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ISTANBUL GEDİK UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

SITE SUITABILITY IN WATER HARVESTING MANAGEMENT USING REMOTE SENSING DATA AND GIS TECHNIQUES: A CASE STUDY OF SULAIMANIYAH PROVINCE, IRAQ

MASTER'S THESIS

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Engineering Management Department

Engineering Management Master in English Program

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LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ MÜDÜRLÜĞÜ

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DEDICATION

This study is wholeheartedly dedicated to my lovely parents, who have been our source of inspiration and gave us strength when we thought of giving up, who continually provide their moral, spiritual, emotional, and financial support. To my brothers, sisters who were my support every time. As well as the two-dearest people in my life, the lovely wife who encourage and support me and made my life easier with my dear, lovely and happy daughter (Shahang). To my best friend, and relative who shared their words of advice and encouragement to finish this study. And lastly, we dedicated this research to the Almighty God, thank you for the guidance, strength, power of the mind, protection and skills and for giving us a healthy life.

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FORWORD

This Project Reports attached entitled “Site Suitability in Water Harvesting Management Using Remote Sensing Data and Gis Techniques: A Case Study of Sulaimaniyah Province, Iraq’’

Submitted by Shaho Khorsheeed Noori Noori in partial fulfilment of the requirement for the degree of Master of engineering management hereby accepted.

January 2021 Shaho Khorsheed NOORI

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ABBREVIATIONS

GIS	: Geographic Information System
RWH	: Rain Water Harvesting
WH	: Water Harvesting
SCS-CN	: Soil Conservation Service - Curve Number
NRCS	: National Resources Conservation Service
USDA	: United State Department of Agriculture
LULC	: Land Use Land Cover
MCDA	: Multı Criteria Decision Analysis
AHP	: Analytical Hierarchy Process
MCDM	: Multı Criteria Decision Making
WLC	: Weighted Linear Combination
TM	: Thornthwaite and Mather
MCA	: Multı Criteria Assessment
MCE	: Multı Criteria Evaluation
GWMP	: Geographic Water Management Potentials
WMS	: Watershed Modeling System
MCM	: Million Cubic Meters
BCM	: Billion Cubic Meters
SSD	: Sulaimaniyah Statistical Directorate
SFDD	: Sulaimaniyah Food Distribution Directorate
IDPs	: Internal Displaced Peoples
DEM	: Digital Elevation Models
DD	: Drainage Density

SYMBOLS

DD **:** Drainage Density
L : Stream Length
A : Basin Area
Q : Runoff depth (mm)
P : Rainfall (mm)
S : Potential maximum retention after runoff starts (mm)
Ia : Initial abstraction (mm) its standard is taken from TR55
CN : Curve number
CR : Compatibility ratio
CI : Consistency Index
RI : Random Index

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SITE SUITABILITY IN WATER HARVESTING MANAGEMENT USING REMOTE SENSING DATA AND GIS TECHNIQUES: A CASE STUDY OF SULAIMANIYAH ANYA PROVINCE, IRAQ

ABSTRACT

The human-induced water use changes are likely to decrease the supply of water, and climate change effects have impartially led to long-term drought, water shortages and some casual flood incidents have impacted the northern region of Iraq over the past few decades greatly. The first has had a negative effect and appears to be a concern across the large variety of regions in the area. However, the latter often occurs in winter due to heavy snow and lack of sufficient dams and artificial drainage. Both issues in this area cause socio-economic harm. To solve this dilemma, water resources management has become important. Also, groundwater is a valuable natural supply, particularly for the arid and semi- arid areas, for consumption, domestic, animal use and irrigation.

The objective of the study is to define appropriate sites for rainwater harvesting in the governorate of Sulaimaniyah, Iraqi Kurdistan region. Using geographic information system (GIS) techniques and a multi-criteria decision making (MCDM). From here, we clarify some of the key points of this approach of selecting suitable areas for water harvesting through remote sensing (RS) and GIS using global maps and rainfall data. Each factor assigned their weight depending on its effect, such as runoff, slope, soil composition, vegetation and bare land then the best places to harvest water will be selected.

Water always store in the reservoirs or in the built dams over the land and it has a lot of benefits, changing the idea to choose this method for harvesting water beneath the earth because it doesn't require a lot of space and it will decrease the evaporation and climate changes losses. As well, the failure ratio is very little or non-existent during the earthquakes or natural disasters and it will not effect on the adjacent area and is not threatened during the battle.

The geographical information system is used to make multi-criteria assessments to assist decision-makers in finding appropriate areas for rainwater storage. For multi-criteria assessment, attention was given to slope, soil texture, rainfall data (2009-2019), drainage density and land use/ land cover.

In our study, only the contributing factors have been used as a subject in the model. Five factors were selected upon on literature review, to identify the best place for water harvesting. The number and weight of each factor in the sample depends on the number and percentage of each factor used in the papers examined. These considerations were prioritized:

The potential runoff of the soil is calculated using the soil conservation service curve number SCS-CN equation. Because the importance of one layer over another layer exists, it is necessary to analyze it. Land use/ cover was derived from LANDSAT satellite imaging remote sensing techniques (2014). For each criterion, the weight estimated. The analytical hierarchy (AHP) method is one of the decision-making processes with many parameters that culminate in a relative value percentage. AHP model consists of three levels of purpose, The optimum position for the storing of water, the parameters used and the alternatives. The relative value calculated by AHP for the creation of appropriate sites is implemented in the GIS overlay process. Suitability is categorized into three categories: "Suitability Level 1" and "Suitability Level 2" representing holding reservoirs, stop dams and check dams. This mapping helps to identify a potential spot in the basin for water storage. The average region that is outstanding and very well suited for water collection is 61% of the area, where 11% are fairly suited, while 28% are badly and marginally appropriate.

Keywords : *GIS, Remote sensing, MCDM, AHP, Rain water harvesting.*

UZAKTAN ALGILAMA VERİLERİ VE CBS TEKNİKLERİ KULLANARAK SU HASADI YÖNETİMİNDE SİTE UYGUNLULUĞU: SULAİMANİYAH İLİ BİR DURUM ÇALIŞMASI, IRAK

ÖZET

İnsan kaynaklı su kullanımındaki değişikliklerin su kaynağının azalmasına ve iklim değişikliği etkileri uzun vadeli kuraklığa yol açmıştır, su kıtlığı ve bazı olağan sel olayları son birkaç on yılda Irak'ın kuzey bölgesini büyük ölçüde etkilemiştir.Yaşanan kuraklıklar yarattıkları olumsuz etkiler sonucu, bölge için endişe edici durumlara neden olmuştur. Bununla birlikte, yaşanan sel ve taşkınlar, genellikle yoğun kar yağışı ve yeterli barajların ve yapay drenajın olmaması nedeniyle kış aylarında meydana gelir. Bu alandaki her iki konu da sosyo-ekonomik zarara neden oluyor. Bu ikilemi çözmek için su kaynakları yönetimi önemli bir konu hale gelmiştir. Yeraltı suyu, özellikle kurak ve yarı kurak bölgelerde tüketim, ev, büyükbaş hayvan kullanımı ve tarım arazilerinin sulaması çin değerli bir doğal kaynaktır.

Bu tezin amacı, Coğrafi Bilgi Sistemi (CBS) ve Çok Kriterli Karar Verme (MCDM) aracılığıyla Irak Kürdistan bölge valiliklerinde bulunan Süleymaniye'de yeraltından yağmur suyu hasadı için uygun alanları belirlemektir. Buradan, küresel haritalar ve yağış verilerini kullanarak Uzaktan algılama (RS) ve GIS ile su hasadı için uygun alanların seçilmesine ilişkin bu yaklaşımın bazı kilit noktalarını açıklığa çıkarılacaktır. Akım, eğim, toprak bileşimi, bitki örtüsü ve çıplak arazi gibi etkisine bağlı olarak her bir faktör için ağırlık belirlenip, ardından su hasadı için en iyi yerler seçilecektir.

Ayrıca rezervuarlarda su depolannbilir veya barajlar inşa edilebilir, çünkü bunun pek çok faydası vardır, ancak bu yöntem yerin altındaki suyu toplamak amacıyla seçıldı, çünkü çok fazla alan gerektirmiyor. Ayrıca bu yöntemde buharlaşma veya iklim değişikliğinden dolayı başka kayıpları yoktur. Bunların yanısıra, depremlerde veya doğal afetlerde başarısızlık oranı çok azdır veya hiç yoktur ve bitişik alanı etkilemeyecek ve savaş sırasında tehdit altında olmayacaktır.

Coğrafi Bilgi sistemi (CBS), karar vericilere yağmur suyunun depolanması için uygun alanları bulmada yardımcı olmak için çok kriterli değerlendirmeler yapmak için kullanılır. Çok kriterli değerlendirme için toprak dokusu, eğim, yağış verileri (2009-2019), arazi kullanımı / arazi örtüsü ve drenaj yoğunluğuna dikkat edilmiştir.

Bu çalışmada, modelde sadece etkili faktörler kullanılmıştır. Su hasadı için en iyi yerleri belirlemek için, literatür taramasından beş faktör seçilmiştir. Örnekteki her faktörün sayısı ve ağırlığı, incelenen kağıtlarda kullanılan her faktörün sayısına ve yüzdesine bağlıdır. Çalışmada bu hususlara öncelik verildi:

Potansiyel akış, SCS-CN denklemi kullanılarak tahmin edildi. Birden fazla parametre olduğu için, bir katmanın değerini başka bir katman üzerinde değerlendirmek önemlidir. Arazi kullanımı / kapsama alanı, LANDSAT uydu görüntülemesinden (2014) uzaktan algılama teknikleri kullanılarak elde edilmiştir. Her kriter için ağırlığı yaklaşık olarak hesaplanmıştır. Analitik Hiyerarşi Süreci (AHP), göreli bir önem yüzdesi ile sonuçlanan çok kriterli karar verme süreçlerinden biridir. AHP modeli üç amaç katmanından oluşur, yani su depolaması için en uygun konum, kullanılan kriterler ve alternatifler. GIS overlay yönteminde, uygun lokasyonların geliştirilmesine AHP tarafından belirlenen nispi değer uygulanır. Uygunluk, "Uygunluk Seviyesi 1", "Uygunluk Seviyesi 2" ve "Uygunluk Seviyesi 3" olmak üzere üç seviyede sınıflandırılmıştır. Bu haritalama, havzadaki su depolama tesisleri için potansiyel bir yer bulmaya yardımcı olur. Mükemmel olduğunu ve su toplama için çok uygun olduğunu gösteren toplam alan, örneğin % 61'idir;% 11'inin makul ölçüde iyi uygunluğa sahip olduğu, % 28'inin ise son derece zayıf uygunluk ve orta derecede uygunluk gösterdiği ortaya çıkmıştır.

Anahtar kelimeler: *Coğrafi bilgi sistemi, Uzaktan algılama, Çok kriterli karar verme, Analitik hiyerarşi süreci, Yağmur suyu hasadı*

1. INTRODUCTION

In the near future, water availability will be very important for various purposes, especially for domestic and irrigation use. Thus it becomes important to tap as much water as possible into the river basin as possible. Harvesting water is one of the essential methods used to tap water by constructing irrigation facilities such as test dams, storage ponds, stop dams, etc. Water preservation acts as a way of avoiding precipitation variability as an insurance strategy (Payen et al., 2012).

In several developing countries, water management practices require supply management as demand growth increases are not feasible in areas of water scarcity over the years. Many studies have shown that demand management practices along with supply management should be implemented in support of sustainable water resources. Categorization of demand management through; Recycling of wastewater, the design of the task should be changed to be done with less water. Also, reduction of movement losses from sources by use to disposal, using the time to off-peak periods shift and improved system performance (Brooks, 2006).

Decades of war and maladministration and the growing demand due to population growth have considered water a scarce resource in Iraq, by Iraq's developing neighbours, Iran, Syria and Turkey, by worse droughts recently recalled. Difficult water shortages in some area have in recent years prompt thousands of people to leave their places, this phenomenon is likely to increase with continuing droughts condition in Iraq. Alternative proposals for reducing Iraq's water shortages therefore urgently need to be enforced (Al-Abadi et al., 2017).

Owing to climate change and high population growth, waters demand is on the rise (Schewe et al., 2014). However, Iraq is an agriculture-based country and water demand increases in order to guarantee food security, for further agricultural production (Noori et al., 2019).

As a result of climate change and increased water demands for urban and agricultural development, the stresses on water supplies are increasing. Aridity and climate variability in the arid and semi-arid areas are the main threats to farmers. These areas have low average yearly precipitation levels and wildly varying distribution of spatiotemporal precipitation. The dryland residents have produced and constructed many rin water harvesting (RWH) methods to increase water supplies to cultivation and development of livestock (Adham et al., 2016).

Rainfall may be the most critical concept in the water balance equation, so it is one of the challenges for engineer's designer and hydrologists to interpret historic data of rainfall and hydrology in terms of potential occurrence probabilities. Annual maximum analysis over the catchment at different daily or better predictive is a fundamental method of safe and economic planning, water management and hydraulic system design (Gavit et al., 2018).

1.1 Background

RWH used to induce, capture, save and use local surface water for agriculture and domestic in the arid and semi-arid countries (Gupta et al., 1997). The main goals for hydrological engineers include an understanding of the performance of the RWH, the catchment water output, and flood flows to plan structures for the harvest of rainwater. Structures for the RWH are designed to capture, within a specific recurrence interval, as much of the anticipated river as possible while meeting crop/tree water requirements (Adham et al., 2016).

The collection and management of surface water and flooded water are the most effective irrigation options in dry areas, particularly for domestic use and agricultural. The main aim of water harvesting is to capture, store and make available the rivers or groundwater for a region with adequate water where water deficits arise (Botha et al., 2011).

Rainfall data can be checked on the likelihood and frequency of receiving expected precipitation amounts for different likelihood (Bhakar et al., 2008). Use equivalent computational techniques to predict the average daily precipitation of predicted events from available evidence (D. Kumar & Kumar, 1989). Rate rainfall analysis is a way of addressing multiple water supply concerns (A. Kumar et al., 2007). Therefore, in the preparation and development of water sources for small dams, lakes, storm drains, drainage systems and rainwater storage facilities (Dabral et al., 2009), the likelihood and duration of the occurrence of potential rainfall events should be used to minimize the risk of floods and drought cycles.

RWH must match water quantity and the storage (structural design) requirements. Therefore, it is necessary to understand the ratio between precipitation and rush in catchments. The hydrological activity of catchments and RWH systems can be analyzed to gain insight into the water cycle, the dominant hydrological processes can be identified (Uhlenbrook et al., 2008). The water balance equation describes the intake, outflow and adaptation of water storage for the environment or water bodies (Tafesse et al., 2010).

In accordance with the WH criteria in the emphasis the WH techniques can be divided into various categories, the two most commonly used of which are the catchment sort and scale, and the form of water storage (Mekdaschi & Liniger, 2013). The WH systems of four catchment forms are inundated water collection, micro-catchment and roofing. WH can become an effective approach to exploiting the excess runoff in arid regions in Iraq which is often lost during water deficits for potential use (Yousif & Bubenzer, 2015). WH contributes to increased water levels per unit of cropland (Sur et al., 2001) and thereby to ameliorate problems of water scarcity, in particular in agricultural and domestic applications (F. Li et al., 2000).

Any WH project would be able to optimize rainwater production and increase the amount of water per cropland unit, based on its efficiency (Mbilinyi et al., 2007). To maximize these parameters, it is important to define suitable sites for WH; however, it depends upon several variables, including geology, weather, hydrology, soil types and socio-economic criteria. Besides, it depends mainly on data availability and situations that such factors are identified.

One of the major components to the watershed creation is water storage, which not only collects, stores and reloads water but also enables groundwater to be recharged (Ahmad & Verma, 2016). Substantial expenditure is expected to be made in storage structures and hence it is necessary to determine before deployment the correct condition of these structures. In order to substantial investments, it is very important to evaluate and plan the amount and type of water-storing systems that must be built using remote sensing and GIS techniques (Singh et al., 2009). Such techniques allow us to quickly and economically carry out watershed assessments.

Runoff is one of the main criteria for the management of water storage sites. This can be processed through the creation of appropriate structures (Ramakrishnan et al., 2009). In certain ways, a potential catastrophe is evaluated at the water collections facilities. SCS-CN is a quick, reliable and consistent storm-based methodology for estimating specific storm depth runoff (Nagarajan & Poongothai, 2012) developed by the united states department of agriculture's national resource conservation services (USDA, NRCS) (Mockus, 1969). This is a tool explaining the dynamic characteristics of a basin land usage, land cover or soil.

Water conservation through raining and groundwater collection, greywater recycling, increasing awareness, differential water tax system, etc. are different water demand management methods.

Oversight and adoption of past expertise of rainfall moving, draining patterning, soil degradation, forest or crop coverage, water collecting areas, the abundance of insect's/animal species, native population feedback in watershed areas have been developing various methods in the past years to conserve water in some way not to serve the problem (Saxena et al., n.d.).

New technologies have been developed recent times to address the shortcomings in traditional water scraping methods such as GIS, remote sensing and multi- criteria decision making that can applied to accurately assess catchment rush production, incorporate spatial and time differences of catchment properties in resource estimation and make informed decision-making (Saxena et al., n.d.).

The compilation of water boundary characteristics, integration of multiple sources of data to a shared standard, and review of hydrological processing to ensure optimal water conservation decision-making was highly successful with spatial technology such as remote sensing and GIS (Saxena et al., n.d.). The selection of installations for water preservation, their capacities and placement are now assessed on the ground using scientific criteria such as fields, contour lines, surface properties, drainage patterns in the surface and under the floor, infiltration rate.

Capturing, infiltrating or utilizing roof precipitation, built catchment areas and entryway lanes, sidewalks, parking lots and streets is the practice of Rainwaters Harvesting (RWH) (Bradford & Denich, 2007). Rainwater can also be used for drinking water use with proper filtration. The water collected can be stored directly or recharged into the underwater. "Identifying appropriate sites for aquatic processing facilities requires a great deal of multidisciplinary data from various sources that have been given much attention in recent years to the purposes of modern remote sensing and geographical data system technology" (A. Kumar et al., 2007). The soil and drainages trends must be captured in GIS remotely for the efficient localisation of the required systems, and the watersheds have distinct physiographical characteristics, such as geomorphology, structures, land use and land cover (LULC).

In recent years, geographical information systems offered a complex and effective forum to combine data from remote sensing and runoff models to optimally position WH structures, normally using spatial analysis instruments (Nykanen, 2011). Description of suitable WH-built fields is also achieved by the integration of numerous overlays and index-based multi-criteria decision analysis (MCDA) variables using GIS, that can provide GIS with a range of effective essential decision-making techniques and procedures (Gbanie et al., 2013).

Analytical hierarchy process (AHP) between MCDM approaches commonly used in different fields of decision-making (Lai, 1995). It provides the product of complex decision-making that is versatile, low-cost and understandable. (Hajkowicz & Collins, 2007) revealed that AHP is perhaps the technique of most common use in all other methods that are available when considering the application of the MCDM technique for controling water supplies. Indeed, the global academic community has widely recognized the GIS-based AHP strategy as a strong method to analyse spatial decisions (Rahmati et al., 2015).

In comparison, fuzzy logic is a logical approach used widely by means of a set of IF-THEN rules to maps the input space in the output space. It provides a method through which unknown, unreliable or imperfect data used in the study of knowledge is routinely calculated. It gives a wide range of fuzzy mixture operators (and, or, sum, product and gamma) in order to cope with challenging decision-making problems, and the choice of fuzzy logic stems from its simple application (Gorsevski & Jankowski, 2010).

Accordingly, MCDM and GIS are implemented in order to enhance site suitability analysis capabilities (Abdulkareem et al., 2018). A Spatial Decision Framework is used for in-depth research with the use of GIS (Abdullahi et al., 2014). Some crucial elements of MCDM include a small range of alternatives and a clear collection of solutions, involving knowledge about the decision maker 's decisions and relying on outcomes (Chakhar & Martel, 2003). When a person addresses an MCDM, the value and weight of the non-substantial characteristics and evaluations of the alternatives must be understood. Simple additive mass, the perfect point form, analytical hierarchy (AHP) and fugitive emblem are the most widely-known MCDM models (Noori et al., 2019).

An earlier study found that the standard form of AHP is sensitive to human uses and that the findings can easily be partial (Chan & Kumar, 2007). Throughout some study, fuzzy logic for suitable site selection is suggested to solve the problem.

In fact, fuzzy logic will deal with ambiguous human-language management laws (Molina-Solana et al., 2017). In struggling with undefined characteristics, Fuzzy logic is an effective approach (H.-X. Li et al., 2017). For GIS soils, this method has to be significant, with amounts between 0 for the smallest soil and 1 for the most significant acceptable soil (Van Ranst et al., 1996).

For the current analysis, a GIS model incorporating the fluctuating logic and the AHP was suggested for Sulaimaniyah governorate in north Iraq to delineate appropriate areas for the structuring of the WH. Fuzzy logic was employed in order to normalize the variable used to classify WH-appropriate locations, while AHP has been used to assess the weight of each factor of impact. Ultimately, the weighted linear combination (WLC) technique used to quantify the variables (Al-Abadi et al., 2017).

The use of GIS and remote sensing technology in water resource management work remains very limit in Iraq despite its extraordinary significance. In particular, no work has been carrying out on the use of GIS and remote sensing to locate the appropriate sites for WH in the study area (Al-Abadi et al., 2017). As such, it is anticipated that the proposed strategy would direct policymakers engaged in water resource management in the area with readily available details.

The approach has been modified, adjusts and utilized in various studies, such as in (Gabos & Gasparri, 1983); (Vandewiele & Xu, 1992); (Arnell, 1992); (Thornthwaite, 1948) then first monthly water balance has been issued. In order to quantify potential drainage areas of Africa and RWH locations. (Durbude & Venkatesh, 2004) implemented remote sensing and GIS model Thornthwaite and Mather (TM), such as outlines, agricultural ponds, slats and percolation tanks. To understand water balance used remote sensing TM models and GIS (Jasrotia et al., 2009).

An empirical relation between average yearly evaporation intensity, rainfall, and the dryness indices in the catchment was established in a study of water intakes (Gebrekristos, 2015), (Budyko & Sedunov, 1990). Budyko's system (Gebrekristos, 2015); (Potter & Zhang, 2009) as a wide implementation of catchment across the globe; (PJ, n.d.). In the annual water balance in spatiotemporal fluctuations in the annual evaporation and the rippling of 108 basins in China (Yang et al., 2007) The study was made of 20 catchments in high blue Nile based on Budyko's time space assumptions using top-down modelling (Tekleab et al., 2011).

Many site-suitability studies were recorded using multicriteria assessment and analytical hierarchy process in each of (Ahmad & Verma, 2018) (Bamne et al., 2014) (Ahmad & Verma, 2016) (Ahmad et al., 2015) (Gavade et al., 2011) (Bodin & Gass, 2004) (Teknomo, 2006) (Harker & Vargas, 1987) (Salih & Al-Tarif, 2012) (Haas & Meixner, 2005) (Triantaphyllou & Mann, 1995) (Banai-Kashani, 1989). As the decision-making method, Analytic Hierarchy Process calculates the percentage value of different criteria in the determination of suitable locations.

1.2 Study Purpose

The aim of the study is to find the amount of rain off in the study area and finding a suitable site for water harvesting using a multi-criteria assessment technique, and the proposed water storage sites will be shown for better water management.

In general, at the sub- basin level, there is no real understanding of hydrological processes. There are a few problems that need to be discussed in the review of RWH systems after implementation. Some research studied the efficient collection and preservation of water in the current usage of land and agricultural development and the use of RWH. To determine, and maximize RWH efficiency in various design and control scenarios, the purpose of this thesis was to formulate and incorporate a basic but widely applicable model of under-catch water harvesting. The intention was to make the various systems, dependent on the needs of crop water, precipitation and runoff, more usable and to make the design of the RWH infrastructure more readily available.

The goal of this study is therefore to assess the ability of water harvesting and to propose appropriate places for water harvesting structures in Sulaimaniyah using GIS, and MCE. as well as to create suitable sub-site barrages at the selected site in the area of study, AHP method has been used due to the reservoir storage requirements in the area.

In view of drought issue in Iraq, the ultimate goal of a report is to identify suitable rainwater areas. In addition, other unique goals have been taken into account:

1- Estimate the capacity for rainwater harvest in Sulaimaniyah, Iraq and build an adequacy map of the rainwater harvest.
2- Identify suitable locations for construction of small and medium dams water reservoirs.
3- Calculate acceptable site characteristics, including dam storage capacity, altitude and length.

1.3 Thesis Outline

The thesis chapters include; The introduction of this subject in chapter 1, which describes the general concept of the water supply management and relevant problems such as the need to decide the correct location for storage water. The second chapter deals with the literature review, which addresses different types of data. Also, this chapter includes the selection of correct location for dam construction, MCDM and AHP method. The third chapter deals with the methodology which gives a methodological flow diagram and a specific description of the field and source of data. Software used in this chapter also discusses image preprocessing, interpolation implied, AHP method for dam site land appropriateness. Chapter four demonstrates the findings and description of the study. The conclusion and recommendation are allocated to chapter 5. The whole thesis is completed and further studies are suggested.

1.4 Research Questions

- Can we do water harvesting in Sulaimaniyah?
- Can GIS use for water harvesting management?
- Is the area of study appropriate for water harvesting?

2. LITERATURE REVIEW

2.1 Introduction

Water is the most important vital on the earth that no creature can live without it. Water scarcity is a global concern with extreme water scarcity in regions. Iraq is considered an arid region and faces immense demand for water supply and maintenance (Sayl et al., 2017). Water is also an essential resource that directly affects socio-economic growth as well as the protection of the environment. Mainly lack rainfall, extreme temperatures and evaporation, and inadequate surface moisture in the soil determine the presence of dry areas. So that the good planning and well management of water supplies are required in arid areas.

The water resources are one of the sources and wealth from which the countries cannot afford to remain without it, since they support people both in daily life and in the economy, as it is mentioned in the UN document 2005 general comment on human rights to water (Klawitter & Qazzaz, 2005).

Water is an essential entity in each part of the planet especially in the arid and semi-arid area for the ecological sustainability of all lives and concerns. For the optimal preparation and use of the proper data collection, assessment and monitoring of water supplies. The fundamental unit for the evaluation and preparation of water supplies is a water boundary (Saxena et al., n.d.). Water is covering about 70% of the earth's surface is an important resource for the world's biodiversity and climate. It has a number of unique chemical and physical properties which make it important to live and makes up approximately 60% of the bodyweight of adults (Foundation, 2010). Water reportedly consolidated in the atmosphere, surface and soil waters with cloud moisture precipitated as snow and plenty of water. At the other side, rainwater is a precipitation process in which liquid water falls to the surface of the earth (Sabina Yeasmin, 2013). The main sources of all drinking water in this planet are assumed to be rainwater and snowmelt (Texas Commission on Environmental Quality, 2007).

2.1 Water Harvesting

The government use, or regulates the runoff as a means of collecting and storing the rainwater and accumulated rain for a number of purposes (Mzirai & Tumbo., 2010), including irrigation, animal uses, household use, agriculture, drainage, and industrial uses.

There are various studies in the world concerning water harvesting and the conservation of water. Some of the past water harvest studies have been discussed in this section. A technique for water harvesting in drought ecosystems from West Asia and North Africa has been developed by (Oweis & Hachum, 2006). Most rainwater is wasted by dry environmental evaporation and thus rainwater production is extremely poor. by using a GIS-based model of suitability, which included integration by Multi-Criteria Assessment (MCE) of different factors the dry spell problem will appear (Ketsela, 2009).

Micro catchments were used to identify ideal water storage areas. Using commercially accessible remote sensing instruments and GIS to identify rainwater harvesting areas in the mainland of Zanzibar (Tanzania), Unguja Island (Munyao, 2010). Micro and macro catchments have been used to map and identify various potential impoundment sites using the multi-criteria assessment process through the integration of remote sensing data, GIS and hydrological modulation (MCE). Multi-criteria appraisal approach (MCE). The effect has been evaluated on agricultural development in the Pangani basin catchment area of Chome-Makanya in Tanzania (Mzirai & Tumbo., 2010). Researchers confirmed that, during the dry season, rivers were used as additional irrigation and the production of crops with rainfall-fed rain was increased by more than 120%.

In order to decide suitable sites for application of water resource management, a model has developed for spatial analysis called geographic water management potentials (GWMP). The analytical model for spatial water conservation in two different areas of study; the catchment of the Nile (Egypt) and in São-Francisco catchment in Brazil, which have various areas and climates. The findings of the model were tested against field proof. By applying the spatial water management potential model, 83% of the connections between the site and the present regional reservoirs have been established. The findings of the regional water model indicate that future rainwater storage areas in the catchment area can be identified

(Weerasinghe et al., 2011). Macro-catchment water harvesting systems in Iraq were studied and revealed water storage issues in the northern mountains in Sinjar. There were picked six macro catchments for the rainwater collection from the rivers and watershed modelling system (WMS) has been used to discover the problems (Zakaria et al., 2012). Therefore the aim of the rainwater harvesting in the area is for supplementary irrigation and other uses (Hameed, 2013).

Rain water harvesting (RWH) systems intended to channel water into a reservoir for crop production, or transfer water directly onto the land, through the rivers and the drainage network of the area cultivated from the catchment area. Both types can range from a few sq. m to a single home, serving a larger community, to a couple of square kilometres. Water systems may be used for different purposes in the storage tanks, such as homes, agriculture or animal use. This method is not commonly used by farmers with limited capital, as the building of storage structures is expensive. Farmers, however, tend to use water collected directly in the cultivated field (Mzirai & Tumbo., 2010).

The storage of rainwater directly on the field involves in-house techniques such as outcropping, deep ploughing, terracing to ensure that scrambling does not take place and that drainage is encouraged when rain falls directly on cropland. For places of heavy precipitation and a strong even distribution of rainfall during the growing period, the technique has more recommendations. At the other end of the spectrum, RWH merges into watering as runoff is filmed from a reliable source (for example, seasonal and permanent rivers) and transferred into the agricultural areas through a network of channels. Nevertheless, in most semi-arid areas, irrigation does not apply such reliable water sources. Their interest in seeking suitable intermediate RWH techniques is growing, despite the technological limitations at either end of the spectrum. All can be defined as a combination of a catchment area generating runoff and a crop area receiving runoff (Boers & Ben-Asher, 1982) a sequence of classifying forms of RWH systems rather than in situ and irrigation have been attempted (Critchley & Siegert, 1991).

Integrated spatial analysis and fluid logic are required to determine appropriate areas and positions for the location of water reservoirs (Hameed, 2013). The The rainwater harvesting system relies on the area from which the river is built and for which used (Mzirai & Tumbo., 2010). Rainwater harvesting can be split into two categories:

A. Rainfall is held where it comes and water collected immediately in the field or region of use may be used for micro-grabbing. The system features small semicircle holes, soil erosion, sub-bands, texture bands and meskat- type structures (Ketsela, 2009). There is a micro catchment area of fewer than 1000 m^2 (Zakaria et al., 2012).
B. The network for macro catchments requires the accumulation of water over several thousand hectares of the 0,1-hectare basin area. The macro catchment is close to or far from the user area (Ketsela, 2009). The machine is mounted outside the operating area with intermediate storage of water. For the macro catchment area, a pitch is between 5 and 50 %. The system includes a network of supplies and machinery for the use of water in the fields of channels, natural springs and sludge (Zakaria et al., 2012).

2.3 Water Management

The management of the watershed's resources includes management of demand and water supply, including conservation of rainwater capturing, groundwater collecting and reservoirs. depending on the worldwide studies the world will face water scarcity and Iraq will be one of these countries.

The precipitation in Iraq is very seasonal and takes place in winter between Oct and May, except the north and northeast part of the country where precipitation takes place between Nov and Apr. The estmated average annual rainfall from 1200 mm to less than 100 mm in the northeast (Bazza et al., 2018).

The Iraqi ministry of water resources-through its management responsibility decided to build 9 large dams and 18 small dams, for the hydrological and related modelling studies, as well as central and field office for water quantity and quality control. The restoration of sealants, including drought and seasonal water shortages, also plays a major role in response to hydraulic disasters. Create a water management plan aimed at rehabilitating drought areas and reducing the likelihood of potential hydrological disasters (UNDP, 2013).

2.4 Water Resources

In Kurdistan region, the water supply is distinguished by many wetlands, reservoirs, springs and groundwater sources. Dokan, Derbandikhan, and Dohuk are also dams and reservoirs. However, rain and snow are the most essential source of water (Hameed, 2013).

In general, the climate in Sulaimaniya dry warm in summer and cold snow in winter. The surroundings are half dry. During the months of October and May, precipitation takes place between NE and SW. Annual average precipitation values in the Sulaimaniyah region increase to more than 1200 mm in the high mountains of north-eastern Iran and north-eastern Turkey (Yenigün et al., 2018).

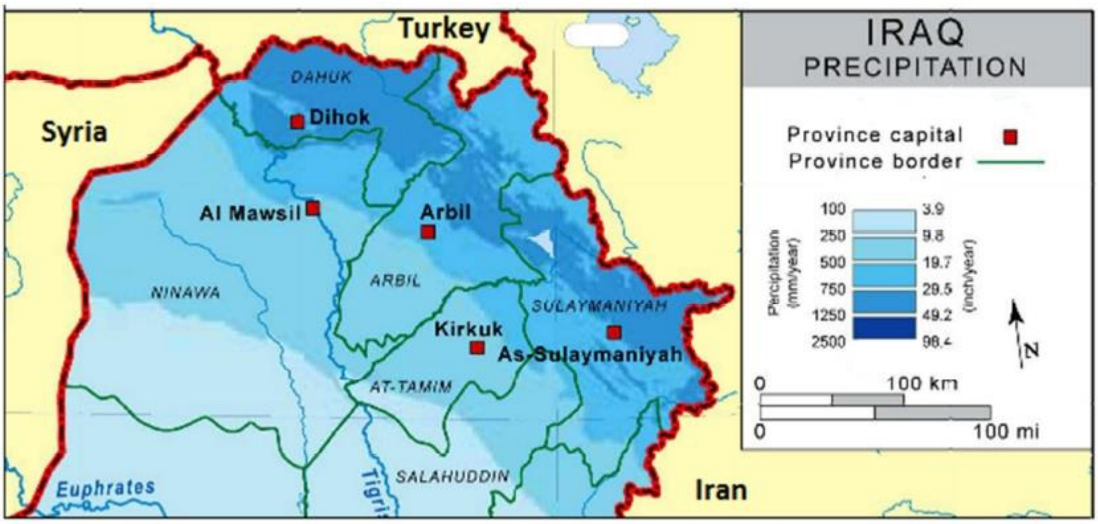

Figure 2.1: The precipitation in Iraq northern governorate

Source: (Anwar Omer, 2011)

2.4.1 Surface water

Surface water sources consist of lakes and rivers. About 40% of the surface water comes from outside Kurdistan. Greater Zab, Lesser Zab, Khabur, Sirwan and Awa Spy are the major rivers in the Kurdistan region (figure 2.2). Each tributary flows into the Tigris river in Iraq. The Tigris river is situated in south of Kurdistan region. (UNDP, 2010).

Lower Zab's passes through the governorate of Sulaimanyah. Between Iran and Iraq, it's an internal channel. Lesser Zab comes from Iran's mountains. The river crosses the Iraq border in the Bedrazhour area (Kurdistan region). The major river in Sulaimaniyah provides the main quantity of water for Dukan dam. Lesser river roughly 400 km long and the catchment area is approximately 22250 km^2. Lesser Zab's annual average discharge of 7.07 MCM is (Heshmati, 2009).

Sirwan tributary originates in Iran and is 385 km long in the region of Kurdistan. It is around 17,850 km^2 of catchment areaThe 70% of it in Iran, with just 30% in Kurdistan. The annual discharge of the Sirwan River is 5.86 BCM or 13.5% of the discharge of the Tigris river. Then Awa Spi tributary comes from the Kurdistan region with a catchment area of 1100 km and 230 km, Awa Spy has an average water stream of 790 MCM. It flows to Tigris in the Blad district of Tikrit (Heshmati, 2009).

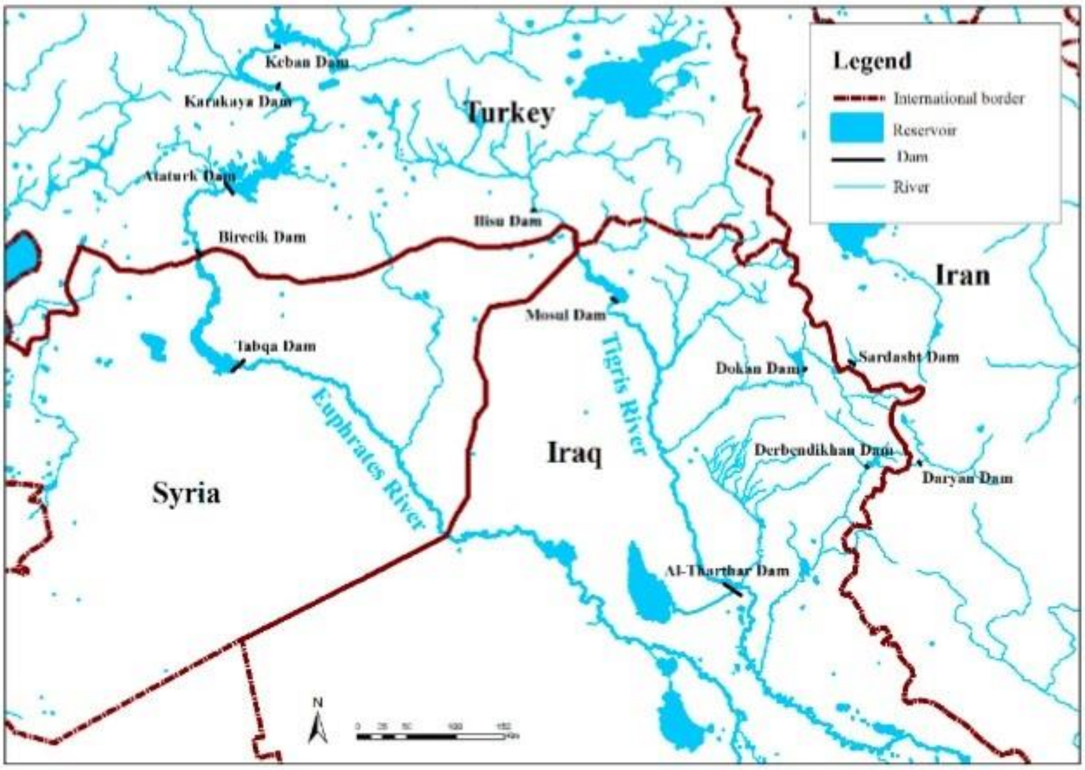

Figure 2.2: Iraqi-Kurdistan region rivers and lakes

Source: (Yousuf et al., 2018)

Iraq's Kurdistan region is famed for its fountains and many springs that provide fresh water. Surface water and groundwater rely on rain and snowfall to feed these springs. The flow of water will increase in springs with an increase in rain and snow. Many of them are located in the three governorates of Kurdistan, namely Erbil, Sulaimanyh and Duhok (Heshmati, 2009).

2.4.2 Ground water

The concept of groundwater vulnerability is based on the presumption that the natural evidence offers some level of protection against natural and human impacts on groundwater, especially for pollutants entering the subsurface environment (Vrba & Zaporozec, 1994).

Groundwater in arid and semi-arid areas is an essential source of drinking water and contributes to water supply for many uses. Many of these basins have become an ideal place for major corporations to invest in the cement and iron mills in particular. There is, therefore, an extensive groundwater extraction. The aim is to categorize and identify the productivity areas by means of remote sensing strategies and the technique of geographic information system (Ahmed & Al-manmi, 2019).

2.4.3 Rain water

Iraq has experienced severe droughts, increasing desertification in many parts of the world since 2007 and worsening living conditions. The Iraq Kurdistan region decreased rain and snowfall caused a rapid decrease in water levels, especially in the driest cities of Erbil, Sulaimaniya and Dohuk, including springs and shallow wells. UN officials and the ministry of agriculture and water resources (MOAWR) reported that the amount of groundwater has fallen over the past few years about 30- 40 meters. Such a dramatic figure reveals the environmental risk vulnerability of the Iraq Kurdistan region and the need for urgent preventive measures.

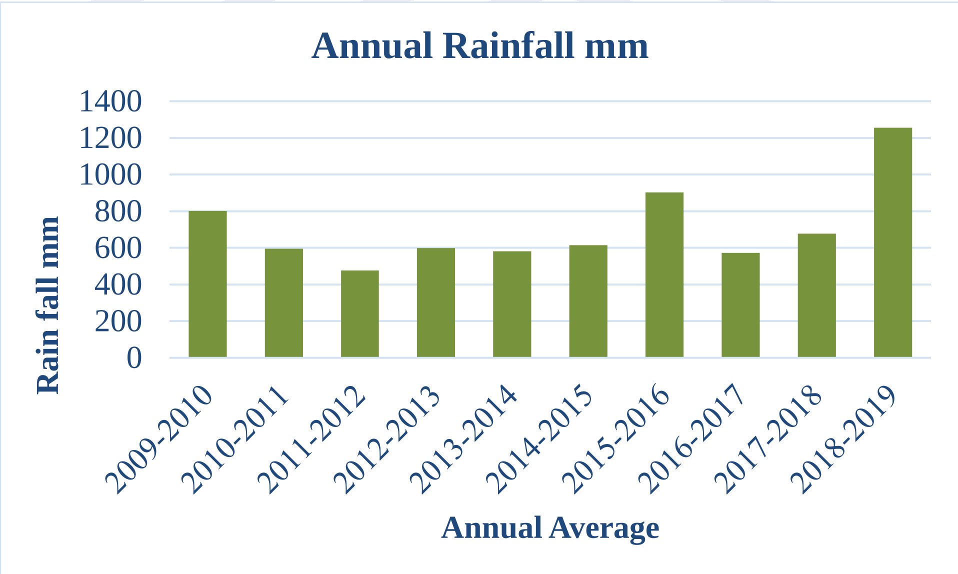

Figure 2.3: Annual average rainfall in sulaimaniyah governorate

2.5 Objective of The Study

Taking into account the drought problems in Iraq, especially in the Sulaimaniyah Governorate, the general aim of the study is to identify appropriate rainwater harvest areas. Furthermore, certain specific objectives have been considered:

1. Estimate the potential rainwater harvest and generate a plan for rainwater collection in the Sulaimaniyah province, Iraq.
2. Identify suitable locations for small and medium dam water reservoirs.
3. Create a new water source in an area that is inaccessible currently.
4. Trying to focusing on making the use of available water and enhancing sources of water.
5. Recharge aquifers for groundwater and mitigate the effects of drought and water shortage problems.

2.6 Drought

Drought affects a significant number of Middle East countries such as Iraq, Iran, Turkey and Syria due to rainfall shortages (UNDP, 2010). In addition, the agricultural sector is plagued by a lack of water supplies and irrigation. However, rising water consumption has worsened the drought conditions in the industrial and domestic sectors. The relation between the water supplies available in the Middle East have been decreased at the last decads in some countries, particularly in Iraq and Syria, (UNDP, 2010).

Iraq has been experiencing drought in recent years, mainly due to reduced precipitation. Another reason is that the tributaries that flow to Iraq have been developed by Iran, Syria and Turkey. For example, Turkey constructed number of barrier dams along the river Euphrates and Tigris, in South-East Anatolia region. The construction of the Ataturk dam project began started on the Euphrates river in 1992. The capacity of the dam is estimated to be 70 BCM. while the construction on the Tigris river began in 2007 with the second dam of the GAP (Ilisu Dam) with an estimated capacity of BCM 11.4. In this regards, Turkey will control 80% of the water flow in the Euphrates and Tigris rivers after completing all the GAP schemes (Al - Yasiri, 2007).

Since 2002, agriculture has withdrawn in development. An FOA analysis showed that agricultural input plummeted from roughly 9% in 2002 to 4% in 2009. Output in agriculture drops by approximately 9%. Between 2002 and 2009, crop coverage in Iraq decreased by about 40% (IAU 2010). Due to the changing climate, this drop in productivity was largely attributed to insufficient precipitation in recent years. Farmers dread the absence of rainfall and are not prepared to take opportunities in cultivation. This problem is taking place in the southern part of the Kurdistan Region, a fertile area with strong agricultural potential (Heshmati, 2009).

2.7 Climate

The amount of rainfall and snow is different in Kurdistan from year to year because of the relation between the precipitation and temperature and geographical position of the region. Precipitation raises impacted water levels in rivers and spring (Noori et al., 2019).

Sulaimaniyah 's geographical position placed a dry and hot summer in June, July and Aug with a temperature rate of 31.5° C on average. While in winter the province usually windy and spilt snow occasionally. This season runs from December and February, the temperature rate is approximately 7.6° C. In summer and winter, the average relative humidity is 25.5% and 65.6%, with evaporation reaching 329.5 mm and 53 mm in summer and winter, however, in winter the average wind speed 1.2 m/d, and in summer increased little more than 1.8 m/d. In winter and summer, sunshine lasts 5.1 and 10.6 hr (Zakaria et al., 2013).

Natural catastrophes such as floods, thunders and drought are the constitutions of our world. This kind of event is catastrophic and irreparable to human life. Literature has shown that the number and duration of these incidents have risen over the past 30 years. Climate practices account for approximately 25%. Drought is one of these events' most important and undoubtedly crucial events (Kogan, 1990). Drying is one of the biggest environmental threats. This inherent danger affects all facets of our lives. A national definition of drought is not a single concept. Typically speaking, as water rains, both locally and at a given time (Viegas et al., 1989). In general, drought happens. Dryness: frequency, length and width are characterized by 3 characteristics. Drought is caused by the length of the drought and is thus characterized by various forms (Yenigün et al., 2018).

2.8 Soil

Soil is one of the major tools for food safety by directly linked to farming production. Over the study field, the depth of the earth varies. In the north and north-eastern mountain zones, the soil is poor. Mountain soil originally comes from the rocks and has the low agricultural ability, but is rich in the natural rangeland (Kahraman, 2004).

The valleys and plains in the south part of the study area provide decent soil for agriculture, as they consist of chestnut, dark brown and black soils. Because of its high depth and strong quality, it is among the best soils for agriculture. It's also high in nutrients. Half mountain regions and most of the plateau is covered by organic soils and brown soils (Kahraman, 2004).

The soil texture and coulor for both of plain and mountain are different in the study area Sulaimaniyah governorate. Strong clay, loam silt, and silt clay, of the composition of the soils in plain regions. Soil colour ranges from dark-brown to light-yellow. Sandy clay, loam-silt or loam-sand, about 130 cm deep in the soil texture in the mountainous areas (Hameed, 2013). All white and dark white have a ground colour.

(Buringh, 1960) categorized the soil types 37 as a broad soil group, with silvery clay, dark brown, permeable surface soil, typically 1 to 4% organic matter, and less than 9% lime. Depending on the united states department of agricultural natural resources conservation service (conservation growth division 1986) (Šimák, 2009) has classified both 38 and 39 soil types as C and D of the hydrological soil group.

Table 2.1: USDA–NRCS hydrologic soil groups

Classification	Type of soil
A (low runoff potential)	High penetration potential soils, even when thoroughly wet; mostly sand and gravel, thick and well-drained.
B	Soils with mild infiltration rates when fully wet; moderately deep to deep, moderately well to well saturated, with moderately fine to moderately rough textures.
C	Soils with a poor penetration rate when fully wet; typically have a coating that prevents vertical runoff or a medium-fine to a fine texture.
D (high runoff potential)	Soils with very poor infiltration rates when completely wet-deep clay with a high swelling potential; soils with a high permanent water table; soils with a clay sheet on or above the surface; shallow soils with almost impervious materials.

Source: (Miller & White, 1998)

3. DATA AND METHODOLOGY

The outcome of this study is based on the various types of data gathered from many sources. The data acquired for the determination of successful rainwater harvesting areas include the ASTER Digital Elevation Model (DEM), Soil Maps, Satellite Imagery Landsat 8 OLI, Geographic Paths, Environment Data and Rainfall.

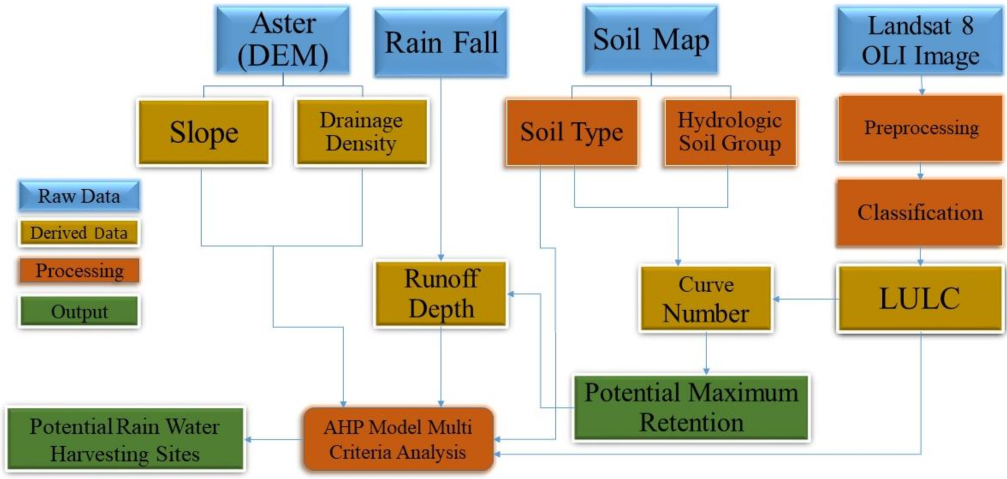

Figure 3.1: Overall Process for Identifying Suitable Sites for Rain Water Harvesting

3.1 Study Area

Sulaimaniyah Province is recognized as the densely populated areas of Iraq, it is experiencing a state accelerated progress expansion where it is the capital of culture in the Iraqi Kurdistan Region (Aziz & Qaradaghy, 2007). The statistical directorate of Sulaimaniyah (SSD) is responsible directorate for collects and records real data on the population and other issues affecting the whole community. However, since the general census was not conducted from (1987) on in Kurdistan, SSD relies on data provided by the Directorate of Food Distribution Sulaimaniyah, known as the Food Coupon (SFDD). Often these details are incorrect (Fulfillment et al., 2013). According to the statistics that we have at the rate of increase over linear and exponentially equations this number is in spite of the huge number of the refugee and IDPs that live in Sulaimaniyah in additional to the people that who get residence to live there and they are from other countries. As well as according to (KRSO, 2018) the population of the Sulaimaniyah has been estimated by 2014, as its over two million people, and this made me think about this study to calculate the availability and quantity of the water in the city and compared it with the population number.

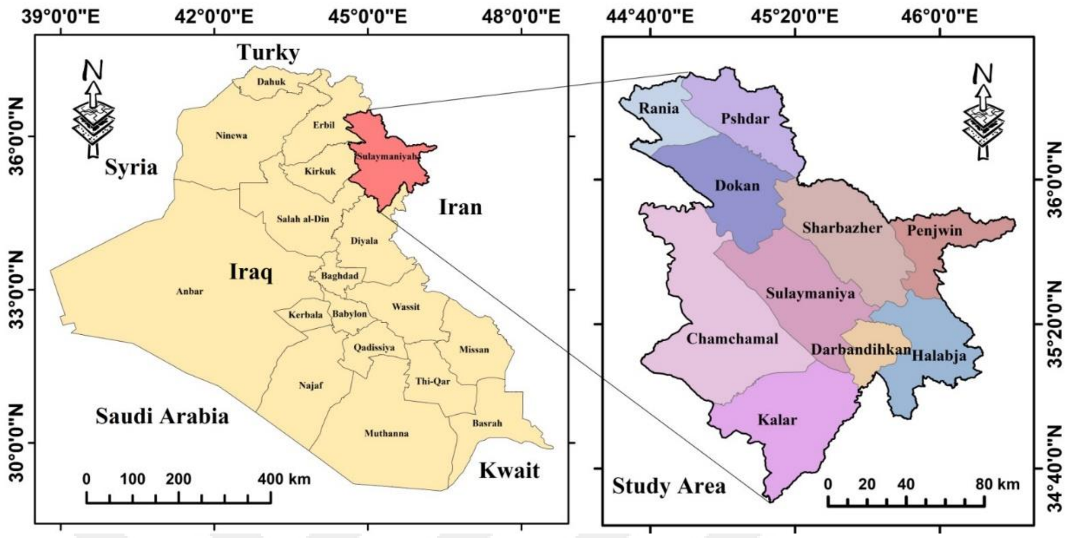

Figure 3.2: Iraq Map Shows Sulaymaniyah Province with Its Ten Districts

3.2 Data

1. The digital elevation model (DEM) extracted and downloaded from United States geological survey (USGS). The DEM resolution is 30 m and the format of the raster data is the date of the WGS-84 data.

2. Temperature data from 2008 to 2018 obtained from Kurdistan Region Government of Iraq's ministry of agriculture and water resources. The statistical analysis work shown in the figure 3.3. The average degree of temperature is 20.1, Median 20.2, Mode 20.1. Also, the minimum and maximum of 19.3 and 21.5. While the standard deviation is 0.6 and skewness 1.04.

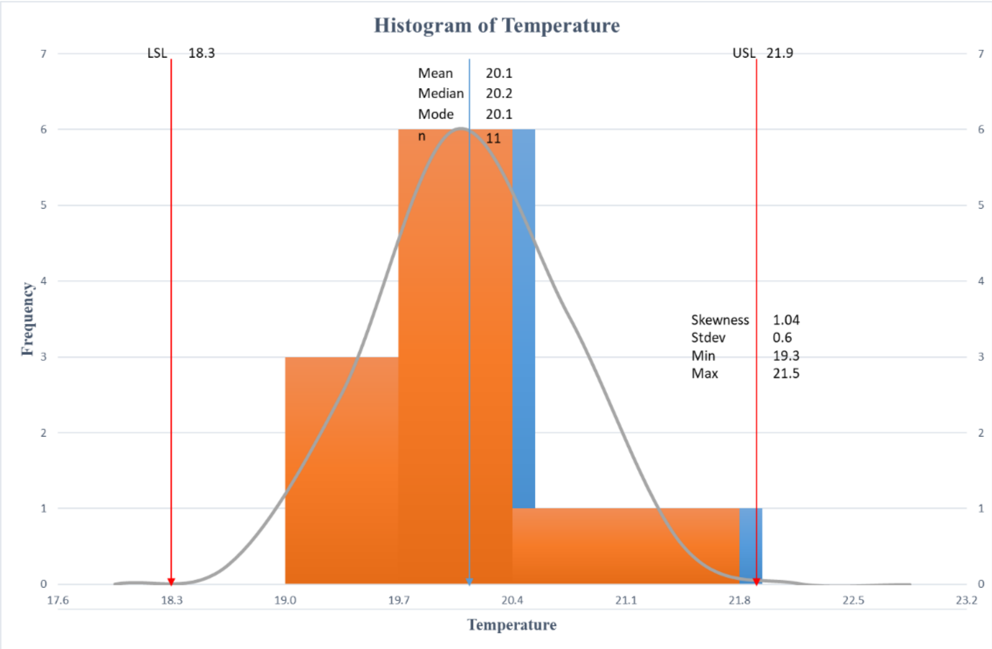

Figure 3.3: Statistical Temperature Data for the Study Area (2008-2018)

3. Precipitation data from 2009 to 2019 obtained from Kurdistan Region Government of Iraq's ministry of agriculture and water resources. The statistical analysis work shown in figure 3.4. The average annual rainfall is 59.2 mm, Median 51.1mm, Mode 59.2 mm. Also, the minimum and maximum 41.2 mm and 104.7 mm. While the standard deviation is 18.9 and skewness 1.83.

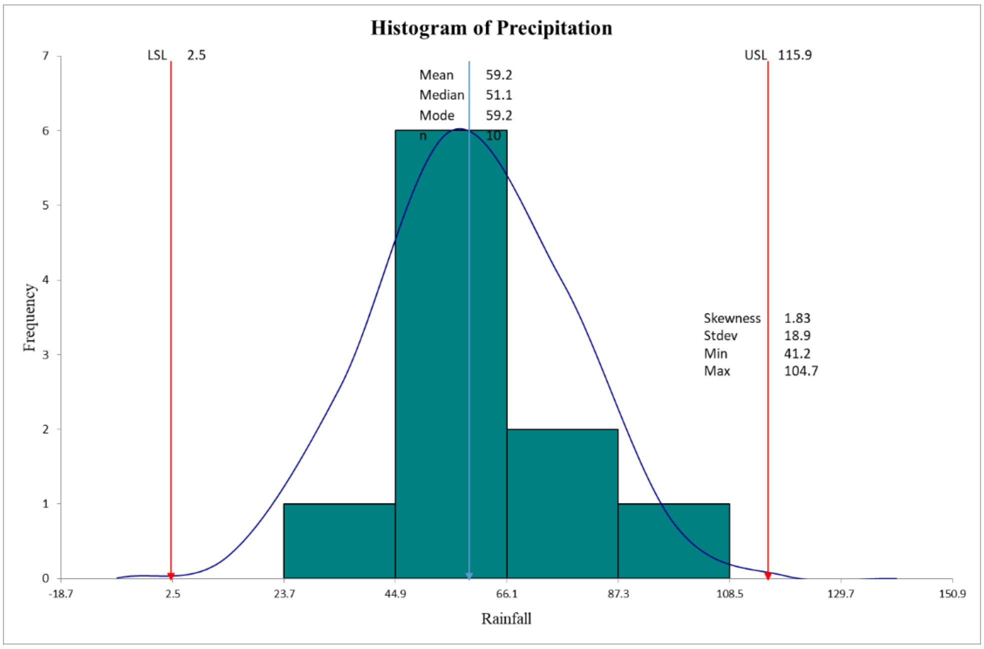

Figure 3.4: Precipitation Data Analysis for the Study Area 2009- 2019

4. North Iraq geology map obtained from the ministry of industry and minerals (Iraq geology survey). It was revise in 2014 and the chart scale 1:250 000.
5. Soil map of Iraqi taken from the ministry of industry and minerals (Iraq geology survey). The soil map describes the texture, density and colour of the area. The size of the map is 1:1,000,000.
6. The Earth Science Data Interface 3 images that downloaded from satellite imagery (Landsat 8 OLI). The shot taken on 26 May 2020 by the satellite. Raster layers resolution of 30 m for six bands, including the 1 to 5 bands, and the seven bands. These details identify the land cover of the field study. The satellite image georeferenced is WGS84 Datum 38N.

3.2.1 Software data

Four program forms used in this study including:

a. ArcMap has used to digitization, interpolation the data, to obtain and find out the final maps for the figures and charts.
b. ENVI 5.1 was used for utilized for pre-processing, treatment (classification).
c. Microsoft Excel (Plus 2016 version 16.0.4266.1001) used for the data preparation and analysis.
d. Microsoft word plus 2016 version 16.0.4266.1001, has used for preparing and writing the thesis.

3.3 Preparing Data and Modelling

Five criteria have been selected for the detection of possible water harvesting sites, including runoff, soil type, slope, drainage density and LULC. These parameters were selected on the basis of previous studies by another researchers.

3.3.1 Digital elevation model (DEM)

Hydrological criteria were obtained using the GIS (ArcGIS 10.4) package. The 30 m resolution digital elevation model can be derived from the accumulation of hydrologic models stream and slope. Each drain was eliminated in order to ensure continuity of flow to the downstream end prior to the use of DEM for the evaluation of the parameters.

3.3.1.1 Altitude

The altitude of the sample area was derived from DEM. The height ranged from 166 meters above sea level to 3412 metres. The digital elevation map after plugs shown in figure 3.5.

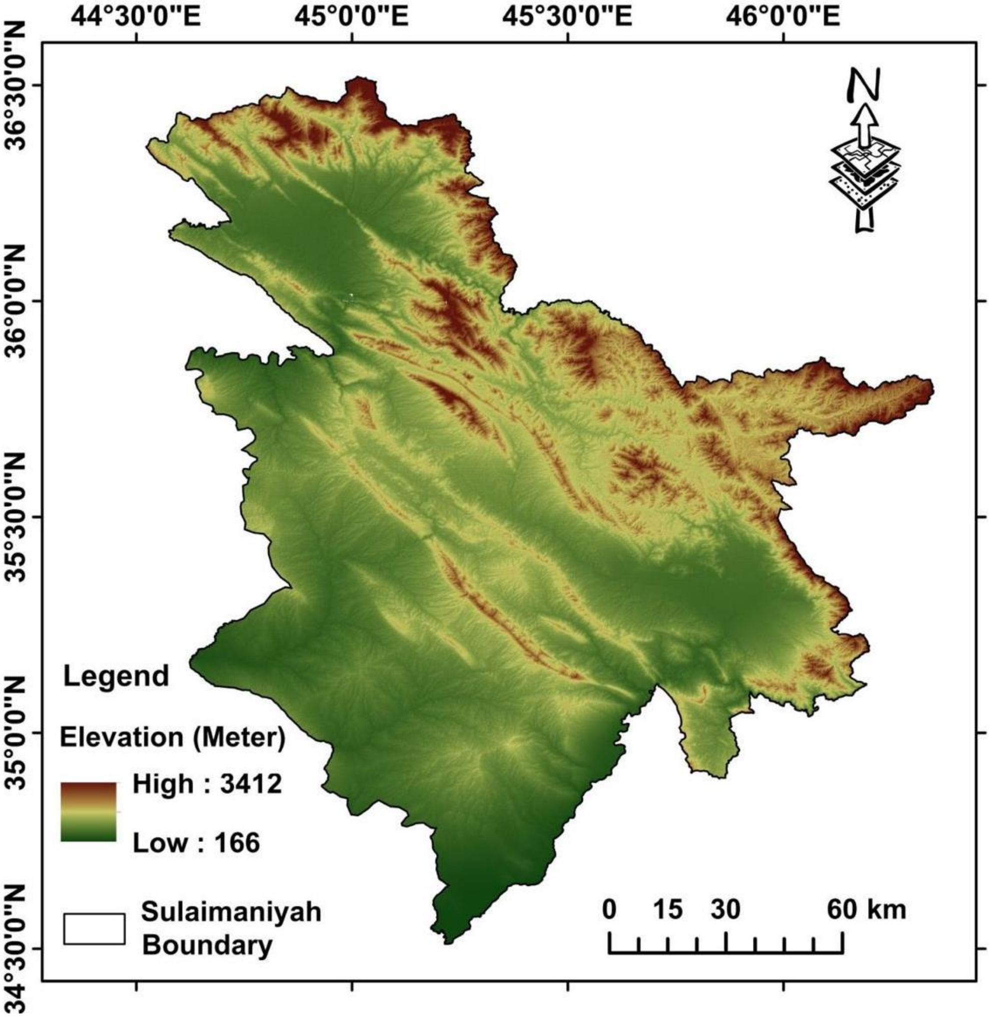

Figure 3.5: Elevation Model of Sulaimaniyah Province

3.3.1.2 Stream network

The following steps have been made to reduce the accumulation of flow and drain trends:

1. The flow direction defines the flow rate of water to each cell. In order to classify the flow of the central cell directly to its neighbouring cells, it determines its direction using the deterministic 8 patterns (Moghadas-Bidabadi, 2009). A unique number assigned to each cell based on its position. Eight single numbers can be established as feasible flow directions; East equal one, and Southeast equal two, while South equal four and Southwest

equal eight, however; West equal to sixteen, and Northwest equal to thirty two, also, North equal to sixty four, and Northeast equal 128” (DALEY et al., 2011).

2. The approximate flux increase by measurement of the flux path grid reveals how many cells flow to each cell (gives water). The role of accumulation is important for drainage perception.
3. The cell determination of a threshold for drainage flow accumulation used to assess streams in the study region with values greater than the threshold. In the flux estimate, the threshold given compared to each cell's value.
4. Strahler classification for linking the drainage network is used to assign a numerical order. It can be converted to a vector layer after classification of network drainage. Figure 3.6 demonstrates the distribution of channels in the study area. It is necessary for the drainage system to select the storage area and also to calculate the storage area with a flow accumulation.

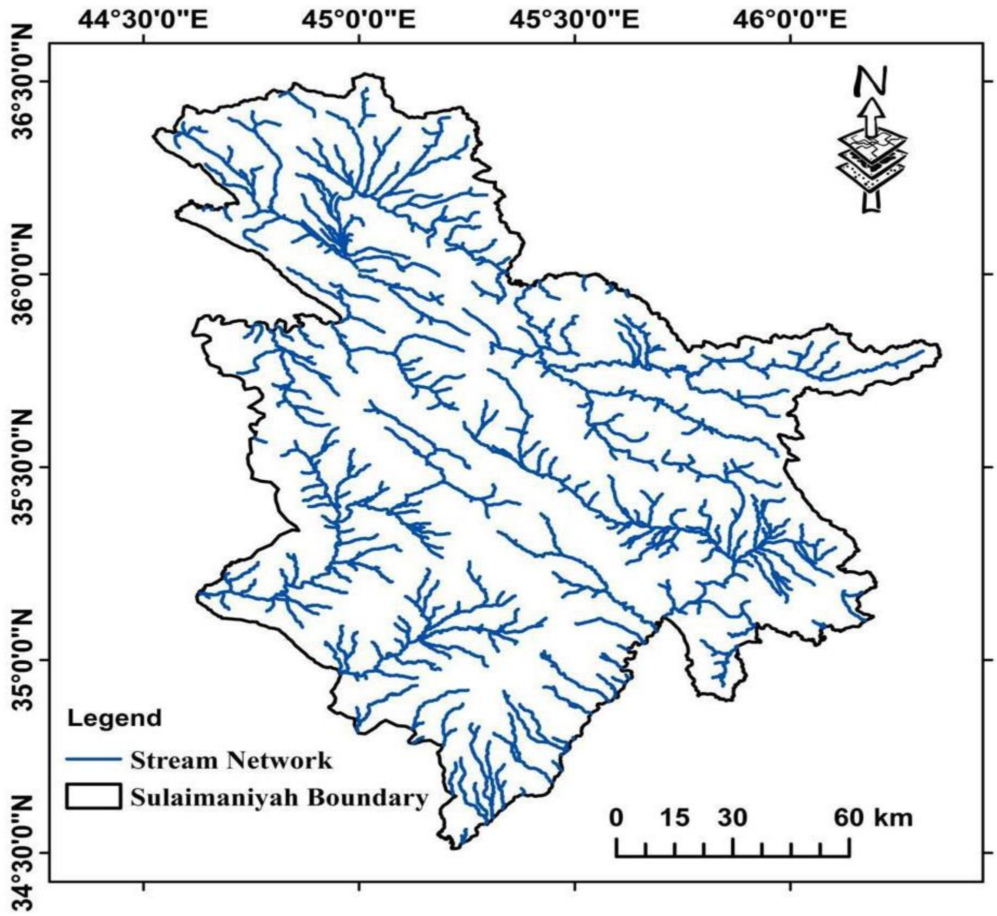

Figure 3.6: Stream Network of Sulaimaniyah Result from Flow Accumulation

In the northern part of the study area, the drainage system is deeper and denser more than the south part, because the northern part is more undulating and more mountainous, giving rivers diversified.

3.3.2 Rainfall analysis distribution from the network of rain gauges

Precipitation stations in Sulaimaniyah governorate are spread throughout the region of analysis and are arranged accurately for measuring the localized precipitation. Measurements of rainfall points reflect monthly values from 2009 to 2019. In areas with no rainfall point measurements, interpolation was used to estimate rainfall. To interpolate the precipitation for the region, 11 rainfall stations are used. figure 3.7 illustrates the rainfall.

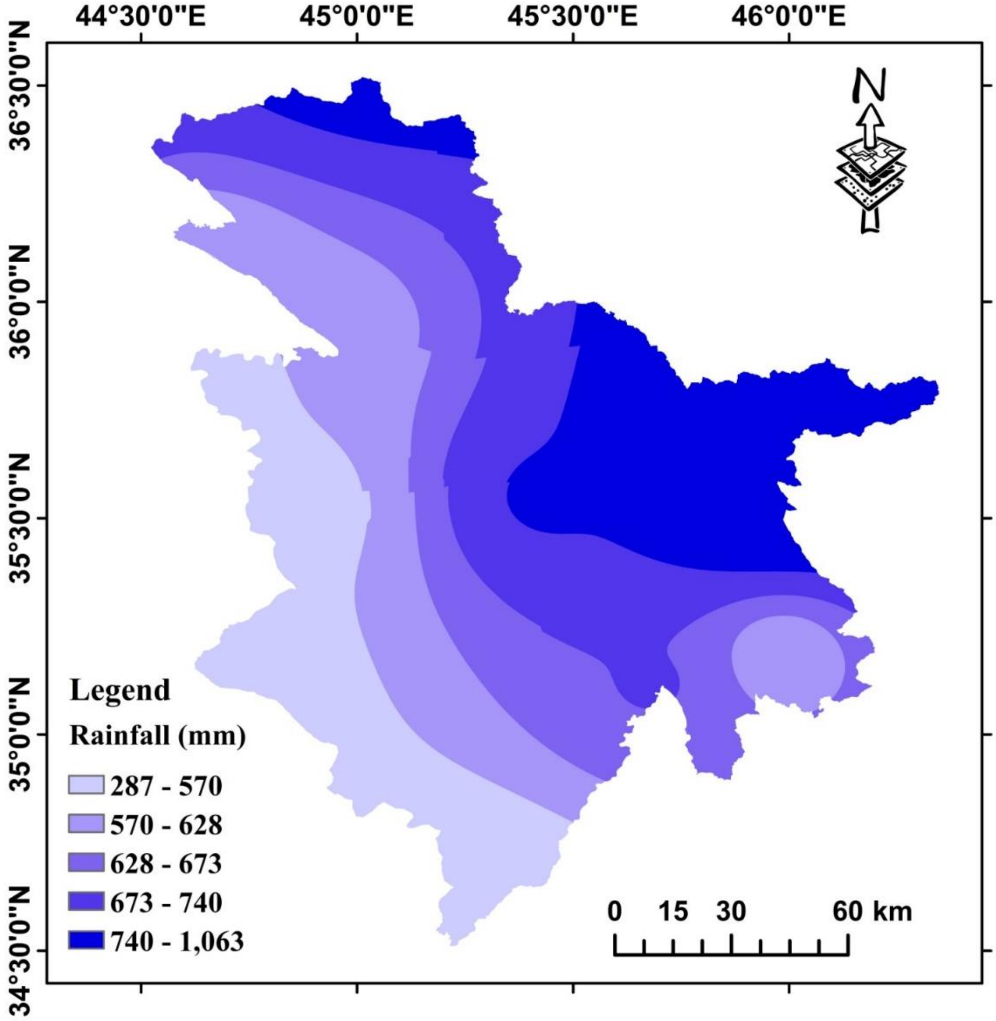

Figure 3.7: Average Annual Rainfall Spatial Distribution in Sulaimaniyha Province

3.3.3 Drainage density

The drainage density seems to be the total length of the rivers and streams determined by the scale of the overall drainage basin. It is a measure of how efficiently a waterfall drains or how badly it drains through a channel stream. The channel is the reciprocal of the channel management constant and the reciprocal of the overland flow is two times long (Choudhari et al., 2018).

$$DD = \frac{\sum_{1}^{n} L}{A} \qquad \ldots (\mathbf{3.1})$$

Where:

DD: Drainage Density

L: Stream Length

A: Basin Area

The drainage density corresponds to the rivers and streams' maximum area in a separate drainage scheme from the overall drainage area (Rahimi et al., 2014). Drainage density indicates the stream channel numbers (Agarwal & Garg, 2016). The region drainage system, according to (Abd Manap et al., 2013), is influenced by the existence and composition of geological formations, the potential for soil absorption by precipitation, the vegetation type, the rate of infiltration and the angle of slope. It has to do with the permeability of geological material in the reverse direction. The higher drainage density, the larger the surface is, the less possible it is to recharge the soil. (Mandal et al., 2016) demonstarte that the area with low drainage density is more suitable for the possibility of a good groundwater regeneration and higher weight should be assigned to it. Drainage density was calculated in the sample area using Kriging density estimation techniques. It was divided into five groups and weighted on the basis of its importance in the selection of suitable groundwater storage sites (figure. 3.8)

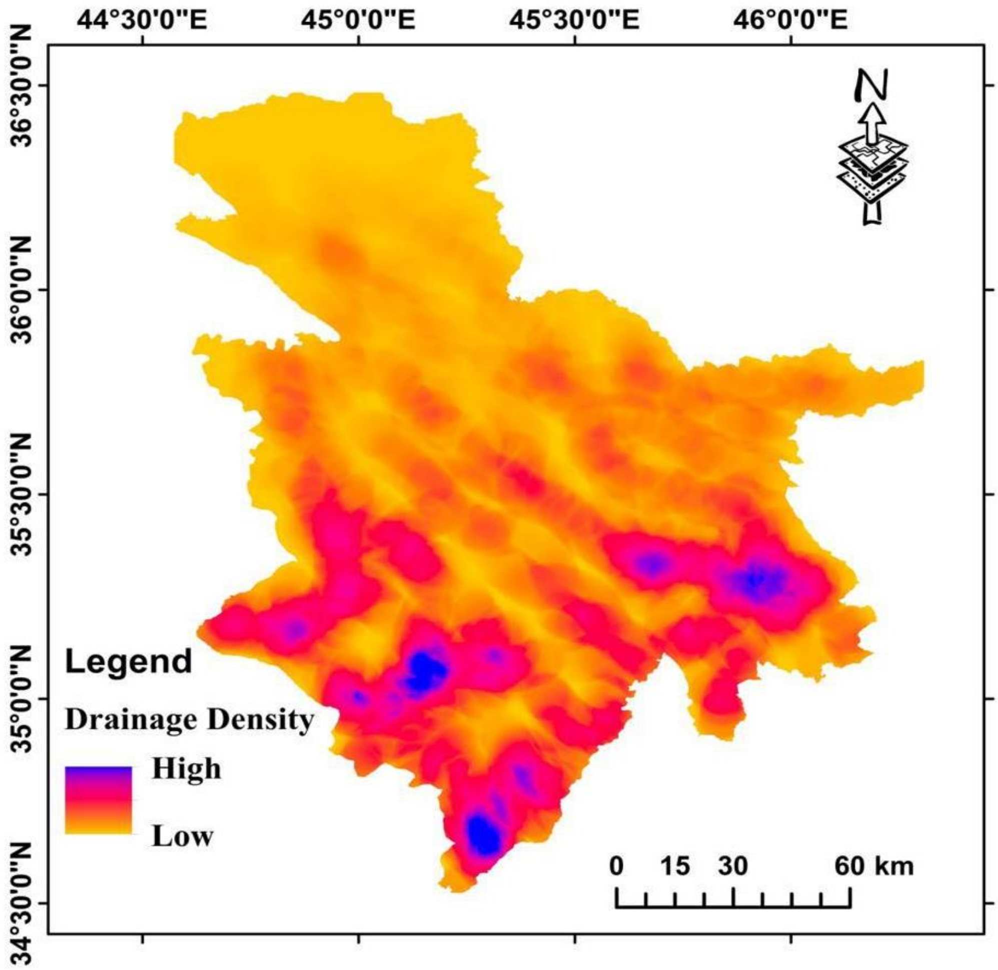

Figure 3.8: Drainage Density of Sulaimaniyha Province

3.3.4 Slope

The slope is created by a topographical proportion, which would be the connection of height differences of the two points divided by a horizontal straight line of two points (de Winnaar et al., 2007a), the course is taken from FAO. Description of the digital elevation model (DEM), which is listed as five percentage categories (de Winnaar et al., 2007b). Table 3.1 indicates the identification of the pistes in 5 positions.

Table 3.1: Slope Classification

No	Slope class	Slope %
1	Flat	< 2
2	Undulating	2 – 8
3	Rolling	8 - 15
4	Hilly	15 – 30
5	Mountainous	>30

Source: (de Winnaar et al., 2007a)

Steep slopes are a very critical consideration for the distribution and implementation of precipitation. High-rain mountainous regions are known as suitable high-runoff regions (de Winnaar et al., 2007a). The slope of the study area according to FAO as shown in figure 3.9. The research zone has moderate paths in the south-west, with steep hills and deep valleys in the north and northwest.

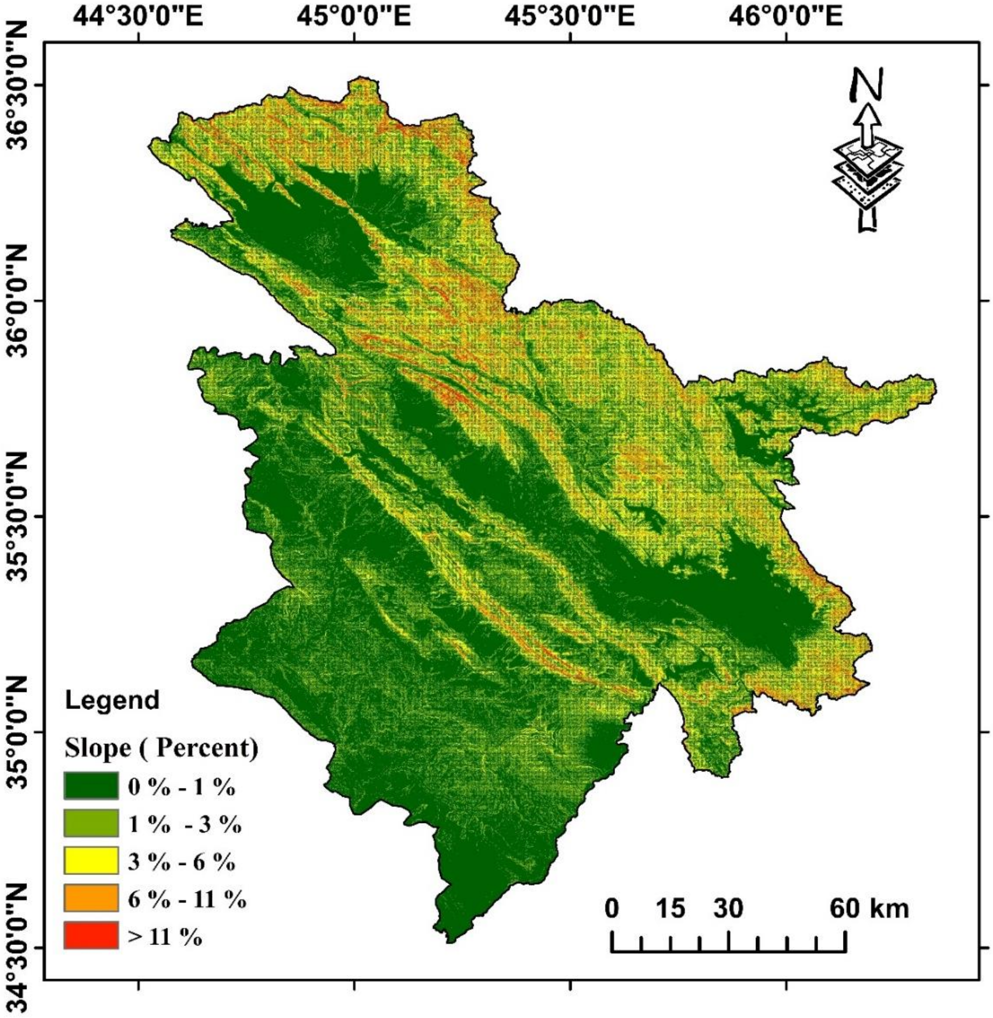

Figure 3.9: Slope Classification of Sulaimaniyah Governorate

3.3.5 Land use/ Land cover

Land cover was obtined from 30 m space-resolution from satellite imaging (Landsat 8) recorded in May 2020. The land cover was derived using ENVI software. A supervised grouping added a separate land cover/ land use type. Three classes of people were used for training site identification (Senf et al., 2015) in integrating fake colour composite pictures with a reference map and the Google map. An example of an educational class such as urban, agricultural, greenery, water and bare soil is a training site according to the scheme of Anderson level 1. Expectations for each knowledge class were generated through the training site characterization. For classifying ground cover the highest likelihood algorithm was used.

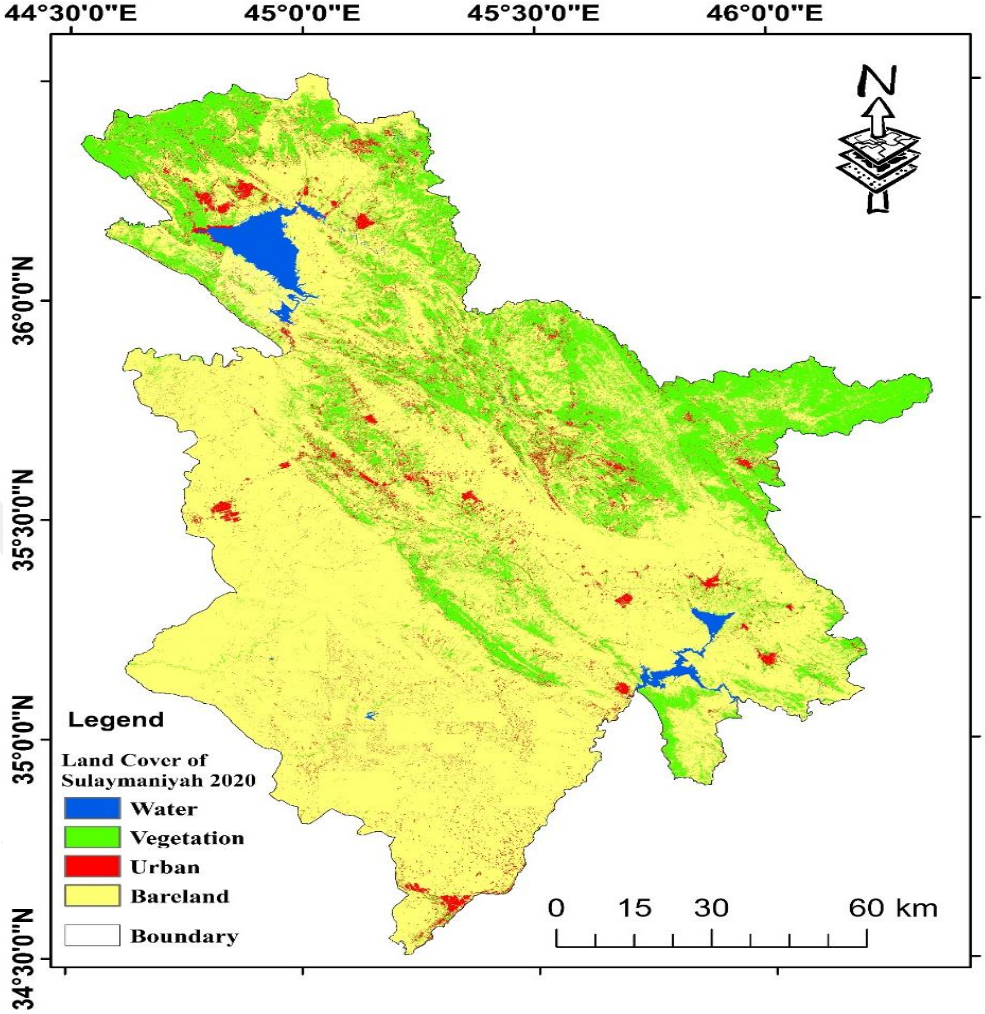

Figure 3.10: Sulaimaniyah Land Use Land Cover

The study area was utilized by four classes of land cover: bare land, urban, water and vegetation (Figure 3.10). When choosing suitable areas to pick water harvesting sites, ground cover is a significant parameter.

3.3.6 Soil map

Raster soil has been preserved (JPG) in appreciation soil of the three northern provinces in the Kurdistan Region's soil chart. In the geo-reference soil map, ArcGIS 10.4 was used and then translated to vector data. However, in the region under analysis, 9 groups were found see (figure 3.7). The area is characterized by virtuosic sandy soils, gypsum, shallow to mildly thick, highly gravel to extremely lime-rich loam silt. The brown soils, medium and low in lime- high gravel, gravel and silt with surface breaks. gravel and medium slight incidence. Brewery, medium and shallow process, lime-rich non-gravel, silt loam. Bakhtiary gravel. On uncovered claystone, chestnut deposits, steep and sloping layers, shallow to intermediate deepness, varying structure and gravel volumes. The rugged, breakable and stony soil with high gravel and stone content is medium to moderately deep and loamy to clay soils. Rough, mildly loamy, with a variable amount of soil, rocky outcrops (Buringh, 1960).

In the plain and mountain areas, the shape and colour of the soil are distinct. Strong clay sand, loam silt and silt mud, maximum depth 140 cm, are the composition of the soils in the plain areas. The soil colour ranges from light yellow to dark brown. The soil textures are sandy mud, loam silt or loam clay sand in the mountainous areas with an average depth 130 cm. Both light and dark light have a floor colour. The Iraq soil chart based on northern Iraq is shownn in figure 3.11.

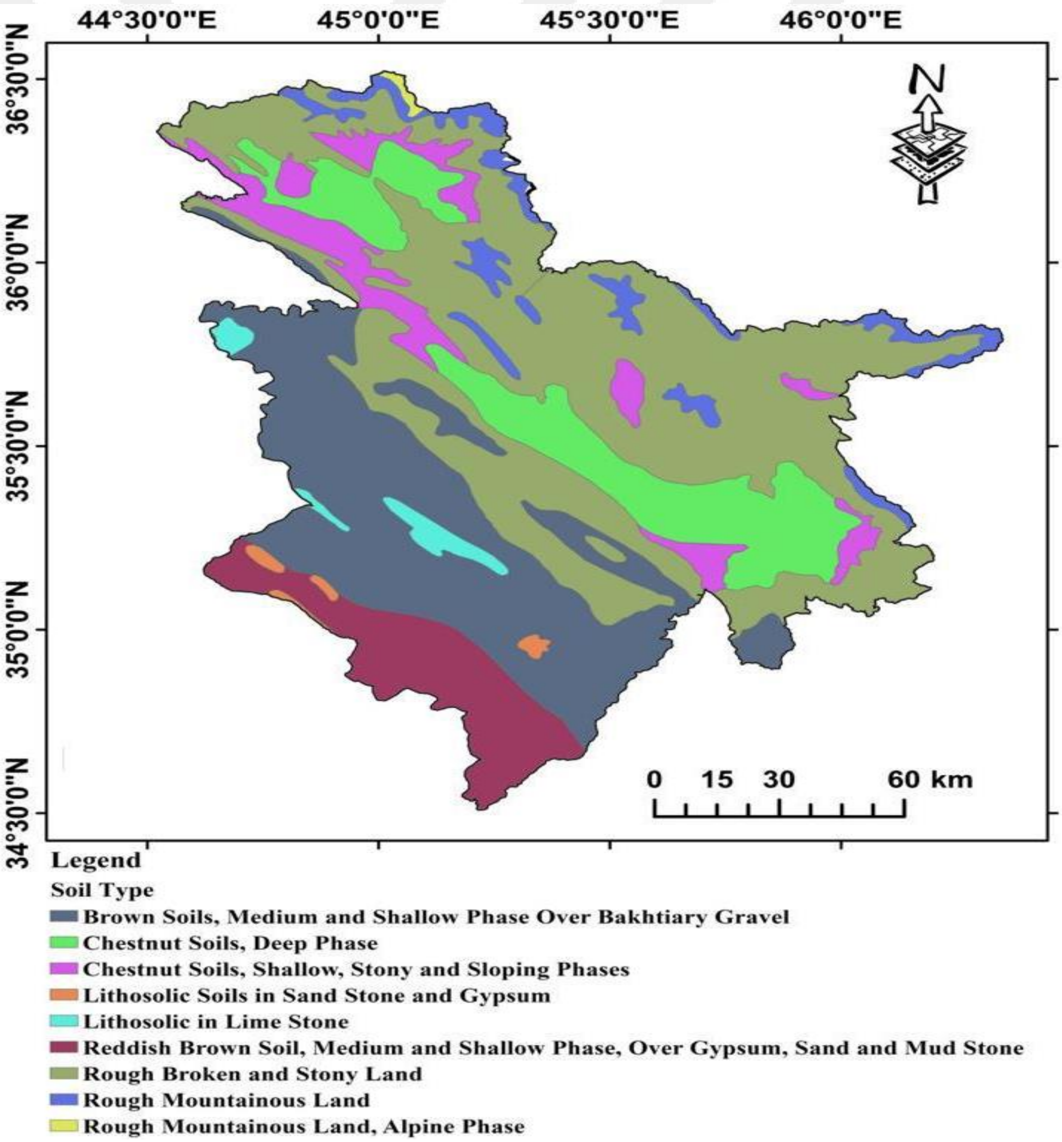

Figure 3.11: Soil Map of the Study Area

3.3.7 Soil conservation service - curve number model

Estimated runoff depth is a significant factor in the assessment of suitable site for rainwater harvesting. After a flood (Melesse & Shih, 2003) the runoff depth is used to tests the available water source. The soil conservation service and curve number (SCS) modelling were used to approximate the runoff depth in the sample area. The ground cover chart was obtained from remote sensing. ArcGIS 10.4 was used to compute precipitation data, and digitize the soil chart of the study area. The efficiency of soil communication system was used to determine the runoff depth from the precipitation for the preparation of water harvest (Gupta et al., 1997). The equation of the soil conservation service model can be expressed as below (McKinney et al., 1993).

$$Q = \frac{(P - Ia)2}{(P - Ia) + S} \qquad \mathbf{(3.2)}$$

Where:

Q: runoff depth (mm)

P: rainfall (mm)

S: potential maximum retention after runoff starts (mm)

Ia: initial abstraction (mm) its standard taken from TR55

Primary abstraction requires all lose before runoff, evaporation and vegetative interception water. By analysis rainfall estimation; Ia= 0.2S (Melesse & Shih, 2003) as assigned to several small field basins. Therefore, it is possible to express soil conservation service equation in the following terms:

$$Q = \frac{(P - 02S)2}{(P + 0.8S)} \qquad \mathbf{(3.3)}$$

By using the curve number (CN) in equation (3.4) the potential maximum retention after runoff starts can be calculated (S) (Melesse & Shih, 2003):

$$S = \frac{254000}{(CN)} - 254 \qquad \mathbf{(3.4)}$$

The strategy of the soil conservation service (SCS) focused on runoff curve number (CN). The effect of soil and land cover on precipitation processes is calculated at the curve number. The number of curves (CNs) range from 1 (100% absorption by rain) to 100. Lower curve numbers indicate lower runoff, while the higher curve numbers indicate higher ripples. Runoff values (Melesse & Shih, 2003).

3.3.8 Estimating curve number

Curve number used to identify drainage resources for a particular land-covered/ land use. The curve number value used as an input parameter in the soil preservation service runoff equation (HydroCAD 1986). For the study area, a pixel-by-pixel estimated number is calculated via the map on the land and the land map that was reclassified in soil hydrology and hydrology as shown in table 3.3. Infiltration relies on the soil feature that influences precipitation and runoff. In compliance with a united states geology study (UNGS), land use and property classification method (A, B, C, and D) (McKinney et al., 1993). Soil management project model separates all property into four hydrological soil classes. The classification of soil hydrology depending on penetration and various soil composition (Melesse & Shih, 2003). The hydrologic soil groups on the basis of the USGS classification system are defined in table 3.3. In the study area alone classes B, C and D have been found.

Table 3.2: Soil Groups and Corresponding Soil Texture

Soil Group	Runoff Description	Soil Texture
A	Poor runoff capacity due to high infiltration rates	Sand, loamy sand and sandy loam
B	Moderate infiltration rates contributing to reasonably runoff capacity	Silty loam and loam
C	High/moderate drainage capacity due to slow penetration speeds.	Sandy clay loam
D	High runoff capacity at very low infiltration rates	Clay loam, silty clay loam, sandy clay, silty clay, and clay

Source: (McKinney et al., 1993)

Hydrological Soil groups of the study area can be found in table 3.2 (see section 3.4.7). However, the hydrological soil groups in the study area are illustrated in figure 3.10.

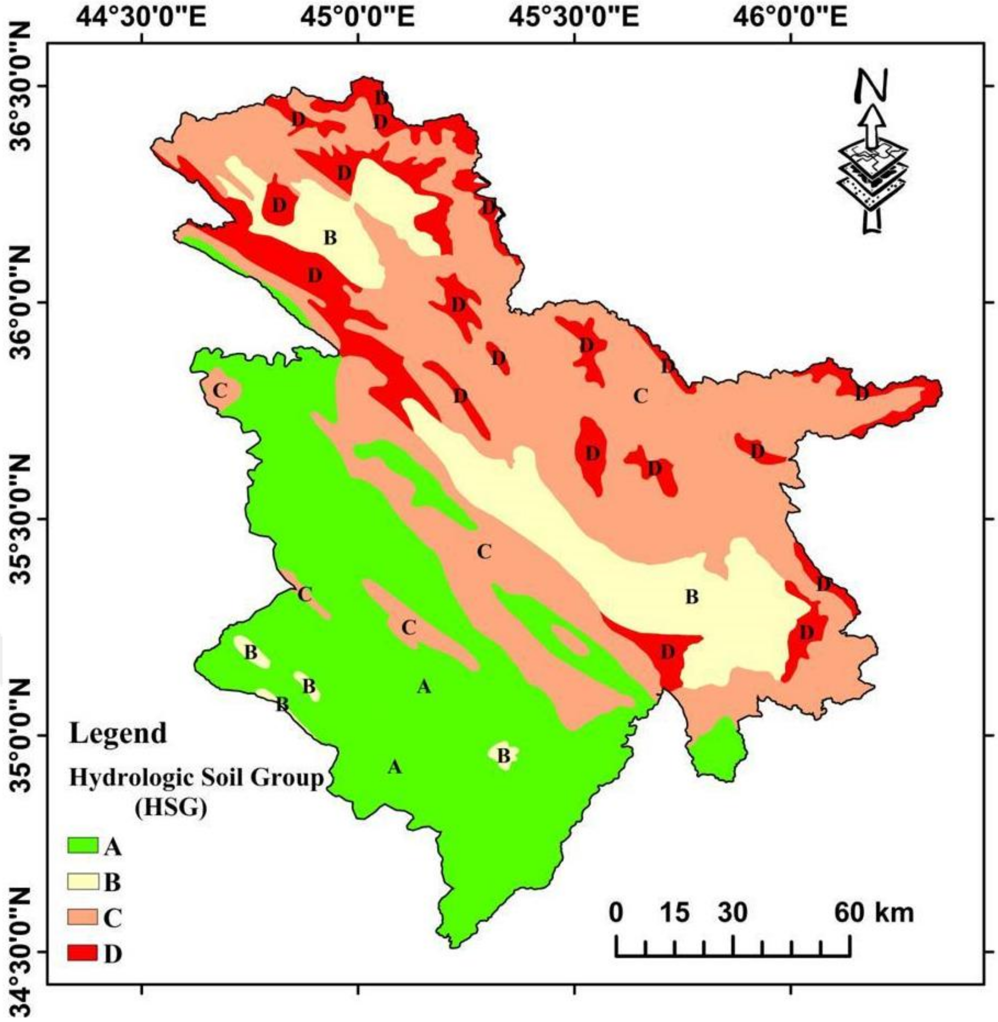

Figure 3.12: Classification Soil Map into Hydrologic Soul Group (A, B, C and D) In the Study Area

High runoff ability is found in the northern part of the area because this zone is stony and low-infiltration with mountain terrain. The colour of the soil is clay or clay silt. There is a mild runoff opportunity in the south of the sample region, as the soil types in the area range from undulating to plain. The colour of the surface is loam silt.

There are many factors that affect the hydrological conditions and have a close relationship with them such as land surface cover, drainage and reflect and the surface conditions in the basin (Munyao, 2010). In accordance with the map of the hydrological soil group in ArcGIS, the land cover given for in figure 3.8 can be used to align the hydrological soil group with land cover. (see Appendix 1). Table 3.4 present the extracted values of curve numbers from (Appendix 2) depending on USGS method (A, B, C and D)

Table 3.3: Runoff Curve Number for Combinations of Different Land Cover and Hydrological Soil Groups

Land Cover	A	B	C	D
Bare Soil	77	86	91	94
Other agriculture	49	69	79	84
Urban	77	85	90	92
Water	97	97	97	97

This led to the production of curve numbers using the U.S. Land Deck (USGS) and hydrologic soil group system (McKinney et al., 1993). Table 3.4 (Ebrahimian, 2012) presents the curve value of the number of each hydrological group of soils and the corresponding land cover class. A high curve number value (for example, 94) refers to an area with high runoff potential and low infiltration. A low curve number value (such as 49) suggests a region with a low runoff and high infiltration potential.

3.3.9 Evaluation runoff depth

After developing maps of curves showing initial rainfall abstrusion through vegetation and soil, the next step was to measure the maximum theoretically retaining value. Equation 3.4 determined the value of S for each pixel. Then in Equation 3.3 we used S to find the depth of runoff.

3.3.10 Evaluation of rainwater harvesting sites

For determining potential rainwater harvesting areas, not all factors have the same importance. Consequently, for the various factors, various weights were listed. The suitability of the site for rainwater depends upon a range of potential sites determining the best site by evaluating all of the sites' characteristics. The weights of the parameters known as the analytical hierarchical method (AHP) is calculated by the paired comparison. This methodology is focused on the application of various parameters (Drobne & Lisec, 2009). Analytical hierarchy process identifies the potential site for rainwater using the multi-criteria assessment module (Al-Subhi Al-Harbi, 2001). In choosing and specifying suitable locations, ArcGIS ecosystem has effective planning and decision-making instruments.

3.4 Multi Criteria Decision Making (MCDM)

GIS is not only a decision-making process, it is a method for decision-making. For that purpose, GIS analytical capabilities in site adaptation must be incorporated in weighting or decision making technologies such as Multi-Criteria Decision Methodes (MCDM). GIS is used for detailed research in the sense of a space decision, on the other hand, while the MCDM compares the set of specified choices (Joerin et al., 2001). Via the Boolean protocol or weighting procedure, MCDM may help achieve results as a fitting map for the particular objective (Fung & Wong, 2007). MCDM is a vital option since the effects are heavily influenced (Al-Shalabi et al., 2006). In accordance with the MCDM's characteristics and functionality, the specificity of the judgment issue (Abdullahi et al., 2014) (Salminen et al., 1998).

3.4.1 Selection criteria

The criteria are focused on the availability of data in the field of study. This study has used runoff, slope, drainage network, land cover type of soil. The runoff depth requirements for each pixel are highly significant in deciding which region has more rainwater than in other areas. The runoff depth was measured at each pixel using soil conservation service (SCS) model as explained in part of methodology (see section 3.3.7) in this study. The runoff depth ranges from 110 mm to 1021 mm/ year. In order to establish suitable area for saving rainwater, also runoff depth shall not be more than 500 mm/ year in previous studies (Tsiko & Haile, 2011).

Various slope types influence the infiltration and runoff volume, thus rainwater harvesting is strongly dependent on the type of slope (Munyao, 2010). However, the direction lowers the river flow. This helps the slope to decide whether the rainwater collection method is appropriate for a macro region (Tumbo et al., 2006). It is categorized in 5 groups, based on a percentage of organizations in food and agriculture: less than 1% is flat, 1% to 3% ondulated, 3% to 6% on roll, 6% to 11% hilly and more than 11% hilly. The rainwater harvest should not exceed 1 percent in a macro catchment and should not exceed 11 percent (Munyao, 2010).

The density of drainage is also a function of the method for collecting water. High drainage density in an area with adequate rainfall leads to higher runoff. Drainage density is also critical for the evaluation of acceptable storage sites or dam structures.

For rainwater harvesting, soil texture is critical since it identifies soil penetration rate and water storage (Tumbo et al., 2006). Fine soil, fine/medium soil, medium/coarse soil and coarse soil are used in this analysis. These groups are defined by the size and distance of soil particles which regulate water movement. Fine soils have high silt and clay proportion, resulting in high resistance to water, whereas rugged soils such as sand and leavened sands have large pores and thus high infiltration rates. Better than hard and medium soils for rainwater accumulation are fine and smooth soils (Tumbo et al., 2006). Table 3.4 illustrates the suitability of soil texture for rainwater harvesting.

Table 3.4: Suitability Level of Soil Texture From

	Optimally suitable	Highly suitable	Moderately suitable	Marginally suitable	Not Suitable
Soil texture	Clay	Silty clay	Sandy clay	Sandy clay loam & sandy loam	Other class

Source: (Tumbo et al., 2006)

41% of study areas, primarily in the south, are simpler and are used for agricultural purposes. Mountain and riparian areas are found in the northern portion, with wilderness, bare soils and open forests. Rainfall rate in the north part is higher than the south part of the sample region. As a result, farm land has been neglected and only mountain and riparian areas have been crowded to identify good locations for water storage. The main routes of the study region have used as a result of field geomorphology. Given that the rocky mountains are the primary part of the country, especially the northern part, and that roads play an important role in regional accessibility, any changes in road networks will have an impact on the socio-economic aspects. Areas around the path have been defined by boolean operations.

3.4.2 Analytic hierarchy process (AHP)

AHP is one of the most widely methods used multi- criteria evaluation (MCE). AHP has used in a wide range of practical applications in various areas, including site selection (Drobne & Lisec, 2009) (Abdullahi et al., 2014). All considerations do not have the same significance for the assessment of future dam site location. As a result, different level of value was established for the various variables.

3.4.2.1 Multi-attribute decision analysis

There are various approaches for combining decision-making into a multi-criteria decision analysis. The weighted linear combination (WLC) used in this thesis to calculate the sum of the weighted parameters. An empirical hierarchical technique, known as a pairwise comparison, is used to apply the WLC process. The weighted linear combination is performed in two steps within the GIS environment: first, the weights associated with the mapping layer parameters are determined. Second; the preference for all hierarchical tiers, including the alternate category, is combined (Drobne & Lisec, 2009).

3.4.2.2 Selecting criteria weights

Therefore, it is useful for decision-makers to consider the relative importance of the parameters. Decision making with several parameters involves different considerations. The decision-making mechanisms are focused on the weight of each factor and are the key step in assessing the weight (Drobne & Lisec, 2009). To gather the weights of the parameters the multi- criteria evaluation (MCE) module is used. In the study, the review process is a contrast in pairs (AHP). This approach was by (Saaty, 1977), each vector can be measured in pairs using the research method. The weight of the parameters in Saatys technology is determined by adding a square matrix of reciprocal equalization of the two variables (Drobne & Lisec, 2009). The comparison by pair compares two parameters to decide which condition for a given function is more relevant than another. Table 3.5 indicates the two-criteria rating (Saaty, 1977, Drobne & Lisec, 2009).

Table 3.5: The Intensity of Relative Importance

Intensity of Importance	Definition
1	Equal Importance
2	Equal to moderate Importance
3	Moderate Importance
4	Moderate to strong Importance
5	Strong Importance
6	Strong to very strong Importance
7	Very strong Importance
8	Very to extremely strong Importance
9	Extremely Importance

Source: (Drobne & Lisec, 2009)

The following measures should be taken in considration to determine the weights of the criteria:

1. Build a corresponding matrix of the parameters. The definition of the pairwise comparison matrix seen in table 3.6, which applies to the intersection of the same parameters in the raw column as seen in the diagonal of the matrix (grey colour). The C1.3 cell applies to the value of criteria 1 rather than criteria 3. Determine the number of the values in each column of pairwise matrix in this step. In this study, five criteria were consider and priority was given to the criteria set out in the previous studies and to the opinions of the expert by means of a questionnaire to be explained later in this chapter. As well as, the sub-criterion of each of the major variables often assumed the same as the main criteria.

Table 3.6: The Pairwise Comparison Matrix

	Runoff Depth	Slope	Soil texture	Drainage Density	Land Use
Runoff Depth	1	2	3	4	5
Slope	0.4	1	2	3	4
Soil texture	0.36	0.4	1	2	3
Drainage	0.3	0.3	0.4	1	2
Land Use	0.2	0.3	0.33	0.4	1
Summation	2.28	4.4	6.8	10.5	15

2. A questionnaire been done to collect and record information on a particular issue. It consists a list of questions with providing clear instructions and room for answers and administrative information. We did the questionnaires for a specific purpose that related to the goals of research and we use the findings clearly from the start.

3. Quantitative and qualitative research, i.e. numerical research (how many? how often? how satisfied?), normally relates to structured questionnaires. Frame works can be use in a number of survey situations. In this context.

4. In this analysis, the questionnaire is structured to provide an opinion on the weight ages of environmental evaluation parameters and the importance of some experts who have known- how in various fields of study. This

questionnaire consists of a matrix for comparison in parallel in this analysis; the experts who assign preference to the element (see the appendix 3).

5. The normalized matrix computed in this step. To fill the values of normalized matrix, divide each cell in the pairwise matrix by its total column see (table 3.7). The sum of each row is then determined from the resultant in table 3.7. These ratios are the proportional weights of the parameters.

Table 3.7: Normalized Matric Calculation

	Runoff Depth	Slope	Soil texture	Drainage	Land Use	Weight %
Runoff Depth	0.44	0.45	0.44	0.38	0.33	0.41
Slope	0.22	0.23	0.29	0.29	0.27	0.26
Soil texture	0.15	0.11	0.15	0.19	0.20	0.16
Drainage	0.11	0.08	0.07	0.10	0.13	0.10
Land Use	0.09	0.06	0.05	0.05	0.07	0.06

3.4.2.3 Estimating consistency of pairwise comparison

The specificity of the relationship is determined by the compatibility ratio (CR) measurement (see equation 3.5). For measuring the relative weighting of each parameter, the precision ratio is used. The precision ratio is the relationship between the Consistency Index (CI) and the Random Index (RI). The comparison of the variables is appropriate if the precision ratio is less than 10%. The accuracy ratio otherwise causes comparisons to be reevaluated.

$$CR = \frac{CI}{RI} \qquad (\mathbf{3.5})$$

The Random Index (RI) can be retrieved from a particular table prepared by (Saaty, 1977), based on the order of the matrix. Table 3.7 displays the values of the random variable by the number of parameters.

Table 3.8: Average Random Consistency Index (RI)

Number of criteria (n)	1	2	3	4	5
Random Index (RI)	0	0	0.58	0.9	1.12

Source: (Drobne & Lisec, 2009)

To obtain the consistency ndex (CI) we follow this way;

Multiply the weight of the first criterion (runoff depth = 0.41) in Table 3.7 by the total of the first column of the original pairwise comparison matrix which is equal to 2.28 in Table 3.6 Then multiply the weight of the second criterion (slope) by the total of the second column of the original pairwise comparison matrix. Repeat this procedure for all weight criteria. Finally, the summation of these values gives the consistency vector (ʎ = 5.11), which is used to compute the consistency index according to equation 3.5.

The consistency Index (CI) has been calculated by using equation 3.6:

$$CI = \frac{\lambda\text{max} - \text{n}}{n - 1} \quad (\mathbf{3.6})$$

Where:

λ max = (Weight1*S1 + Weight2*S2+ Weight3*S3+…………)

n = number of criteria

The value of the consistency index from the above process is 0.027. We applied consistency ratio equation (CR) of this study and the result is 2 %, which is less than 10%, so the comparison between the factors is acceptable. while if the CR rate more than 10% the comparison between the factors will be not acceptable and we should recheck the work.

4. RESULTS

In this study, an Adequacy Map was created in the ArcGIS setting using the AHP tool and graded into five suitability classes: bad, medium, decent, very high satisfaction. The resulting map reveals that the central and southern regions are ideal for rainwater harvesting potential areas. The proposed rainwater collection sites are made from highly desirable locations. However, some regions of the North part, some areas of the North East and some parts of the Northwest in the study area are listed as less acceptable and suitable.

4.1 Rainfall analysis

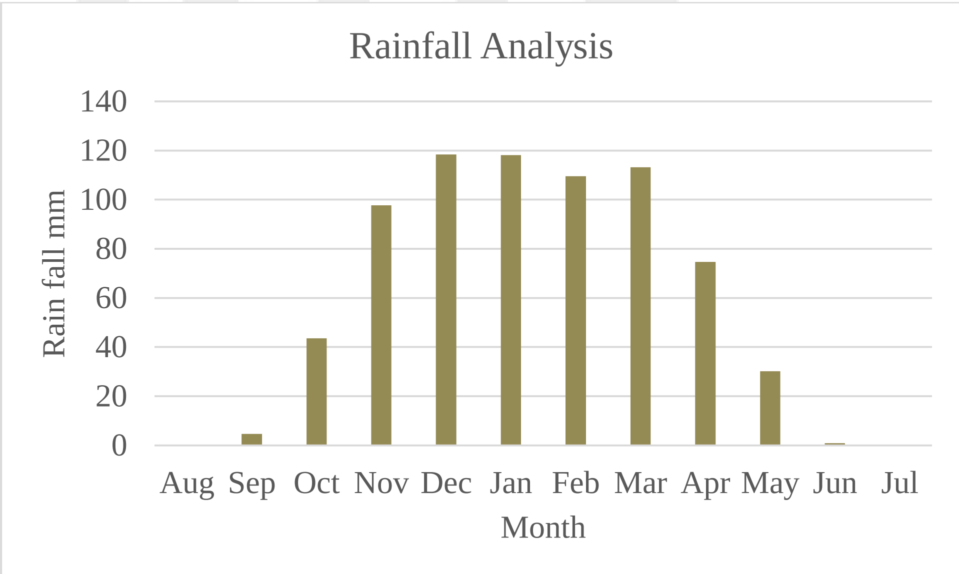

Figure 4.1: Average of Monthly Rainfall in the Study Area 2009 - 2019

The weather in the study site between the Mediterranean and the warm steppe climate is changing. Moist and dry conditions for this climate are typical (Kahraman, 2004). The typical 10- year data shows the season of precipitation indicated from October to May. Between June and September the dry season takes place. Figure 4.1 shows the average rainfalls per month for 2009-2019. The global average annual runoff from December to April in the high rainy season to the rate of 75%. The short rainy season between May and June and September and December adds up to 25% to the usual runoff year, while the rainy period in July and August is almost zero.

4.2 Potential Runoff

The runoff potential in the study area for regular rainfall years was divided into 5 layers which were not appropriate (> 813 mm), less appropriate (662-813 mm), appropriate (529-662 mm), quite appropriate (404-529 mm) and suitable (< 404 mm). Fuzzified runoff depth layer map reveals that a large part of the sample region is very suitable for extremely suitable applications. A substantial portion of the research area is also ideal for the storage of rainwater in terms of runoff depth. However, some of the eastern, northern and northeastern regions of the study region are less suitable for rainwater harvesting (figure .4.2).

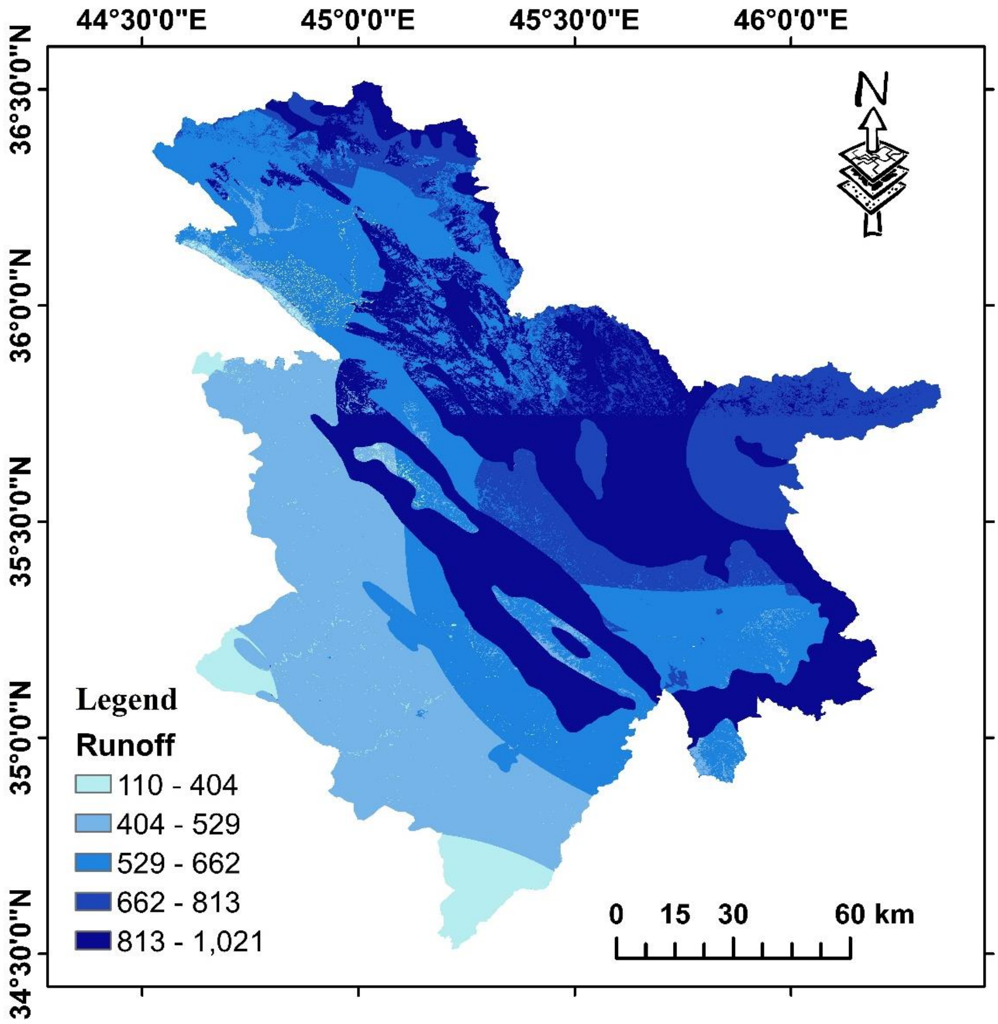

Figure 4.2: Potential Runoff Map

Curve numbers (CN), based on the use of equations, are obtained to classify the potential runoff. The curve number is based on two multivariate constructs, namely the land use group and the hydrological soil group (HSG).

The HSG map is drawn up from the manual TR 55 soil series. Depending on the penetration and drainage capacity, the soil is classified into four classes A, B, C and D known as HSG. The key features of HSG (Weerasinghe et al., 2011) are set out in Table 3.3. The scale of the HSG area is seen in figure. 3.12.

4.3 Soil

Soil map of study area shows 9 main groups as seen in (figure 3.11) the major portion of the area was covered by rugged fractured and stony ground. Spread over 7158 km^2 in the central and southern sections of the study country. The next main soil groups are grey, medium and low over 4353 km^2, followed by chestnut, which cover 2226 km^2 in the 3rd section. Bakhtiary gravel 4353 km^2 Four reddish-brewed soils, medium and shallow level, in a patch covering an area of 1418 km^2 gypsum, sand and dung stone are extracted. The chestnut soils, shallow, stony and sloping phases occupy 1196 km^2. The rough mountainous and lithosoilic soil in the limestone occupied 744 km^2 and 234 km^2 respectively. The last section covering the lithosoil bit region is sandstone & gypsum soil and rugged mountainous terrain, alpine process 94 km^2 and 28 km^2. The fuzzified existing soil outcome has also shown that some areas of the area of study are from an exceptionally suitable class for RWH, except in the central mountainous zones, the northern, north-eastern and some western parts of the study.

4.4 Slope

The findings for fuzzification showed that the most southern and central portion of the sample region is < 1, which is very fine for RWH. However, significant part of the research area in eastern and north regions are more than 11 fluctuation values, which is considered not suitable for water harvesting. The area's pathways were classified into five-pitch grades, including approximately 0–1%, mild 1–3%, fairly smooth 3–6%, fairly steep 6–11%, very steep >11% respectively. Eastern and southerly regions, As well as the central section of the areas, the higher altitudes are covered, such as the Mount, which creates steep slopes in the northern part. Certain central parts of the study area to the south-west are appropriate for RWH (figure 3.9).

4.5 Drainage density

Drainage density ranged between 1.5 < and > 2 / km^2 within the sample area. The findings of the fluctuation in the drainage density show that the south and western areas of the research region are highly well matched. In the south-east and the north of the study area, though, unique regions are less fit. The area with broad irrigation surface densities is less favourable for collecting rainwater on the ground surface and is thus superior to low surface drainage area according to the point of view of rainwater harvesting as shown in the (figure 3.8).

4.6 LULC

The LULC map of the area classified into four categories, such as bare land, water, urban and vegetation. The largest part of the study area of 125552 km^2 is covered by bare soil, followed by vegetation of 3703 km^2 and urban area of 854 km^2 and the remainder by water of 313 km^2. Fuzzified LULC map reveals that the central and southern sections of the study show vegetation and bare land ideal for rainwater harvesting. While the area under the settlement is fuzzified as not appropriate with membership value 0 as shown in (figure 3.10).

4.7 Rainwater Harvesting Potential Map

Run-off depth, slope, land use/land cover, soil texture and drainage density combined in multiple capacities provided appropriate units for assessment of rainwater development sites. ArcGIS used a multi-criteria appraisal (weight linear combination) in a model constructor in the criterion layers. Map showing the possible sites for rainwater harvesting in the Sulaimaniya Governorate (figure 4.3).

The multi-criteria evaluation study contributed to assessing general rainwater harvesting suitability zones. Five comparable units suggested alternative locations for water collection: excellent, very good, good, moderate and poor. The constraint area (built-up layer) was not the required area. figures 4.3 and 4.4 show possible rainwater collecting sites and the proportion of the area that is protected by numerous water harvesting suitability areas.

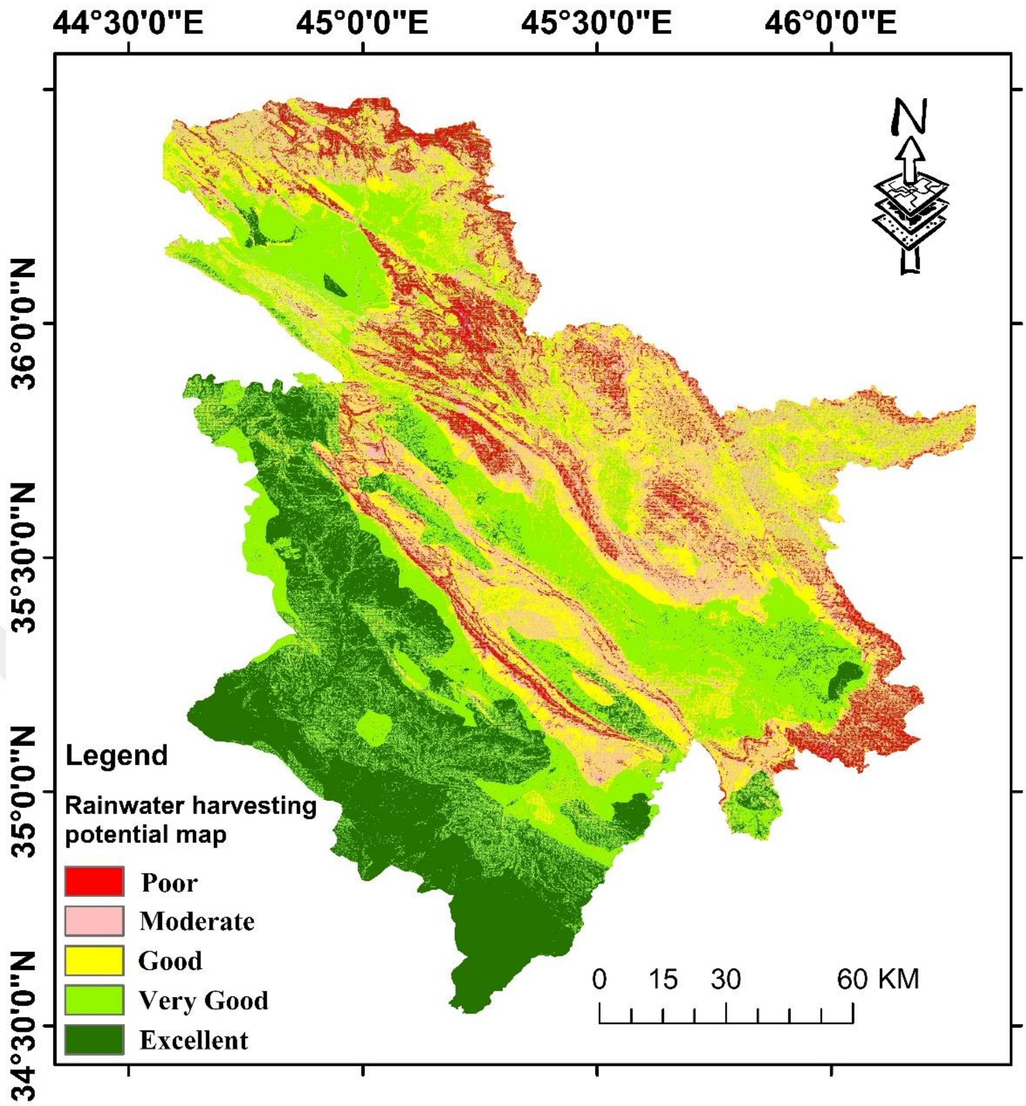

Figure 4.3: Rainwater Harvesting Potential Map for the Study Area

Most northern areas of the study region were determined to be not ideal for the collection of water. The northern area is clearly concentrated in the steep slopes and thick hydrological system. High above 529 m and steeper than 11% on slopes are the key areas decided as acceptable areas for water development. In the southern part of the research, region are the main areas that are known as a medium- and medium-aptitude regions. These areas are less than 529 m long and less than 6% on the slopes. Areas with low to very low water harvest suitability are more influenced by runoff depth and slope than by other criteria. Future water harvest sites map indicates that nearly 79557.42 km^2 of desirable and highly acceptable areas are protected. There are nearly 36518.16 km^2 of low and low-fit areas, while the moderate area of fitness is just 14346.42 km^2.

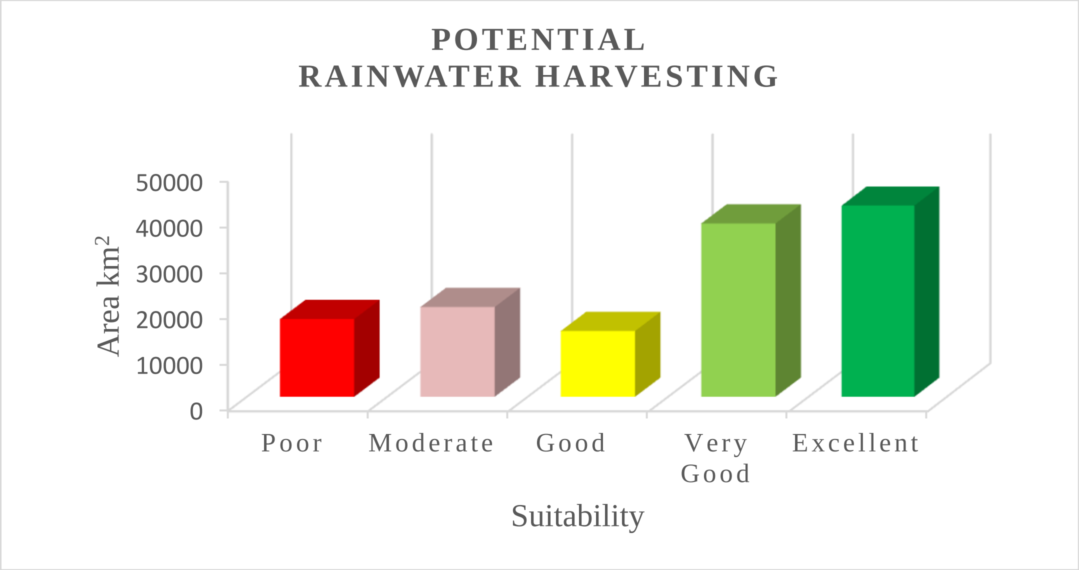

Figure 4.4: Percentage of Areas Suitability for Rainwater Harvesting

The areas that not recommended for RWH and its poor area 13%. Also, 15% rated as moderate. As well as 11% of the total area considered as good. The very good area that extracted for water harvesting is 29%. The rest 32% are exceptionally excellent for collecting rainwater.

5. DISCUSSION

The Acknowledgement as a multi-objective and multi-criteria issue of a suitable site for water collection in the study area. This research varies from other experiments in the amount of determining factors used such as Rainfall, Slope, Soil texture, DD and LULC. The five factors that used to assess suitable water locations. In this study the amount and weight of each factor depend on the number and percentage of the use of each factor in the literature papers.

Climate change brings enormous challenges to the sustainability of socio-economic developments around the world. Its effects will overreact to arid and semi-arid areas, where the economies depend heavily on climate conditions, like rain fed farming. The rainwater harvesting is identified and internationally agreed on a solution for having accessible water for agricultural and related activities.

The current study produces the future selection model for rainwater sites by identifying more influential and appropriate variables to select possible sites using the AHP modeling method. The correlation coefficient between each factors listed was near zero for most of the variables, which implies, excluding rainfall-runoff correlation, that there is no structural codifying between the variable. The surface rinse is an important hydrological measure in surfactants and associated experiments. The advanced rainfall-runoff is a non-linear, dynamic and complicated mechanism and has multiple physical and sometimes interrelated variables. The estimation of downtime from conventional methods is complex, fault-prone, costly and time-consuming due to inaccessible areas. For the calculation of runoff depth, comprehensive and precise spatial knowledge is required for the test area.

The research proposes an optimized approach to modelling the spatiotemporal pattern of runoff areas with remote-sensing feedback and GIS supporting data using the SCS-CN-model (T. Kumar & Jhariya, 2017). In this form of hydrological analysis integration of RS and GIS is a successfully applied solution (Shamsi, 2005); (Haile & Suryabhagavan, 2019).

All requirements for research identified were not equally relevant for selecting possible RWH sites in the sample area. This disparity has been handled in order to represent the weight of each criterion through multifactor assessment of the weighted linear aggregation approach for weight estimation. This can be successful as it allows the decision-makers to take all aspects decision carefully into account. Important metrics may have a stronger effect on the outcomes by assigning objective weights than other metrics. Although the selected requirements have been weighted, minimal and undesirable application areas need to be regarded as restrictions.

the selecting acceptable sites by reducing the water's flow rate, encouraging the sediment to settle, and minimize erosion. This ensures that land and water are covered (Potter & Zhang, 2009). Underneath the rinse field, percolation tank sites with an earth gradient of 3% - 6% that allows water to percolate across layers were identified. Percolation tank is valuable to the environment when the water flows continuously and steadily into an aquifer (Wang et al., 2011).

The zone of excellent to very good groups was mostly populated with land slopes between 0°C and 6°C. The current geological and geomorphological characteristics make a high level of water penetration and groundwater regeneration.

The method used in this study, was RS and GIS techniques, is of great significance and benefits to the management of water resources in the Sulaimaniyah governorate and else where in Iraq. The SSGWR maps are useful for the management and protection of water supplies and identify suitable locations for different methods of water harvesting.

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Choosing an appropriate water harvesting location in most of the world's cities is an important task. The most popular tools for these purposes are remote sensing and GIS. Remote sensing offers data and knowledge on the research region while GIS involves spatial processing and simulation in order to generate appropriate locations. In addition to the devices, a process or technique for determining the conditioning factors that lead to water harvest suitability at the field. Decisions based on AHP are among the common techniques used in literature. AHP and the decision-making mechanisms have been incorporated in this study. The weights subsequently came from decision-making models and the appropriateness maps were developed in GIS. The model was analysed and compared with a new methodology.

Multiple dependent variables, such as land cover, soil texture, slope, drainage density and runoff, were considered for multi-criteria assessment, land cover was taken from a 30-metre LANDSAT satellite image. The Iraq Kurdistan Governorate, soil map has been digitized. The pitch 2 of the slope was drawn by the digital elevation model. A digital elevation model derived the drainages density map. Furthermore, the soil control model was used to assess the depth of runoff in the study area. The parameter values have been reclassified from zero to one to hit a single 30 meters standard on each sheet as numerical values.

In Sulaimaniyah area, the model for the conservation of the soil was applied to estimate the river depth using average annual rainfall from 2009 to 2019. The precipitation study reveals that a considerable annual depth of rainfall can be harvest. The outcome show that the runoff depth volume is greater than the reservoir water storage capacity. These excess water volumes guarantee that the rainy season tanks are filled. The findings also reveal that the volume of rush in the north and the south portion of the sample region is very different. The mean depth of runoff in the south section is about 110 mm, whilst the estimated depth of runoff in the northern section is more than 1000 mm.

A multi-criteria assessment model was used to assist decision-makers in choosing appropriate areas for water harvesting in the Study area a ride and semi-arid zones. GIS advocates multi-criteria testing that incorporates multiple forms of criteria in order to make the right decision. Then a nuanced question can quickly be addressed, and a multi-criteria assessment can help make the unclear decision correct. The assessment of multi-criteria was helpful by the systematic use of the AHP for the creation of an effective strategy for precipitation technologies.

Collection artificial rainwater are promising strategies for addressing water shortage challenges successfully by rising long-term sources of water. This research reveals a rigorous approach for extracting possible sites using AHP techniques in order to tackle this problem. If reliable data are available, this technique would be more efficient and helpful, especially in inaccessible regions where rainwater reaping is needed in order to improve water protection and water production. The use of rainwater technology allows the city directly to mitigate the crisis in water. The central and southwest areas of the research region are very suited to rainwater harvesting because of the effects of this research raining and soil texture. The adequacy of this area for the RWH provides a good chance for rainwater storage and irrigation of nearby agriculture.

In conclusion overall, The highly suitable regions are 32 % of the area and 29 % of the area are suitable. as well as 11 % of the area are fine. While the remaining 28 % is less and not desirable. Rainwater development should be extended by a field analysis because the geographical reach of the survey does not guarantee that all locations in a zone defined as low-level areas are still low-level areas. Any location in the region identified as suitable does not mean that it is appropriate, as some of these locations may be socially influenced by enclosed areas, small villages or other hydraulic factory systems.

6.2 Recommendation

While this study has developed and proposed AHPs for the identification of the appropriate water harvesting venues in the area studied, the following points can be further improved:

1. Use LiDAR data to draw out detailed parameters of geomorphology and hydrology.
2. Develop the precise and consistency of land use cover maps by satellite pictures focused on objects and with very high resolution.
3. Perform further validation experiments using various types of data and fields of study.
4. Developing programming machine learning to reduce the time and getting a good result.
5. Developing new effective and economical data collection technology.
6. Enhancement of data analysis tools to be faster and conveniently.

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APPENDIX

Appendix 1: Shows the Resulting Union between the Land Cover and HSG

from essentially 0 micrometers per second (0 inches per hour) to 0.9 micrometers per second (0.1 inches per hour). For simplicity, either case is considered impermeable for hydrologic soil group purposes. In some cases, saturated hydraulic conductivity (a quantitatively measured characteristic) data are not always readily available or obtainable. In these situations, other soil properties such as texture, compaction (bulk density), strength of soil structure, clay mineralogy, and organic matter are used to estimate water movement. Tables 7–1 and 7–2 relate saturated hydraulic conductivity to hydrologic soil group.

The four hydrologic soil groups (HSGs) are described as:

Group A—Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.

The limits on the diagnostic physical characteristics of group A are as follows. The saturated hydraulic conductivity of all soil layers exceeds 40.0 micrometers per second (5.67 inches per hour). The depth to any water impermeable layer is greater than 50 centimeters [20 inches]. The depth to the water table is greater than 60 centimeters [24 inches]. Soils that are deeper than 100 centimeters [40 inches] to a water impermeable layer are in group A if the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface exceeds 10 micrometers per second (1.42 inches per hour).

Group B—Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.

The limits on the diagnostic physical characteristics of group B are as follows. The saturated hydraulic conductivity in the least transmissive layer between the surface and 50 centimeters [20 inches] ranges from 10.0 micrometers per second (1.42 inches per hour) to 40.0 micrometers per second (5.67 inches per hour). The depth to any water impermeable layer is greater than 50 centimeters [20 inches]. The depth to the water table is greater than 60 centimeters [24 inches]. Soils that are deeper than 100 centimeters [40 inches] to a water impermeable layer or water table are in group B if the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface exceeds 4.0 micrometers per second (0.57 inches per hour) but is less than 10.0 micrometers per second (1.42 inches per hour).

Group C—Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.

The limits on the diagnostic physical characteristics of group C are as follows. The saturated hydraulic conductivity in the least transmissive layer between the surface and 50 centimeters [20 inches] is between 1.0 micrometers per second (0.14 inches per hour) and 10.0 micrometers per second (1.42 inches per hour). The depth to any water impermeable layer is greater than 50 centimeters [20 inches]. The depth to the water table is greater than 60 centimeters [24 inches]. Soils that are deeper than 100 centimeters [40 inches] to a restriction or water table are in group C if the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface exceeds 0.40 micrometers per second (0.06 inches per hour) but is less than 4.0 micrometers per second (0.57 inches per hour).

Group D—Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential. All soils with a depth to a water impermeable layer less than 50 centimeters [20 inches] and all soils with a water table

Appendix 2: Curve Number (CN) Indices Under AMC II Condition Based on TR 55 Table.

Land use classes	Hydrologic soil group			
	A	B	C	D
Forest	30	55	70	77
Rubber	61	70	77	80
Oil palm	71	80	87	90
Grassland	71	81	84	87
Paddy	60	72	80	84
Other agriculture	64	75	82	85
Bare soils	49	69	79	84
Urban	77	85	90	92
Water	97	97	97	97

Appendix 3: Questionnaire

Example:

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage	Land Cover
Runoff Depth	1	2*1			
Slope		1	3*2		
Soil texture			1		
Drainage				1	
Land Cover					1
Summation					

It means:

*1 Criteria 1, which is Runoff, Is Equal to moderate importance than criteria 2, which is Slope.

*2 Criteria 2, which is Slope is of stronger importance than criteria 3, which is Soil texture.

According to the table of "Intensity of importance definition", what value do you specify from among the degree of significance of each main objective towards others?

Criteria

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage Density	Land Use
Runoff Depth	1	3	3	4	5
Slope	0.33	1	4	3	4
Soil texture	0.33	0.25	1	2	3
Drainage	0.25	0.33	0.5	1	5
Land Use	0.20	0.25	0.33	0.2	1
Summation	2.11	4.83	8.83	10.2	18

Example:

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage	Land Cover
Runoff Depth	1				
Slope		1			
Soil texture			1		
Drainage				1	
Land Cover					1
Summation					

It means:

*1 Criteria 1, which is Runoff, Is Equal to moderate importance than criteria 2 which is Slope.

*2 Criteria 2, which is Slope is of stronger importance than criteria 3 which is Soil texture.

According to the table of "Intensity of importance definition", what value do you specify from among the degree of significance of each main objective towards others?

Criteria

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage Density	Land Use
Runoff Depth	1	4	4	2	2
Slope	0.25	1	3	3	3
Soil texture	0.25	0.33	1	2	2
Drainage	0.5	0.33	0.5	1	2
Land Use	0.50	0.33	0.5	0.5	1
Summation	2.5	6	9	8.5	10

2

70

Example:

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage	Land Cover
Runoff Depth	1	2*1			
Slope		1	3*2		
Soil texture			1		
Drainage				1	
Land Cover					1
Summation					

It means:

*1 Criteria 1, which is Runoff, Is Equal to moderate importance than criteria 2, which is Slope.

*2 Criteria 2, which is Slope is of stronger importance than criteria 3, which is Soil texture.

According to the table of "Intensity of importance definition", what value do you specify from among the degree of significance of each main objective towards others?

Criteria

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage	Land Cover
Runoff Depth	1	1	2	2	8
Slope	1.00	1	1	5	7
Soil texture	0.5	1	1	2	4
Drainage	0.5	0.2	0.5	1	2
Land Cover	0.13	0.14286	0.25	0.5	1
Summation	3.125	3.34286	4.75	10.5	22

Example:

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage	Land Cover
Runoff Depth	1	2*1			
Slope		1	3*2		
Soil texture			1		
Drainage				1	
Land Cover					1
Summation					

It means:

*1 Criteria 1, which is Runoff, Is Equal to moderate importance than criteria 2 which is Slope.

*2 Criteria 2, which is Slope is of stronger importance than criteria 3 which is Soil texture.

According to the table of "Intensity of importance definition", what value do you specify from among the degree of significance of each main objective towards others?

Criteria

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage Density	Land Use
Runoff Depth	1	1	4	4	6
Slope	1.00	1	4	5	3
Soil texture	0.25	0.25	1	3	3
Drainage	0.25	0.2	0.33	1	1
Land Use	0.17	0.33	0.33	1	1
Summation	2.66	2.78	9.66	14	14

2

Example:

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage	Land Cover
Runoff Depth	1	2[*1]			
Slope		1	3[*2]		
Soil texture			1		
Drainage				1	
Land Cover					1
Summation					

It means:

[*1] Criteria 1, which is Runoff, Is Equal to moderate importance than criteria 2, which is Slope.

[*2] Criteria 2, which is Slope is of stronger importance than criteria 3, which is Soil texture.

According to the table of "Intensity of importance definition", what value do you specify from among the degree of significance of each main objective towards others?

Criteria

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage Density	Land Use
Runoff Depth	1	1	2	4	5
Slope	1	1	2	2	6
Soil texture	0.5	0.5	1	2	4
Drainage	0.25	0.5	0.5	1	2
Land Use	0.2	0.16	0.25	0.5	1
Summation	2.95	3.16	5.75	9.5	18

Example:

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage	Land Cover
Runoff Depth	1	2*1			
Slope		1	3*2		
Soil texture			1		
Drainage				1	
Land Cover					1
Summation					

It means:

*1 Criteria 1, which is Runoff, Is Equal to moderate importance than criteria 2, which is Slope.

*2 Criteria 2, which is Slope is of stronger importance than criteria 3, which is Soil texture.

According to the table of "Intensity of importance definition", what value do you specify from among the degree of significance of each main objective towards others?

Criteria

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage Density	Land Use
Runoff Depth	1	2	2	3	5
Slope	0.50	1	1	2	6
Soil texture	0.5	1	1	2	2
Drainage	0.33	0.5	0.5	1	1
Land Use	0.20	0.16	0.5	1	1
Summation	2.53	4.66	5	9	15

2

Example:

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage	Land Cover
Runoff Depth	1	2[*1]			
Slope		1	3[*2]		
Soil texture			1		
Drainage				1	
Land Cover					1
Summation					

It means:

[*1] Criteria 1, which is Runoff, Is Equal to moderate importance than criteria 2 which is Slope.

[*2] Criteria 2, which is Slope is of stronger importance than criteria 3 which is Soil texture.

According to the table of "Intensity of importance definition", what value do you specify from among the degree of significance of each main objective towards others?

Criteria

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage Density	Land Use
Runoff Depth	1	2	2	4	3
Slope	0.50	1	2	5	2
Soil texture	0.5	0.5	1	5	2
Drainage	0.25	0.2	0.2	1	1
Land Use	0.33	0.5	0.5	1	1
Summation	2.58	4.2	5.7	16	9

2

Example:

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage	Land Cover
Runoff Depth	1	2*1			
Slope		1	3*2		
Soil texture			1		
Drainage				1	
Land Cover					1
Summation					

It means:

*1 Criteria 1, which is Runoff, Is Equal to moderate importance than criteria 2, which is Slope.

*2 Criteria 2, which is Slope is of stronger importance than criteria 3, which is Soil texture.

According to the table of "Intensity of importance definition", what value do you specify from among the degree of significance of each main objective towards others?

Criteria

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage Density	Land Use
Runoff Depth	1	4	2	5	3
Slope	0.25	1	2	3	2
Soil texture	0.5	0.5	1	2	5
Drainage	0.2	0.33	0.5	1	4
Land Use	0.33	0.5	0.2	0.25	1
Summation	2.28	6.33	5.7	11.25	15

2

Example:

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage	Land Cover
Runoff Depth	1	2*1			
Slope		1	3*2		
Soil texture			1		
Drainage				1	
Land Cover					1
Summation					

It means:

*1 Criteria 1, which is Runoff, Is Equal to moderate importance than criteria 2 which is Slope.

*2 Criteria 2, which is Slope is of stronger importance than criteria 3 which is Soil texture.

According to the table of "Intensity of importance definition", what value do you specify from among the degree of significance of each main objective towards others?

Criteria

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage Density	Land Use
Runoff Depth	1	2	2	5	6
Slope	0.50	1	2	2	5
Soil texture	0.5	0.5	1	2	3
Drainage	0.2	0.5	0.5	1	2
Land Use	0.17	0.2	0.33	0.5	1
Summation	2.36	4.2	5.83	10.5	17

2

Example:

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage	Land Cover
Runoff Depth	1	2[*1]			
Slope		1	3[*2]		
Soil texture			1		
Drainage				1	
Land Cover					1
Summation					

It means:

[*1] Criteria 1, which is Runoff, Is Equal to moderate importance than criteria 2-which is Slope.

[*2] Criteria 2, which is Slope is of stronger importance than criteria 3,which is Soil texture.

According to the table of "Intensity of importance definition", what value do you specify from among the degree of significance of each main objective towards others?

Criteria

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage Density	Land Use
Runoff Depth	1	3	4	5	3
Slope	0.33	1	3	4	3
Soil texture	0.25	0.33	1	3	2
Drainage	0.2	0.25	0.33	1	1
Land Use	0.33	0.33	0.5	1	1
Summation	2.11	4.91	8.83	14	10

2

Example:

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage	Land Cover
Runoff Depth	1	2 [*1]			
Slope		1	3 [*2]		
Soil texture			1		
Drainage				1	
Land Cover					1
Summation					

It means:

[*1] Criteria 1, which is Runoff, Is Equal to moderate importance than criteria 2, which is Slope.

[*2] Criteria 2, which is Slope is of stronger importance than criteria 3, which is Soil texture.

According to the table of "Intensity of importance definition", what value do you specify from among the degree of significance of each main objective towards others?

Criteria

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage Density	Land Use
Runoff Depth	1	1	2	3	5
Slope	1.00	1	2	2	5
Soil texture	0.5	0.5	1	2	2
Drainage	0.33	0.5	0.5	1	2
Land Use	0.20	0.2	0.5	0.5	1
Summation	3.03	3.2	6	8.5	15

2

Example:

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage	Land Cover
Runoff Depth	1				
Slope		1			
Soil texture			1		
Drainage				1	
Land Cover					1
Summation					

It means:

*1 Criteria 1, which is Runoff, Is Equal to moderate importance than criteria 2 which is Slope.

*2 Criteria 2, which is Slope is of stronger importance than criteria 3 which is Soil texture.

According to the table of "Intensity of importance definition", what value do you specify from among the degree of significance of each main objective towards others?

Criteria

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage Density	Land Use
Runoff Depth	1	4	4	2	2
Slope	0.25	1	3	3	3
Soil texture	0.25	0.33	1	2	2
Drainage	0.5	0.33	0.5	1	2
Land Use	0.50	0.33	0.5	0.5	1
Summation	2.5	6	9	8.5	10

2

Example:

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage	Land Cover
Runoff Depth	1	2*1			
Slope		1	3*2		
Soil texture			1		
Drainage				1	
Land Cover					1
Summation					

It means:

*1 Criteria 1, which is Runoff, Is Equal to moderate importance than criteria 2 which is Slope.

*2 Criteria 2, which is Slope is of stronger importance than criteria 3 which is Soil texture.

According to the table of "Intensity of importance definition", what value do you specify from among the degree of significance of each main objective towards others?

Criteria

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage Density	Land Use
Runoff Depth	1	1	2	3	4
Slope	1.00	1	2	4	1
Soil texture	0.5	0.5	1	1	4
Drainage	0.33	0.25	1	1	3
Land Use	0.25	1	0.25	0.33	1
Summation	3.08	3.75	6.25	9.33	13

2

Example:

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage	Land Cover
Runoff Depth	1	2*1			
Slope		1	3*2		
Soil texture			1		
Drainage				1	
Land Cover					1
Summation					

It means:

*1 Criteria 1, which is Runoff, Is Equal to moderate importance than criteria 2, which is Slope.

*2 Criteria 2, which is Slope is of stronger importance than criteria 3, which is Soil texture.

According to the table of "Intensity of importance definition", what value do you specify from among the degree of significance of each main objective towards others?

Criteria

Criteria / factors	Runoff Depth	Slope	Soil texture	Drainage Density	Land Use
Runoff Depth	1	4	3	2	4
Slope	0.25	1	1	3	3
Soil texture	0.33	1	1	3	3
Drainage	0.5	0.33	0.33	1	4
Land Use	0.25	0.33	0.33	0.25	1
Summation	2.33	6.66	5.66	9.25	15

RESUME

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Bachelor: 2013, Mosul University, Engineering, Dams and Water Resource

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