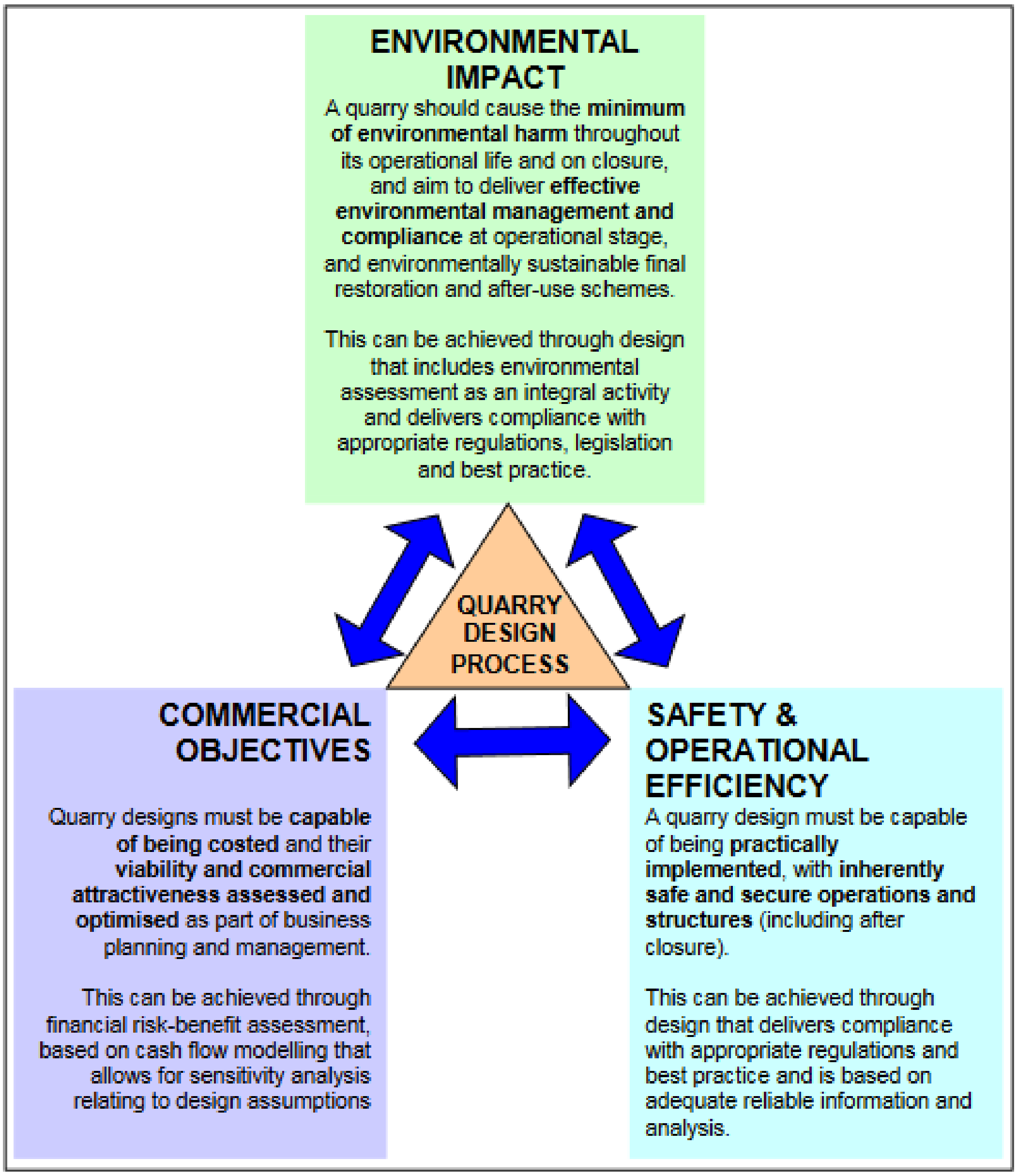


Fig. 5.21 The process of quarry design (Cohen, 2014)

5.6.3 The quarries in the study area

The study area has many sand and gravel quarries (Fig.5.22). It is considered important economically as well as scientifically, as it is characterized by stratigraphic sequences containing types of rocks and minerals. We have wide rock detectors, the height of which reaches 20 m in some areas.

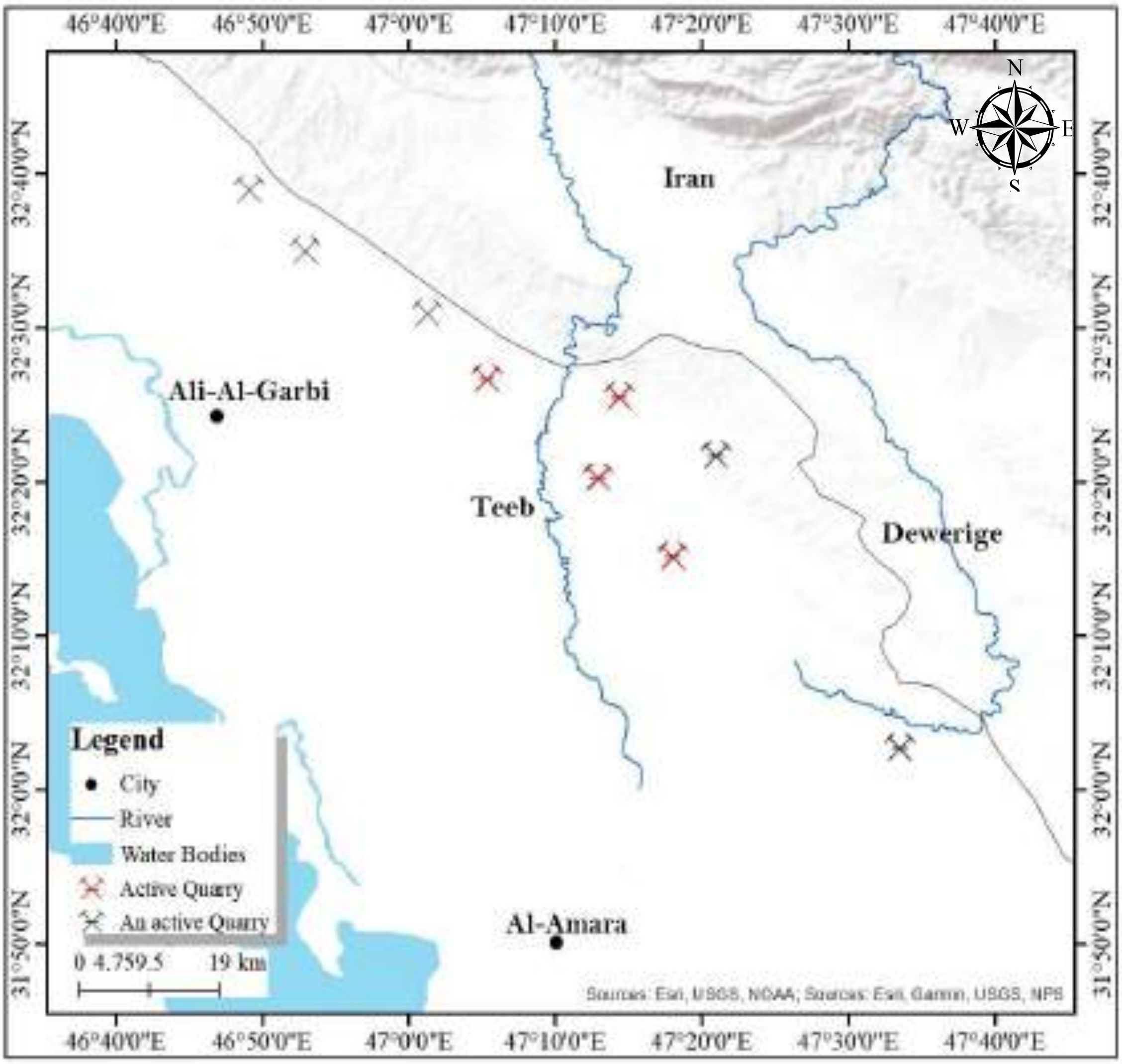


Fig. 5.22 Distribution of quarries in study area

5.7 Impact of quarries on water harvesting areas (topography)

During the final stage of field work and drone photogrammetry, the impact of negative management of quarries can be observed which changing the area topography, which directly affects the selection and distribution of water harvesting areas (Figs.5.23 and 5.24).

Fig. 5.23 Quarries impact on distribution of water harvesting area (Site4)

Fig. 5.24 Quarries impact on distribution of water harvesting area

5.8 Impact of quarries on extent of canal (the old project)

During the fieldwork and aerial photography of the canal project, the impact of quarries' activities and their damages on the project were observed (Fig.5.25 and 5.26).

Fig. 5.25 Influence of quarries activity on the canal project

Fig. 5.26 Influence of quarries activity on the canal project

Chapter Six

Conclusions and Recommendations

Conclusions and Recommendations

6.1 Conclusions

1. **GIS Techniques and Remote Sensing Results:**

I. The study area is suitable for the establishment of a water harvesting system, based on the results of the topographical analysis and soil test.

II. According to Analytical Hierarchy (AHP), the chosen sites were classified into five subclasses in terms of water harvesting suitability: very low, low, medium, high, and very high.

III. The high efficiency of the photogrammetry through:

   a. Obtaining high-quality aerial photographs.
   b. Controlling on resolution and scale based on amount of flight height.
   c. Easy to process images in a short time.
   d. The cost of the equipment is less compared to the cost of very high-resolution images.

2. **Questionnaire results:**

I. All questionnaire samples are supportive for water harvesting project and considered these types of projects as important and crucial to save the governorate.

II. Research specialist sample was mentioned to amount of losses in precipitation in the study area, had been done by evaporation and infiltration in saline or polluted soil.

III. Development of agriculture, especially in arid and remote areas, where a stable source of water is not available.

IV. Protection and recovery of livestock by providing enough potable water, herbs, and weeds.

V. Activating the investment and developing water spaces for their role in improving the climate and tourism reality for the area.

3. According to the classification of flooding hazard, the suggested projects have been in high erodible soil within high flooding risk.
4. The classification method of landscapes by the Keyline strategy represents a major leap in the development of sustainable agriculture permaculture.

5. Assessment of projects and structure in study area

I. Based on soil texture classification of water harvesting components, the soil type in the four sites is suitable for catchment area that agree with the location of the old channel.

II. The old canal project includes optimal investment of rainwater and flood water.

III. Selection cropping area (application area) in a way that guarantees its success and does not creep sand dunes and limited desertification.

IV. The selected sites for suggested project in study area (Arus Missan, Kuissa, Al-Gafta, Gena) area characterized by:

a. Sandy soil sites, at high slope area.
b. The conditions of those sites predict problems and obstacles that previously occurred in Dewerige Dam.

V. Instead of creating the same threatened sites, the old canal project must be re-activated.

VI. The presence of old projects in the study area that can be used and maintained to face the water crisis in the area.

6.2 Recommendations

1. Preparing extensive studies on water harvesting systems because it is the perfect solution to the problem of the water crisis and preventing the risk of flooding in the future.
2. Developing the surveying using photogrammetry in the fields of geology in the future, and we recommend establishing a separate specialty in this field, as it provides services for all disciplines of geology.
3. The necessity of studying the old canal project in detail and trying to find its documentation as soon as, possible to solve the problem of desertification and drought in Maysan.
4. Studying the impact of quarries on the watershed areas, as they cause a change in the path of rivers and drainage valleys in the area.
5. Establishing a research center for water harvesting consisting of specialized researchers and members of specialized departments linked to an executive authority.
6. Maintenance and investment of the old canal project because it achieves the ethical balance that related to water harvesting projects.
7. recommendations and suggestions of specialists through the questionnaire are the following:
    a. In view of the water scarcity that the country faces, it is necessary to think seriously about all ways to invest in water harvesting projects.
    b. That the investment in these projects be approved, and the investor establishes, operates, and maintains these projects to avoid the problems of state funding for projects that are not optimally exploited and end up with extinction.

c. The maintenance of the old canal project, which extends along the eastern region of Maysan, will encourage the construction of modern villages, research centers, and natural reserves.

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المستخلص

أدت التغيرات المناخية مؤخرا الى الحاجة الى انشاء أنظمة و طرق غير تقليدية لخزن و إدارة المياه للمشاريع الزراعية وخصوصا المشاريع بمقياس صغير (الحقول و المزارع بمساحة عدة هكتارات). و في دراستنا الحالية تم التركيز على منطقة شرق ميسان لأهميتها الزراعية والاقتصادية و البيئية للمحافظة. درست الخارطة الموضوعية المعدة من قبل مديرية زراعة ميسان لتوزيع المنطق الزراعية في المنطقة.

كمرحلة أولى استخدمت الصور الفضائية الملتقطة من قبل القمر الصناعي (Landsat) لسنة 2020 بعد ان تمت معالجتها بطريقة (Image Enhancements) باستخدام برنامج (Erdas). حللت النتائج احصائيا باستخدام طريقة (Analytical hierarchy processes). في نهاية المرحلة تبين إمكانية انشاء نوعين من أنظمة حصاد المياه في المنطقة الأول هو نظام حصاد مياه الفيضان ويتركز في اودية الأنهار و السيول و الثاني حصاد مياه الامطار ويكون في مناطق حافات التلال. ولدى مطابقة النتائج مع خارطة توزيع الحقول الزراعية في المنطقة تبين ان النوعين يمكن ان يستخدمان لحل مشكلة ازمة المياه في منطقة الدراسة.

المرحلة الثانية اعتمدت على تحليل ودراسة جيومورفولوجية المشهد الأرضي (Landscape) لغرض تحليل خطوط مسار المياه وسرعتها باتجاه الأراضي الزراعية، اعتمدت الطريقة على تحليل الخطوط الكنتورية لتصنيف المنطقة الى حافات رئيسية و أولية ووديان أولية وتعيين خطوط تقسيم المياه بدقة. كما تم تحليل انحدار كل منطقة و تحليل نماذج التربة فيها لمعرفة مناطق التعرية و الترسيب و بالتالي تحديد منطقة الكي بوينت ورسم الكي لاين لاختيار افضل موقع لإنشاء موقع تجميع المياه او حفر بركة السقي.

في المرحلة الثالثة درست المشاريع المقامة فعليا او المخطط اقامتها في منطقة الدراسة. استخدمت طريقة الميزان الأخلاقي البيئي في تحديد نقاط القوة و الضعف لكل منها. اهم المشاريع المخطط اقامتها سد الطيب و الجفته و خويسه و عروس ميسان و جني. اما المشاريع العاملة فعلا فهي سد الدويريج ومشروع قنوات شرق ميسان. في هذه المرحلة تم استخدام الصور الملتقطة من الطائرات المسيرة الصغيرة بعد ان تم اجراء بعض الحسابات الفوتوغرامترية للحصول على نتائج ذات دقة عالية.

أظهرت الدراسة أهمية تحليل العناصر الطوبغرافية و مواصفات التربة و اتجاه الرياح و زاوية السقوط الشمسي لانشاء مشاريع حصاد مياه فعاله قادرة على الصمود ذاتيا دون الحاجة اللى أي نوع من أنواع الصيانة مستقبلا.

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رسالة مقدمة الى
كلية العلوم / جامعة البصرة
كجزء من متطلبات نيل درجة دكتوراه فلسفة
في (التحسس النائي و الجيولوجيا الهندسية)

من قبل
زهراء رسول فاخر
ماجستير جيولوجيا هندسية 2018

بأشــــــــراف
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