Site Suitability in Water Harvesting Management Using Remote Sensing Data and Gis Techniques: A Case Study of Sulaimaniyah Province, Iraq

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Abstract

The human-induced water use changes and the climate change effects have impartially led to long-term drought, water shortages and some casual flood incidents. These, have significantly impacted the northern region of Iraq over the past few decades. Water resources management has become a key to resolving this dilemma, particularly for the arid and semi-arid areas. Harvested water could be exploited for consumption, domestic, and animal use. Moreover, it is considered a valuable resource for irrigating agricultural lands. This study aims to identify appropriate sites for rainwater harvesting in the Sulaimaniyah province, Iraqi Kurdistan region. These processes have been done by using remote sensing, Geographic Information System (GIS) techniques and multi-criteria decision making (MCDM). The analytical hierarchy process (AHP) model has been used to find out suitable locations for water harvesting. The criteria considered were runoff, slope, soil type, land cover and drainage density. Each factor is assigned to its weight depending on its effect. Based on the findings, the average region that is outstanding and well-suited for water collection is 32% of the whole area. The model that has been applied in the current study is extremely significant and supportive for water resource management.

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 and dams, etc. Water preservation acts as a way of avoiding precipitation variability as an insurance strategy (Payen et al., 2012).

Decades of war and maladministration and the growing demand for water due to population growth have considered water a scarce resource in Iraq, as well as the droughts recently recalled by Iraq's developing neighbours, Iran, Syria and Turkey because of their siege. Difficult water shortages in some areas have in recent years prompted 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 water 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 (A. M. Noori et al., 2019).

Rainfall may be the most critical concept in the water balance equation, so it is one of the challenges for engineer designers 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).

Rain Water Harvesting (RWH) is used to induce, capture, save and use local surface water for agriculture and domestic in 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).

Rainfall data can be checked on the likelihood and frequency of receiving expected precipitation amounts for different likelihoods (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.

New technologies have been developed in recent times to address the shortcomings in traditional water scraping methods such as GIS, remote sensing and multi-criteria decision making that can be 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 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).

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 (A. M. Noori et al., 2019).

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.

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).

Using commercially accessible remote sensing instruments and GIS to identify rainwater harvesting areas in the mainland of Zanzibar (Tanzania), and 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, Hydrological Modulation and Multi-criteria appraisal approach. 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%.

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 estimated 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 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). 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 addition 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, this made us to think about this study to calculate the availability of the water in the city and compared it with the population number. Figure 1 show Sulaymaniyah province with its ten districts with Iraq map.

3 Methodology

The overall methodology process of this study is shown in Fig. 2. To find suitable sites for water harvesting in Sulaymaniyah, various types of data have been 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.

4 Data

4.1 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 and the review of criteria in rain water harvesting management (S. Noori & Ghasemlounia, n.d.).

4.1.1 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.

4.1.2 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 Fig. 3. A.

4.1.3 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).

2. 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. B demonstrates the distribution of channels in the study area. 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..

4.1.4 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 and11 rainfall stations are used in the study. Figure 3. C illustrates the rainfall.

4.1.5 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). 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 Fig. 3. D.

$$DD = \frac{\sum_1^n L}{A} \ldots (1)$$

Where:

DD: Drainage Density

L: Stream Length

A: Basin Area

4.1.6 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 1 indicates the identification of the pistes in 5 positions.

Table 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
(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 Fig. 3. E. The research zone has moderate paths in the south-west, with steep hills and deep valleys in the north and northwest.

4.1.7 Land use/ Land cover

Land cover was obtained 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.

The study area was utilized by four classes of land cover: bare land, urban, water and vegetation Fig. 3. F. When choosing suitable areas to pick water harvesting sites, ground cover is a significant parameter.

4.1.8 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 as shown in (Fig. 3.G) (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 Fig. 3. G.

4.1.9 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).

$$Q = \frac{(P - Ia)\,2}{(P - Ia) + S}\,(2)$$

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= $\frac{(P-02S)2}{(P+0.8\mathrm{S})}(3)$

By using the curve number (CN) in Eq. (4) the potential maximum retention after runoff starts can be calculated (S) (Melesse & Shih, 2003):

S= $\frac{254000}{(CN)} - 254\,(4)$

4.1.10 Estimating curve number

Curve number used to identify drainage resources for a particular land-covered/ land use. 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. In the study area alone classes B, C and D have been found.

Table 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
(McKinney et al., 1993)		

Table 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

Hydrological Soil groups of the study area can be found in Table 2 (see section 4.1.9). However, the hydrological soil groups in the study area are illustrated in Fig. 3. H.

Table 4
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
(Drobne & Lisec, 2009)	

4.1.11 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. Eq. 4 determined the value of S for each pixel. Then in Eq. 3 we used S to find the depth of runoff.

4.1.12 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 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.

4.2 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).

4.3 Selection criteria

The criteria are focused on the availability of data like runoff, slope, drainage network, land cover type of soil to determine the water conservation potential of certain areas. It has used a model using soil conservation service (SCS) model to measure the runoff depth at each pixel. The amount of rainwater collected in each pixel was determined by measuring the amount of water in the infiltration rate of each pixel and the soil texture (Tumbo et al., 2006). It was also determined by the size and distance of soil particles that regulate water movement.

4.4 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.

4.5 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).

4.6 Selecting criteria weights

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 5, 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.
2. 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 6). The sum of each row is then determined from the resultant in Table 6. These ratios are the proportional weights of the parameters.

Table 5
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

Table 6
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

Table 7
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
(Drobne & Lisec, 2009)					

2.1.1.1 Estimating consistency of pairwise comparison

The specificity of the relationship is determined by the compatibility ratio (CR) measurement (see Eq. 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.

$$CR = \frac{CI}{RI}(5)$$

The Random Index (RI) can be retrieved from a particular table prepared by (Saaty, 1977), based on the order of the matrix. Table 6 displays the values of the random variable by the number of parameters.

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

Multiply the weight of the first criterion (runoff depth = 0.41) in Table 6 by the total of the first column of the original pairwise comparison matrix which is equal to 2.28 in Table 5 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 (= 5.11), which is used to compute the consistency index according to Eq. 5.

The consistency Index (CI) has been calculated by using Eq. 6:

$$CI = \frac{\lambda \mathrm{max} - \mathrm{n}}{n - 1}(6)$$

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.

5 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.

4.7 Rainfall analysis

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 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.

4.8 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 Fig. 5.

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. The scale of the HSG area is seen in (Fig. 3. H).

4.9 Soil

Soil map of study area shows 9 main groups as seen in (Fig. 3. G) 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.

4.10 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 (Fig. 3. E).

4.11 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 (Fig. 3. D).

4.12 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 (Fig. 3. F).

4.13 Rainwater Harvesting Potential Map

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 6 and 7 show possible rainwater collecting sites and the proportion of the area that is protected by numerous water harvesting suitability areas.

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.

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.

6 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.

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. 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.

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.

7 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.

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.

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. in this case we can benefit from this huge amount of the potential area for water harvesting and using the stored water for domestic, industrial and animal use, as well as facing the problem of desertification and using it for agriculture. 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.

Declarations

Competing Interests

“The authors have no relevant financial or non-financial interests to disclose.”

Author Contributions

All authors contributed to the study's conception and design. Material preparation, data collection and analysis were performed by [Shaho Khorsheed Noori], [Redvan Ghasemlounia] and [Abbas Mohammed Noori]. The first draft of the manuscript was written by [Shaho Khorsheed Noori] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.”

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Availability of data and materials

All authors sure that all data and materials as well as a software application or custom code support thei published claims and comply with field standards.

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Figures

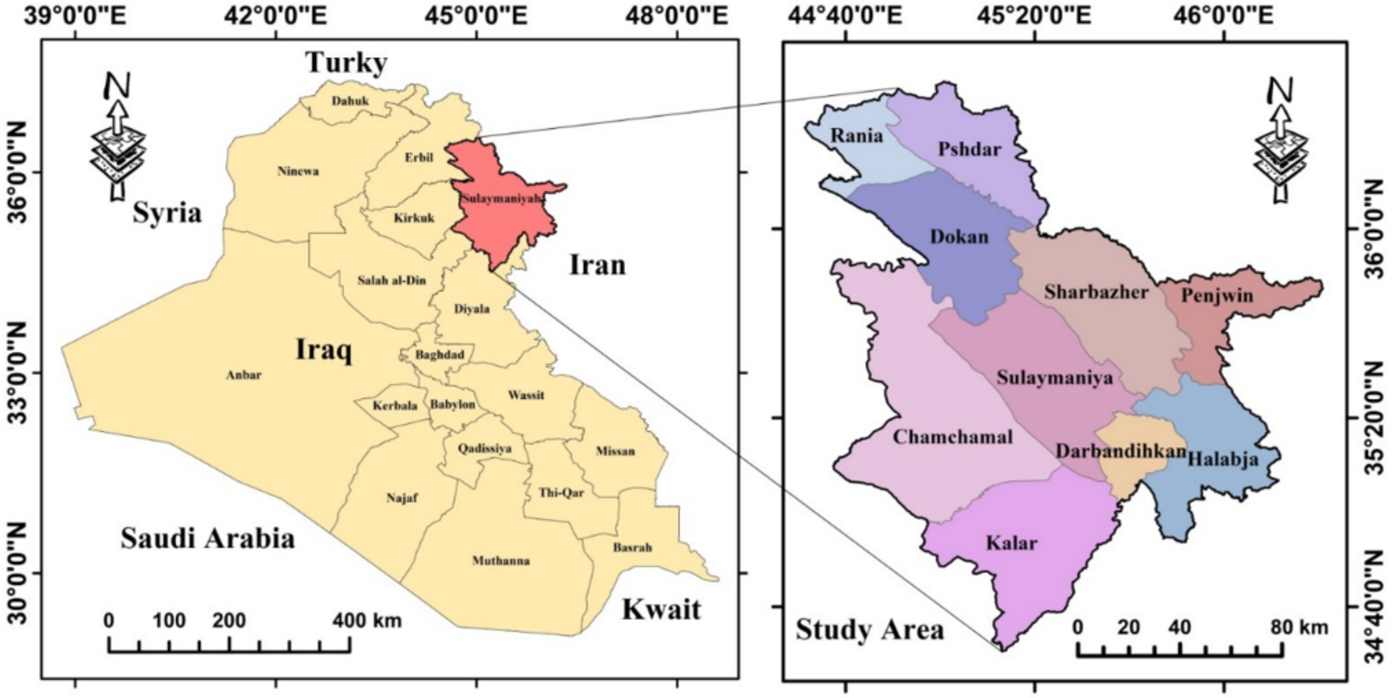

Figure 1

Iraq map shows Sulaymaniyah province with its ten districts

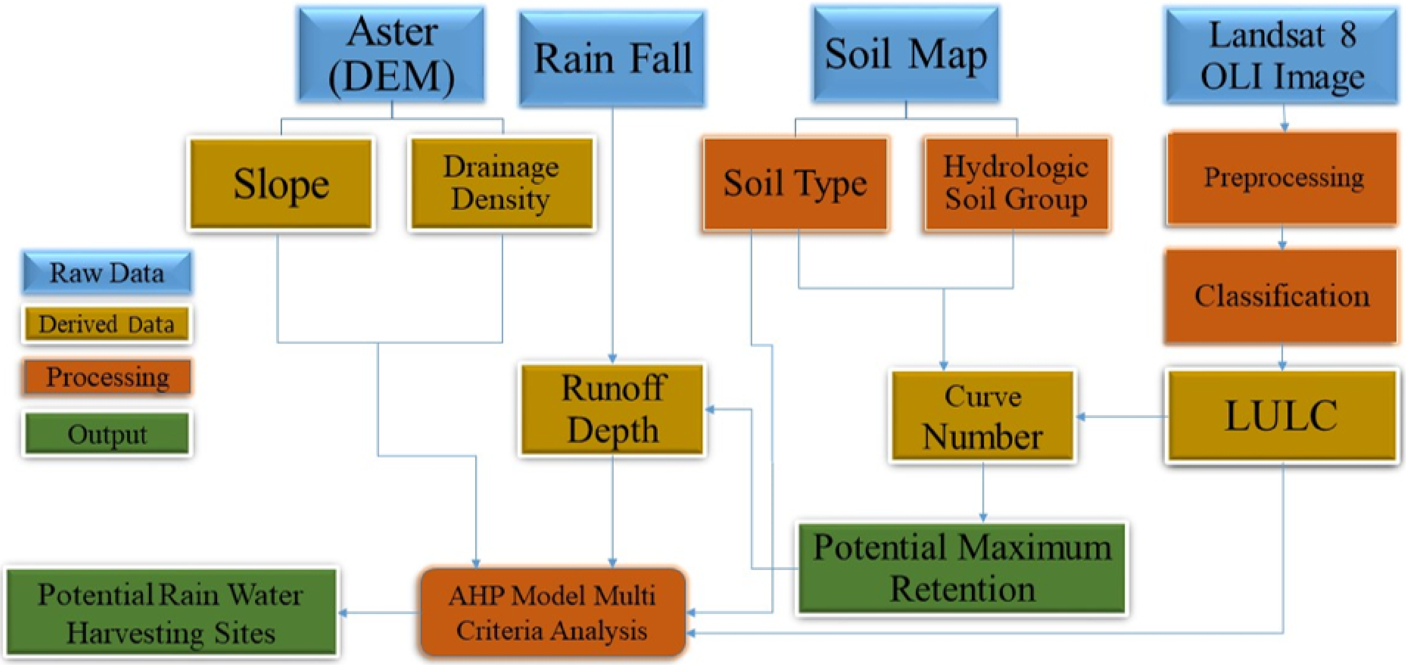

Figure 2

Overall process for identifying suitable sites for Rain Water Harvesting

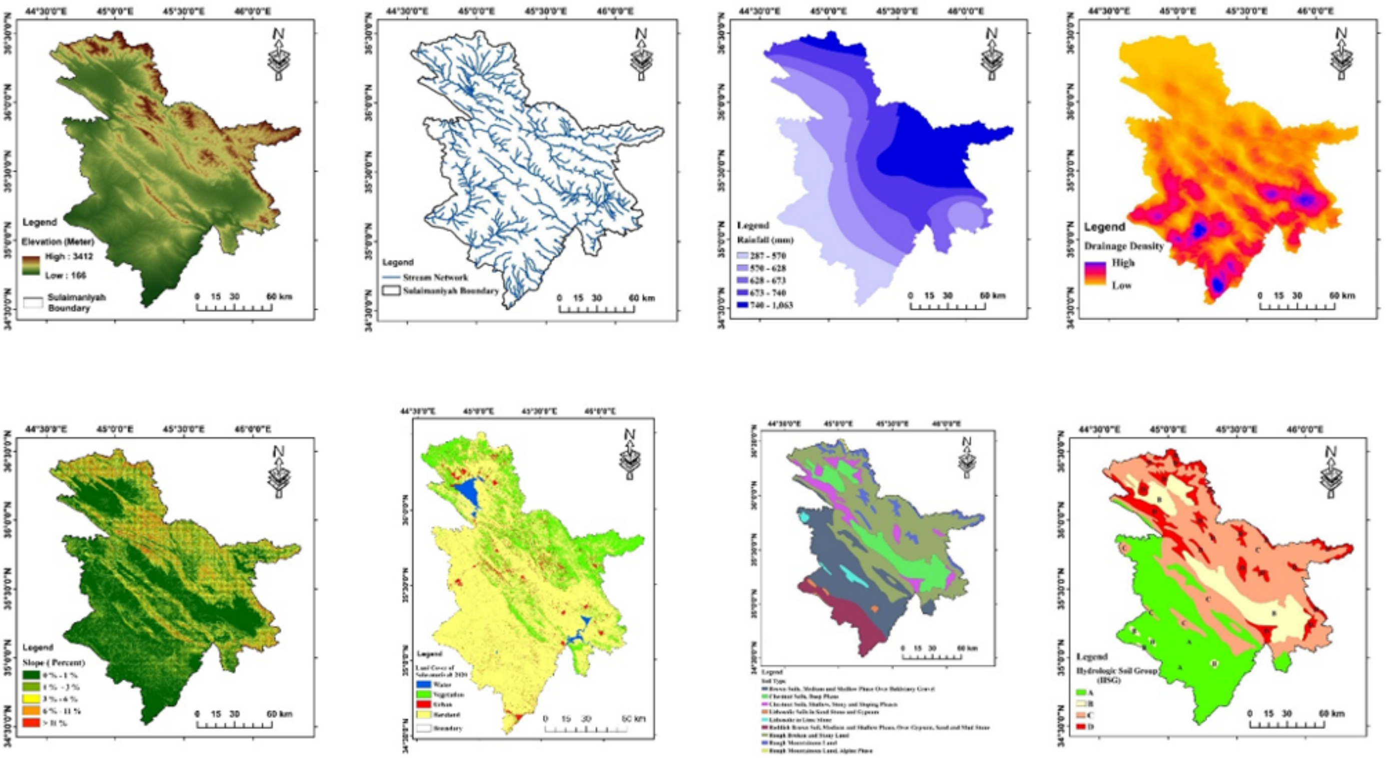

Figure 3

A.Elevation Model, B.Stream network from flow accumulation, C.Average annual rainfall spatial distribution, D.Drainage density, E.Slope Classification, F.Land Use Land Cover, G.Soil map, H.Soil map Classification into hydrologic soul group (A,B,C and D)

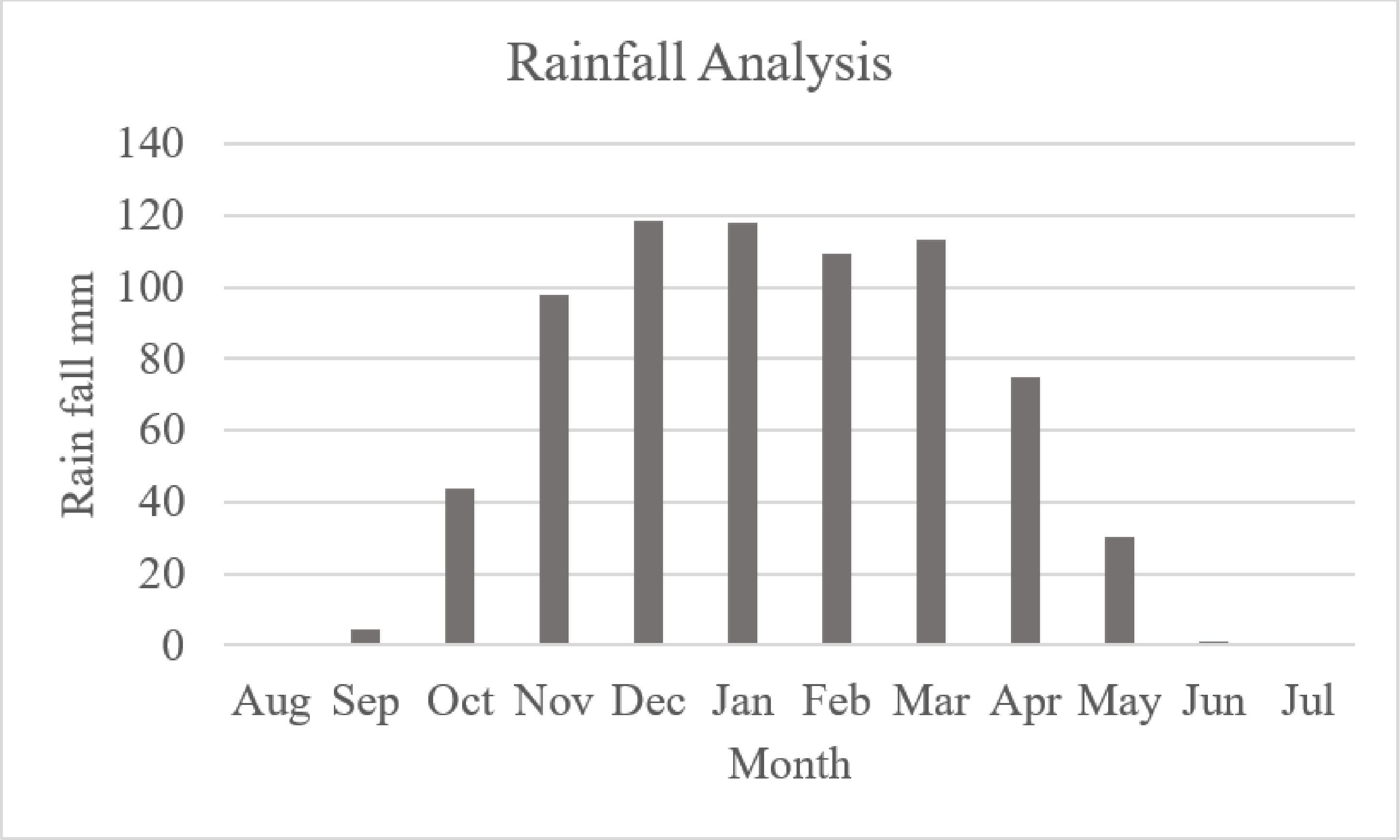

Figure 4

Average of monthly rainfall in the study area 2009 - 2019

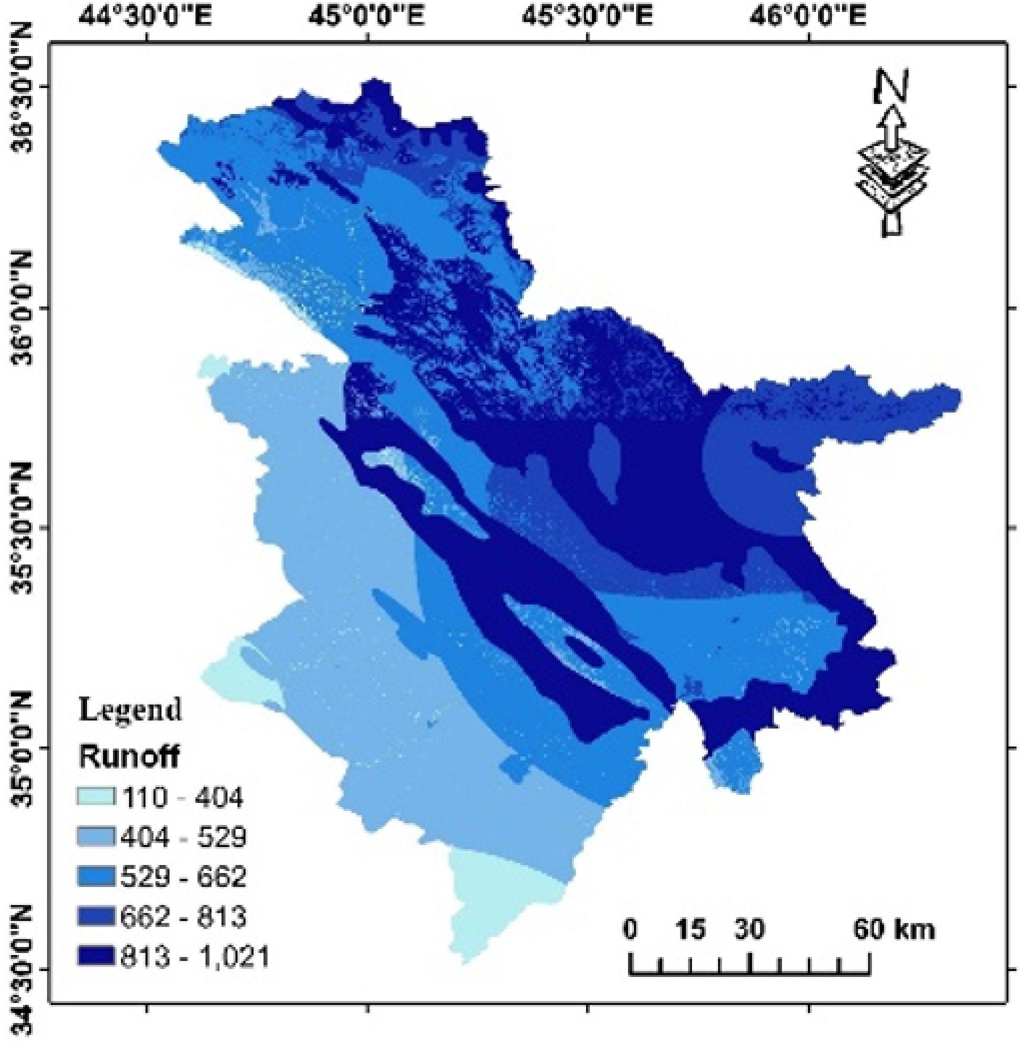

Figure 5

Potential Runoff Map

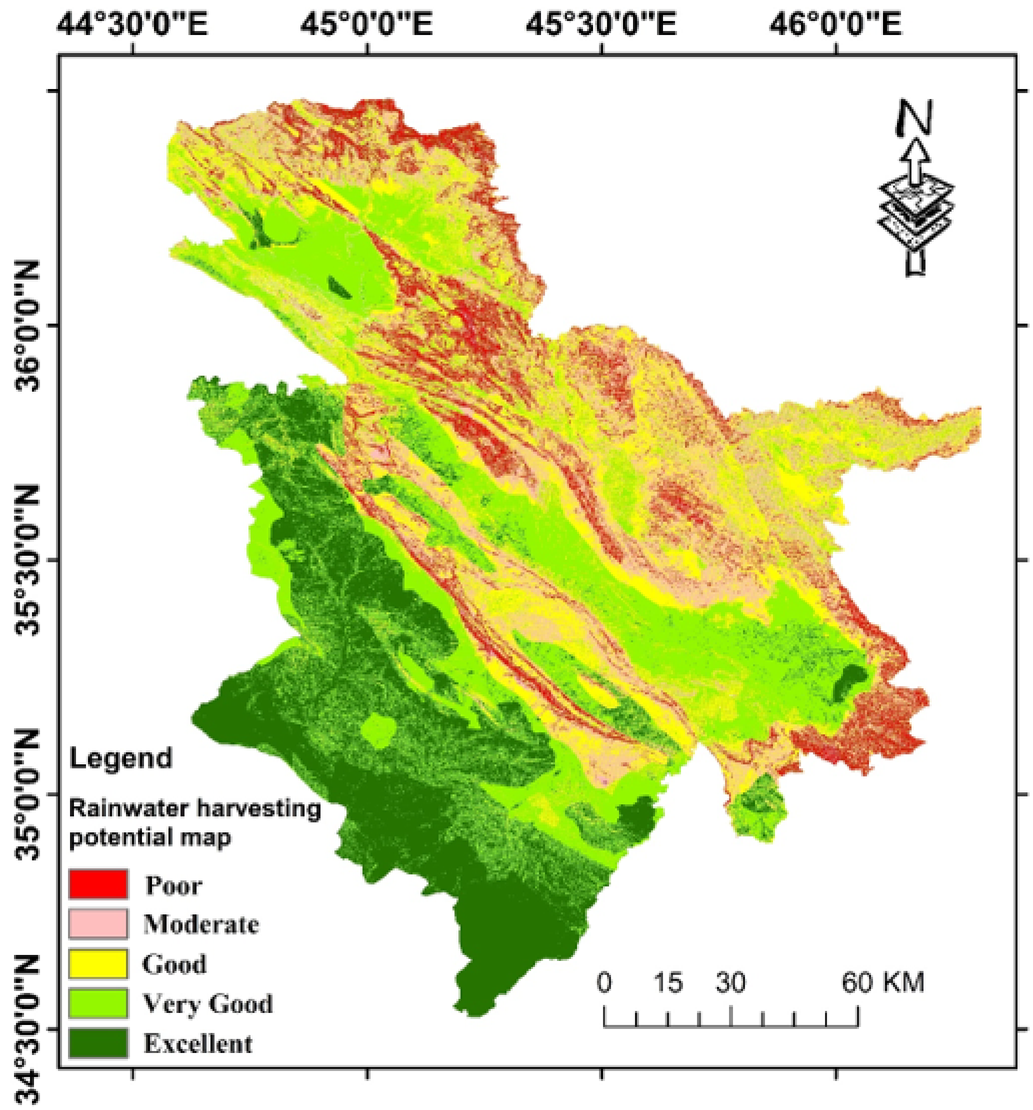

Figure 6

Rainwater harvesting potential map for the study area

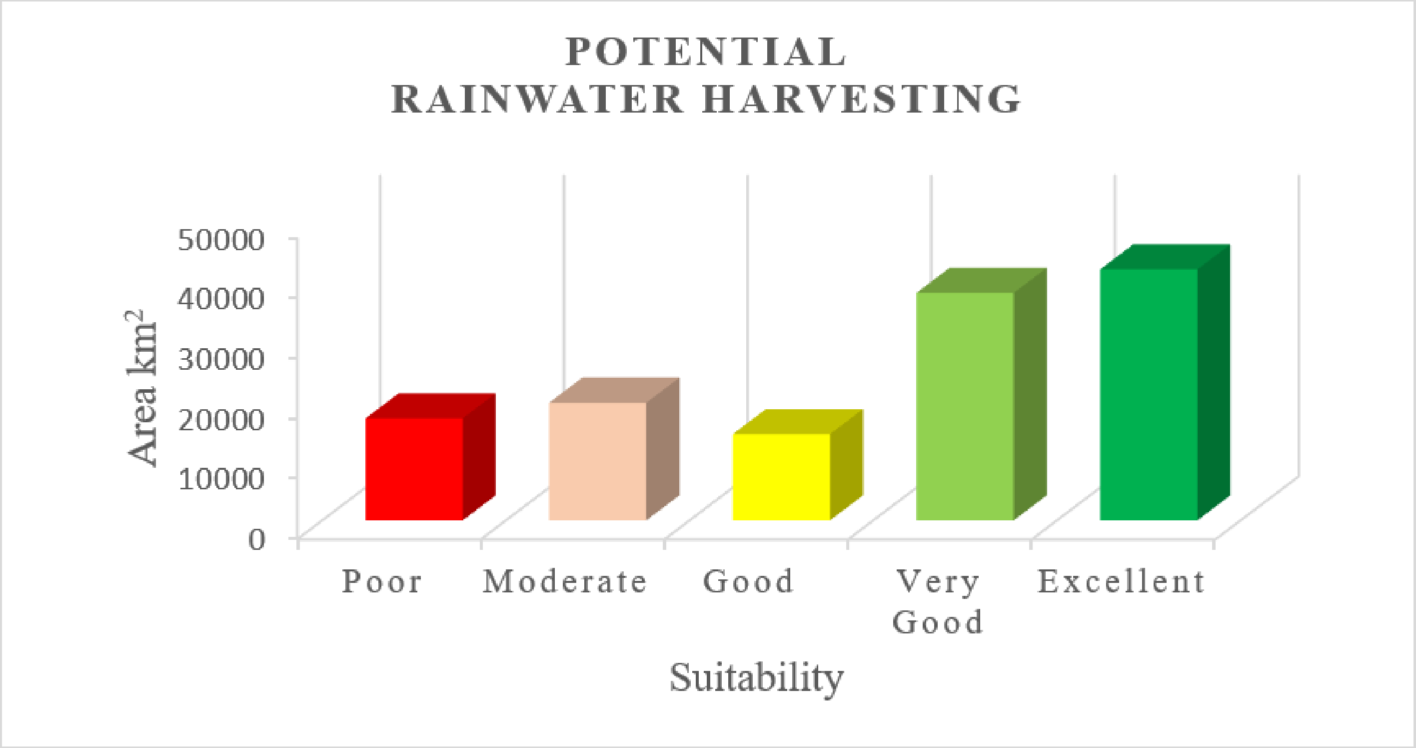

Figure 7

Percentage of areas suitability for rainwater harvesting