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RESEARCH ARTICLE - HYDROLOGY

RS- and GIS-based modeling for optimum site selection in rain water harvesting system: an SCS-CN approach

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Abstract

In this study, an integrated approach has been adopted for optimum selection of locations for rain water harvesting (RWH) in Kohat district of Pakistan. Various thematic layers including runoff depth, land cover/land use, slope and drainage density have been incorporated as input to the analysis. Other biophysical criteria such as geological setup, soil texture and drainage streams characteristics were also taken into account. Drainage density and slope were derived from digital elevation model, and map of land use/land cover was prepared using supervised classification of multi-spectral Sentinel-2 images of the area. Aforementioned thematic layers are assigned respective weights of their importance and combined in GIS environment to form a RWH potential map of the region. The generated suitability map is classified into three potential zones: high, moderate and low suitability zones consisting of area 638 km^2 (21%), 1859 km^2 (62%) and 519 km^2 (17%), respectively. The suitability map has been used to mark accumulation points on the down streams as potential spots of water storage. In addition, site suitability of artificial structures for RWH consisting of farm ponds, check dams and percolation tanks has also been assessed, showing 3.2%, 3% and 4.5% of the total area as a fit for each of the structure, respectively. The derived suitability will aid policy makers to easily determine potential sites for RWH structures to store water and tackle acute paucity of water in the area.

Keywords Site suitability · Rain water harvesting · Remote sensing · Geographical information system

Introduction

Water is indeed one of the primary driving forces of our very nature. It is the basic need for human as well as for the animal and plant life. The global requirement of water is intensifying with time due to rapid increase in the world population, modern and improving living standards, industrialization and irrigated agriculture (Buraihi and Shariff 2015). Especially under the current climate change scenario where changed rainfall patterns are causing either scarcity or floods, the natural water balance has been lost. So at this time it is more important to manage fresh water resources than ever it was needed before. South Asian countries are more likely to get affected by this scarcity. Pakistan is a typical example of a country facing effects of this natural imbalance. It was a water surplus country once but now turning into a water deficit region as the fresh water is depleting rapidly. Pakistan is ranked third among the countries which are facing substantial water crisis unheeded by the authorities (Nabi et al. 2019). And the country may run dry by 2025 if such trend continues. It is an agricultural country and its economy relies heavily on the growth of agriculture sector which needs the water most (Ahmed et al. 2007).

Over the time people have acquired many alternative ways to get water for different purposes including digging wells, harvesting rain water, melting snow and ice, accumulating fog and dew, collecting water from the evapotranspiration of plants (Kadam et al. 2012; Tumbo et al. 2012). One of these management solutions is the rain water harvesting (RWH). In areas where water supply is barely sufficient this solution proves to be a propitious method to support scarce water resources of the area to satisfy the demand (Buraihi and Shariff 2015; Mugo and Odera 2019). This research aims to locate potential areas to efficiently harvest rainwater. At one side, proper management of rain water can help in avoiding

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or at least reducing intensity of floods and at the other end provide naturally filtered water in the dry spells to fulfill domestic and other uses (Sekar and Randhir 2007; Buraihi and Shariff 2015). RWH is a combination of versatile and resourceful techniques to filter, stock, and distribute rain water for various domestic purposes. This is the simplest and easily accessible alternative of water management in areas with sufficient rain as it yields extra water to deal water deficit problems (Helmreich and Horn 2009; Gavit et al. 2018). This process of RWH simply expresses the undeviating hold up of rainwater as surface runoff. For domestic purpose, the surface runoff from the roof of an individual house or from paved surface can be harvested. There are many advantages of RWH, i.e., rainwater is not chlorinated so it is unpolluted and open source of water, this harvested water is ideal for crop planting due to its clarity (Buraihi and Shariff 2015). The degree of harvesting can be enhanced from an individual to a bigger catchment or reservoirs for public use. This process of RWH is also useful for the enhancement of ground water recharge. This system has been proved to be very beneficial for many countries in the world.

Although RWH has its history expanded over centuries but now in these modern days, for better results, before installation of RWH system, there are proposed analyses to check the land suitability for such an installation (Mugo and Odera 2019). The more effective and popular analyses made use of the geographic information system (GIS) and satellite remote sensing (SRS) utilities (Buraihi and Shariff 2015). To serve the purpose, various procedures are in practice. One of the methods is the Analytic Hierarchy Process (AHP), a multi-criteria decision analysis. It assigns weights to each of the input criteria showing its level of contribution in the decision support system. Another GIS-based method used in order to delineate these sites for RWH is the weighted overlay of geographic distribution of the involved input parameters, i.e., drainage density, slope, runoff depth, the soil map and the land-use/land-cover (LULC) map (Kadam et al. 2012; Buraihi and Shariff 2015). It also assigns weight to each of the parametric layers. This study has made use of these SRS- and GIS-based strategies to proposed potential rainwater harvesting sites for the district Kohat, Pakistan.

SRS has been emerged as an alternative of traditional in situ sampling methods that were expensive, time-consuming and tedious in their (Mahmood et al. 2017a; Manzo et al. 2017). Its ability to provide bird eye view of larger area with detailed topography and many other proxy factors helping in understanding ongoing process and natural settings of a region at once are the factors making it a better substitute in many environmental related studies (Manzo et al. 2017; Mahmood et al. 2019). The basic data of SRS is reflectance of Earth's surface measured in various spectral range which is interpreted using spatial analysis of various types provided by GIS (Yan et al. 2014; Manzo et al. 2017). In addition to processing of SRS data GIS also provide ease and accuracy of many other space related data handling, a typical example of it is the Weighted Linear Combination (WLC) of multiple geographic datasets. A general recommendation by researchers is the SRS data with better spatial resolutions, i.e., QUICKBIRD with pixel dimensions of 0.65 m. However, depending upon phenomenon under consideration, freely available SRS data of Sentinel 2 with generalization dimensions of 10 m may prove to be a very suitable option. So both these techniques (SRS and GIS) are helpful for studying surface phenomenon, i.e., RWH of an area.

Study area

The study area for this research is Kohat district located in the province Khyber Pakhtunkhwa (KPK) of Pakistan, situated adjacent to the Potwar plateau. The zone lies in the range from 33.06° N to 33.75° N and from 71.06° E to 72.01° E. Geographical association of the study area is shown in Fig. 1. With an area of about 2987 km^2, it contains a population of 723,000 (Population and Household Detail from Block to District Level: Khyber Pakhtunkhwa, 2018). Administration wise the area has been divided into two tehsils Kohat and Lachi.

The climate of the area is semiarid and sub-humid subtropical continental highland. The average temperature of the region varies with altitudes, i.e., plains are relatively warmer and mountains are cooler. The weather remains hot from May to September with peak in June (average maximum temperature 41 °C), whereas coldest month is January (average minimum temperature 5 °C). Annual average temperature in the region is around 24 °C. Monthly average temperature of the region, as per 40 years' record from 1978 to 2017, is shown in Fig. 2. Annual average precipitation in the region, as per 40 years' record from 1978 to 2017, is 580 mm. The monsoon downpours peak in July and August. Looking at the seasonal rain fall patterns (Fig. 3), Kohat district has an additional advantage of two well separated peaks of higher precipitation. One of the peak, relatively smaller, is in March with 82 mm precipitation in a month, for which the surplus rainwater can serve as a reserve for the dry months of May and June, whereas the major peak centers in July and August with about 180 mm in 2 months, for which the collected rainwater can serve as a source for the upcoming dry months of October, November and December. So this way Kohat has two sets of supply and demand periods and seasonally the RWH system of the region can be divided into two temporal frames leading toward smaller collection units with maximum efficiency.

Fig. 1 Study area map

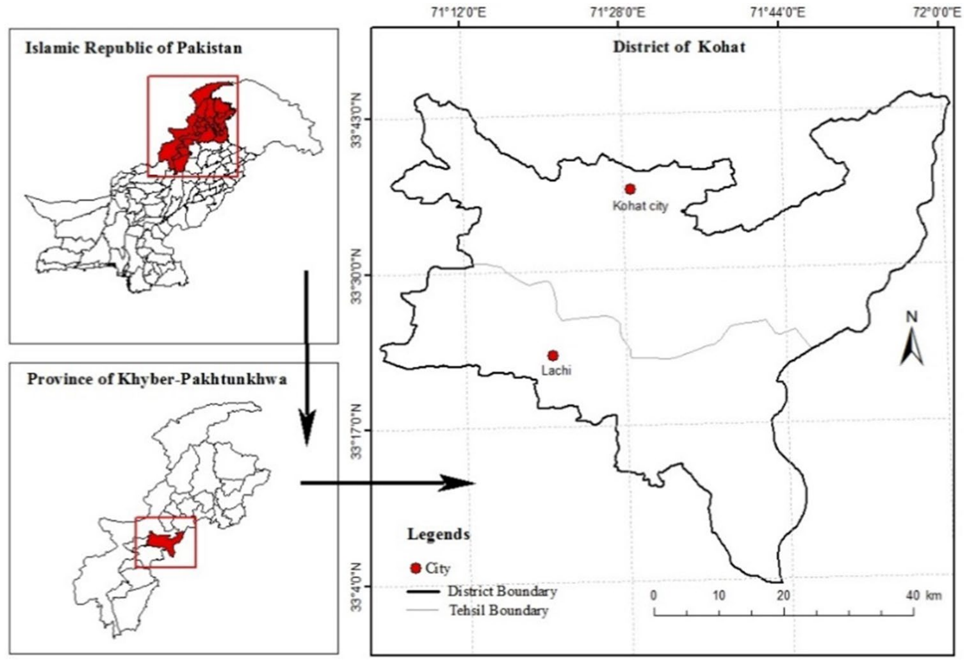
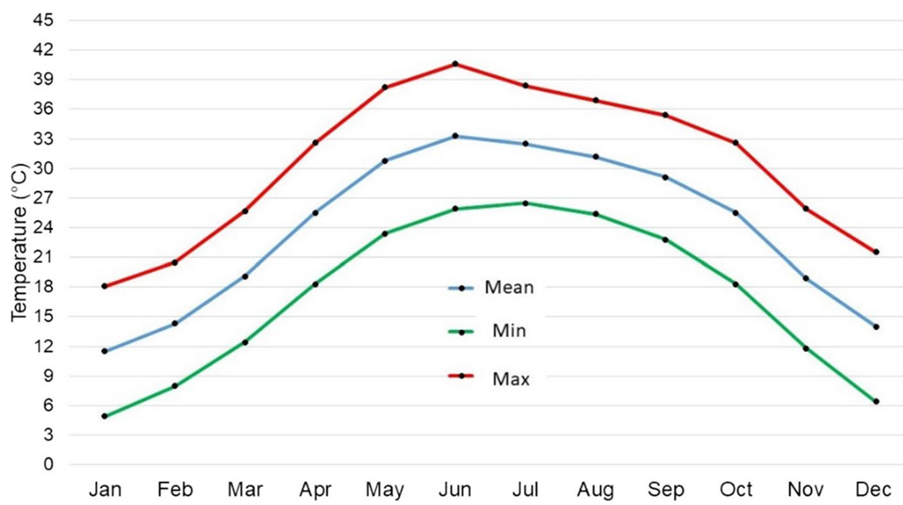


Fig. 2 Average monthly temperature profile of Kohat (from 1978 to 2017)



Materials and methods

Datasets collection

The SRS data of Sentinel 2B acquired on 15-11-2018 has been used for preparing LULC of the area. For elevation, data of SRTM DEM with spatial resolution of 30 m has been used. A detailed soil map, topographic information, soil texture triangle and soil series information of Kohat district were acquired from Soil Survey of Punjab. Finally, for accurate rainfall information, data of past 10 years from two sources were obtained, Pakistan Meteorological Department (PMD) and Soil Survey of Punjab (Soil Survey of the Punjab, Pakistan).

Datasets preparation

The preprocessing on acquired four Sentinel-2B images was done, during the preprocessing stage, the bands (red, green, blue, NIR) with 10 m spatial resolution were stacked together, the four images were mosaicked, and the area of interest was clipped using ERDAS Imagine platform; the output is shown in Fig. 4. To prepare a Hydrological Soil Group (HSG) map the geo-referencing and digitization of

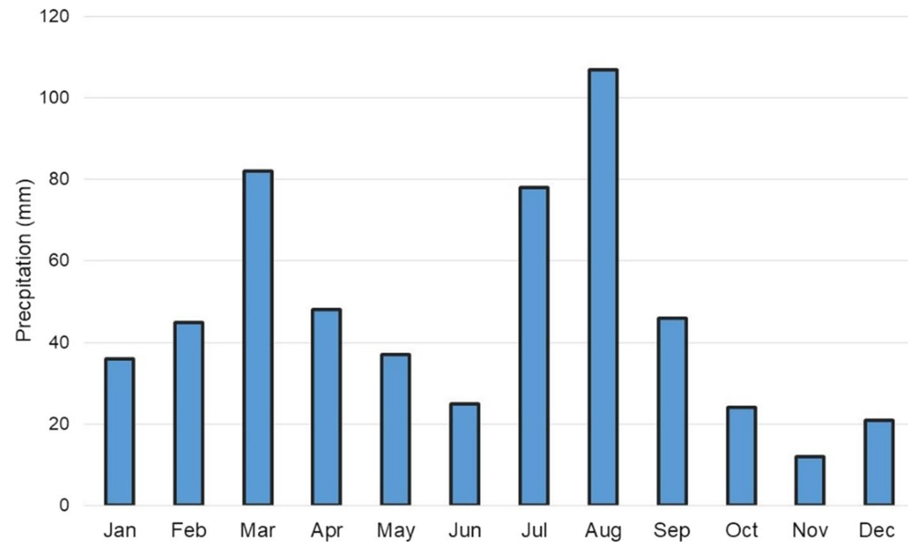


Fig. 3 Average monthly rainfall of Kohat (from 1978 to 2017)

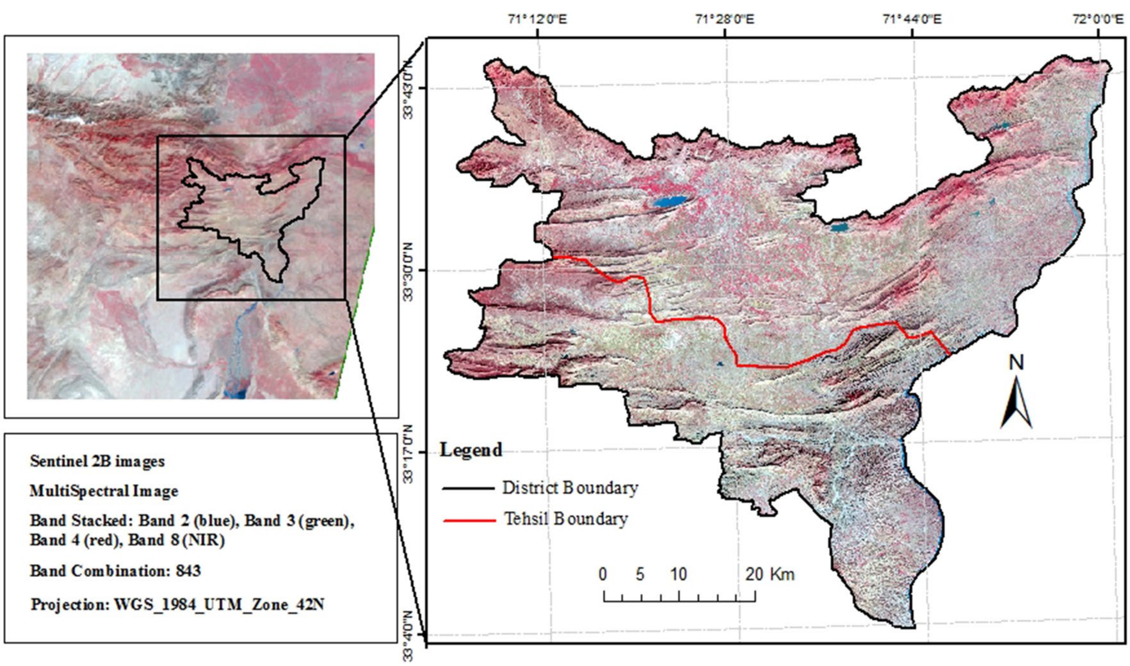


Fig. 4 Sentinel 2B image (Kohat district)

detailed soil information map of Kohat was carried out using Arc GIS as the GIS platform. Later on, hydrological soil groups were computed using soil texture triangle and Kohat soil series information. The 40 years' rainfall information of Kohat district was utilized to calculate average monthly as well as annual rainfall of the area, the monthly average details are given in Fig. 3, and annual average is 560 mm.

Overall layout of the methodology has been given in Fig. 5. Solution of the problem statement initiated with the preparation of thematic layers using the collected data sets. This selection of the four contributory thematic layers comprises of runoff depth, slope, drainage density and land use/land cover which has been made based on the reviewed literature (Khalid et al. 2017). In order to prepare a land-use/land-cover layer of the region, preprocessing and classification of Sentinel-2B images performed in ERDAS Imagine, followed by supervised classification using maximum likelihood algorithm of images to six classes, were made, i.e., bare land, grassland, crops, fallow, urban, and open water. Topographic slope layer has been prepared by selecting appropriate z-factor value which computed to be 0.00001036 depending on latitude range of the area by method devise by

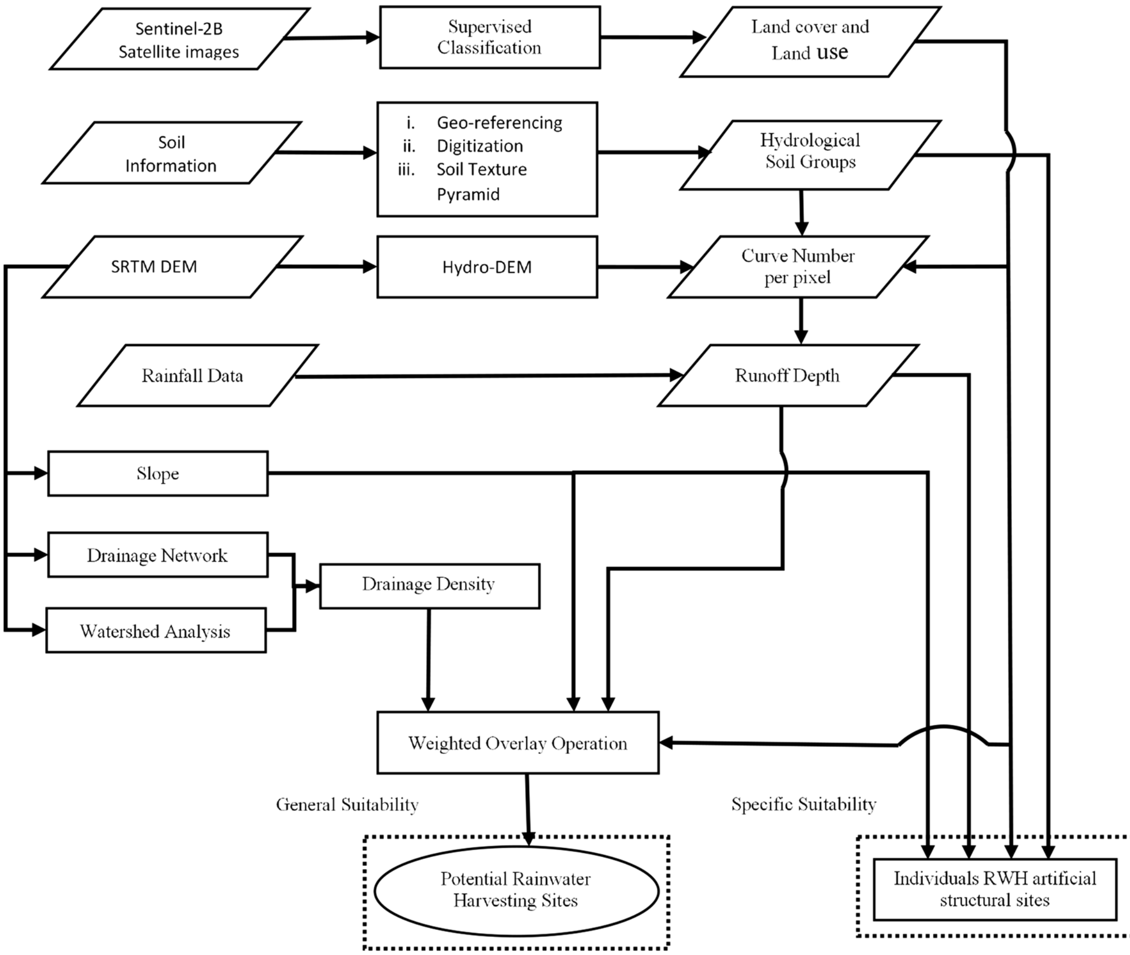


Fig. 5 Flow chart diagram of methodology

Fry (2007). Drainage density is defined as "the total length of streams per unit catchment area" and mathematically as follows (Dragicevic et al. 2019).

$$\mathrm{DD} = \frac{\sum_{i=1}^{n} L}{A} \tag{1}$$

where n is number of streams, L is length of the streams (km) and A is contributing drainage area (km). For quantifying drainage density, drainage network information and watershed delineation were required. Drainage network was derived from DEM using stream raster and flow direction raster, and then "Stream to Feature" tool was used to convert it to vector format. Watershed delineation was carried out using flow-direction raster and stream-link raster, using hydrology tools. Spatial join has been used to combine the information of area of watershed and lengths of the streams falling in the respective watersheds for calculating drainage density per watershed.

Assessment of surface runoff has been made using SCS-CN method, initially developed by USDA, Soil Conservation Service (SCS). It is explained in fourth section of National Engineering handbook (NEH) (Ponce and Hawkins 1996). The main cause of success of SCS-CN is that this method compiles the parameters that affect the generation of runoff like, soil types, land use and land cover, moisture conditions of that area, surface condition, incorporated by single CN variable (Soulis et al. 2009; Kadam et al. 2012). The method based on the calculation of water balance is written as follows (Li et al. 2015):

$$P = \mathrm{Ia} + Q + F \tag{2}$$

$$\frac{Q}{P - \mathrm{Ia}} = \frac{F}{S} \tag{3}$$

where P is total rainfall (mm), Ia is initial abstraction (mm), F is cumulative infiltration excluding Ia (mm), S is potential maximum retention (mm) and Q is direct runoff (mm). By the combination of Eqs. (2) and (3), standard form of SCS-CN method turns out into following equation.

$$Q = \frac{(P - \mathrm{Ia})^2}{P - \mathrm{Ia} + S} \quad (4)$$

which is effective when $P \geq \mathrm{Ia}$; else $Q = 0$. This approach relies on two essential assumptions; first ratio of maximum possible runoff to actual rainfall is equal to ratio of real infiltration to maximum possible retention (Satheeshkumar et al. 2017). As per the second supposition, the volume of Ia is the segment of maximum possible retention. Ia = 0.2S (Li et al. 2015; Satheeshkumar et al. 2017).

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad (5)$$

S is calculated by using a mathematical mapping equation depicted in the form CN as follows:

$$S = \frac{25400}{\mathrm{CN}} - 254 \quad (6)$$

where CN is the curve number that depends on LULC, HSG and AMC (Antecedent Moisture Condition) and can be obtained from SCS handbook of Hydrology (NEH-4), section-4 (Satheeshkumar et al. 2017). In addition to that Arc Hydro extended tool has a built-in function to generate CN lookup table and CN value raster. It has no dimensions and has a range of 0-100 and depicts the abstraction properties of watershed. Ideal Impermeable surfaces such as water surfaces where all rainfall become runoff would have CN = 100. And the surfaces which absorb all rainfall would have CN = 0 (Gray and Burke 1983).

Runoff can be computed using Eq. (5), provided the value of CN is known. Estimating the CN for a catchment is considered an important application of GIS. In this research HEC-GeoHMS (Geospatial Hydrologic Modeling Extension) incorporated by Arc Hydro Tool has been used to investigate the value of curve number raster. Hydrological soil group chart has been prepared and is shown in Table 1. The participating layers have been classified before their unification using weighted overlay analysis (Satheeshkumar et al. 2017).

Hydrological Digital Elevation Model (Hydro-DEM) was generated from Arc hydro extension of ArcGIS. CN-Look-up table was made using curve number details with respect to land cover as defined by USDA. Along with LULC and HSG merged layer, hydro-DEM and CN-Look-up table, "Generate CN Grid" tool from HEC-GeoHMS was used in the estimation of curve numbers per pixel (Amakrishnan et al. 2009; Shukur 2017).

The weights, showing relative importance of each of the parameters in assessing RWH potential, need to be specified so that contributing factor of each of used parameters can be controlled. For this study these weights to each of the contributing factors have been assigned based on the reviewed literature, followed by pairwise comparison metrics analysis (Maina and Raude 2016; Mugo and Odera 2019). Classification of all the input variables along with their weight of importance has been given in Table 2. Finally, weighted sum

Table 2 Factors and scale values of different factors (Buraihi and Shariff 2015)

Factor	Weight of class (Pi) (%)	Classes	Rank of class (Wi)
Land use	7	Barren	9
		Grassland	7
		Crops	3
		Fallow	3
		Urban	1
		Water	1
Slope (%)	30	0–4.27	1
		4.28–10.36	9
		10.37–17.98	7
		17.99–27.73	5
		27.74–77.7	1
Runoff (mm)	48	217–301	1
		302–411	3
		412–462	5
		463–479	7
		480–529	9
Drainage density (km/km^2)	15	0–0.14	1
		0.15–0.37	3
		0.38–0.57	5
		0.58–0.86	7
		0.87–1.87	9

Table 1 Soil Conservation Service classification

Hydrologic soil (HSG)	Soil textures	Runoff potential	Final infiltration
Group A	Deep, well-drained sands and gravels	Low	> 7.5
Group B	Moderately deep, well drained with Moderate	Moderate	3.8–7.5
Group C	Clay loams, shallow sandy loam, soils with moderate to fine textures	Moderate	1.3–3.8
Group D	Clay soils that swell significantly when wet	High	< 1.3

has been carried out to unified score for each of the location using individual ranks assigned by each of the parameters.

The specific suitability of individual RWH storage structures

In order to find suitability sites for individual RWH storage structures, the generated thematic layers of LU/LC, slope, HSG and runoff were considered. The layers were overlaid and suitable sites for RWH structures like farm ponds, check dams and percolation tanks were found. Characteristics of each criterion on the basis of which the sites for each structure were found are given in Table 3.

Results and discussion

This study has made use of different parameters. and each of them has its critical role in deciding ability of a location to be a potential RWH site. Out of all the four layers, runoff depth was assigned the highest weight (48%), whereas the lowest weight was assigned to LULC that is (7%). The slope and drainage density were given 30% and 15%, respectively. Assessing land cover distribution in the region, 0.65% out of the total land cover is water majorly consisting of small lakes (spatially found concentrated in the north) and stream/rivers flowing along eastern boundary of the area. This small percentage is considered to be absolutely unsuitable for the installation of any rainwater harvesting system. Grasslands occurring at the outskirts along northern and western boundary has a coverage of 29% and 0.5% is covered by crops and lies in the northeast, whereas the urban settlements are occupying a small percentage of 0.2% and definitely unsuitable for constructing RWH sites. Fallow lands are peppered throughout the study area, covering 11%, whereas major portion (59%) is barren land. Spatial arrangement of all these land covers is shown in Fig. 6a.

The soils of Kohat region were categorized into four hydrological sets A, B, C and D in accordance with the rates of infiltration of different types of soils on the basis of their textures, for example loamy, sandy clay loam, etc., as referred by Soil Conservation Service Classification (USDA 1974). The type A soil (the well-drained soils and gravels), mainly covering northern regions of the area, consists of about 135 km^2. Type B soil (the moderately drained), expanding toward north from center, has an area coverage of about 438 km^2. Type C soil (clay loams), having coverage along eastern and western boundaries of the area, is found to have an area value approximately 364 km^2. The Type D is with the maximum area coverage of about 2050 km^2 and is situated mostly on edges of the region. As it is previously mentioned in Table 1, the suitable soil type for installing RWH structure is type D because of its high runoff potential and low infiltration rate and luckily it is the top existing soil (70% of study area). The spatial distribution of these four hydrological soil groups is shown in Fig. 6b.

An average rainfall of 529 mm is generating surface runoff ranging from 217 mm to 529 mm depending on the geographical situations, whereas for a site to be suitable the runoff should be greater than 300 mm so 98% of the area satisfying this condition (Buraihi and Shariff 2015), while the remaining 2% area of non-suitability is covered either by urban settlements or water bodies, which is already excluded for the potential list. Figure 6c illustrates spatial distribution of curve numbers on the basis of which runoff depth has been calculated that is shown in Fig. 6d. Slope was assigned the second highest weight (30%) in the analysis and ranges between 0%-77%, as shown in Fig. 6e. Most of the areas have range of 0–10% that is considered RWH site, while the edges of the boundary in the north part of Kohat are considered to be unsuitable for rainwater harvesting due to the very high values of slope. Drainage density, carrying an importance of 15% in the analysis, has been shown in Fig. 6f for individual watersheds that ranges from 0 to 1.874 per km which is quite suitable for potential RWH site.

RWH potential suitability map

The final output of unified suitability score with geographical spread has been given in Fig. 7. The output has been divided into three classes of suitability level and percentage area for each of the class has been calculated to assess overall suitability of the study area for RWH potential. This classification over weighted overlay raster has been performed using equal interval classifiers that divides input values to specified number of classes (three in this particular case) while giving same value intervals to each of the class.

Only 17.2% of the study area has been categorized into poorly suitable as potential site for RWH. This area mainly consists of urban settlements and the water bodies which is already discussed as the non-suitable land covers for such an arrangement. Major portion (61.6%) of the study area lies with optimized score range of moderately suitability and 21.1% has been assessed as the region of top suitability. For the most suitable sites, the runoff values were maximum, the infiltration rate was least, and land cover was mostly the barren land. However, these regions of high suitability have

Table 3 Selection of artificial structures for RWH (Ammar et al. 2016; Khalid et al. 2017)

Artificial RWH structure	Slope (%)	Land cover type	Soil type
Farm-pond	< 5	Agriculture	C and D
Check dam	< 15	Barren	C
Percolation tank	< 10	Barren	B

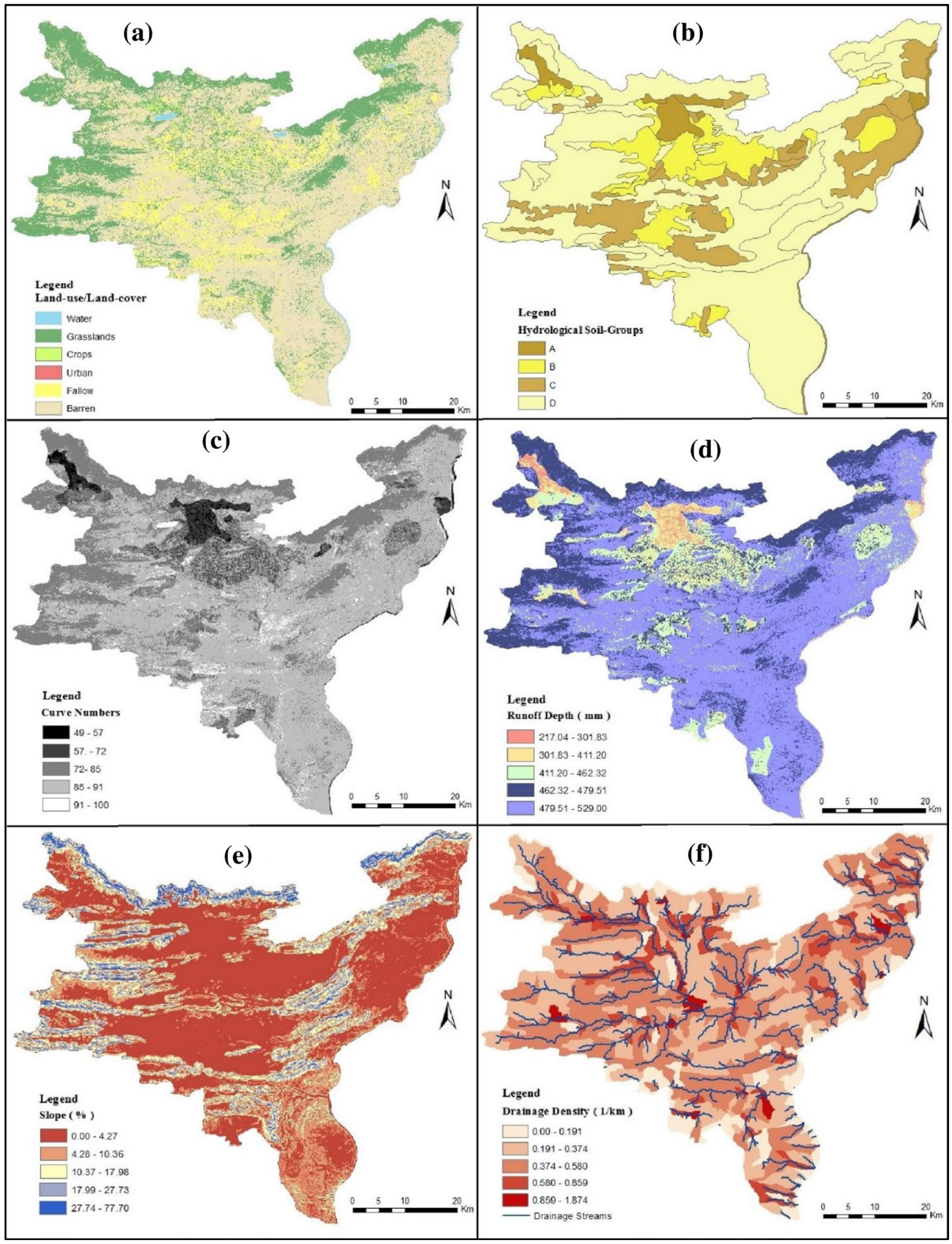


Fig. 6 Geographical display of various parameters (**a** LULC; **b** hydrological soil groups; **c** curve numbers; **d** runoff depth; **e**: slope; **f**: drainage density)

their spread throughout the region, with high concentration in the extreme southern parts which can get the maximum accumulation of rain water. Similarly, areas with low suitability have high concentration in the north. Emergence of these patterns with large rainwater collecting areas as the most suitable sites is an advantage of the region, making the area naturally blessed with high potential of success rate as a pilot project of RWH. Looking at the potential points of rain water collection, the highly suitable stream points are distributed throughout the area, not showing the similar extreme concentration in the south as was shown by the suitable geography. It is because of the fact that the points have been marked at end of the suitable stream with some specific amount of water to be tackled at the location, whereas the low suitability points are well concentrated in the low suitable geography in the central north. The distribution of most suitable location throughput the area can lead to a highly efficient system of RWH in the region in terms of water storage as well as utilization management.

Artificial storage structures map

In addition to general suitability of sites, additional analysis has been performed to assess sites for artificial RWH storage structures, i.e., check dams, farm ponds and percolation tanks as shown in Fig. 8. It will prove a further help

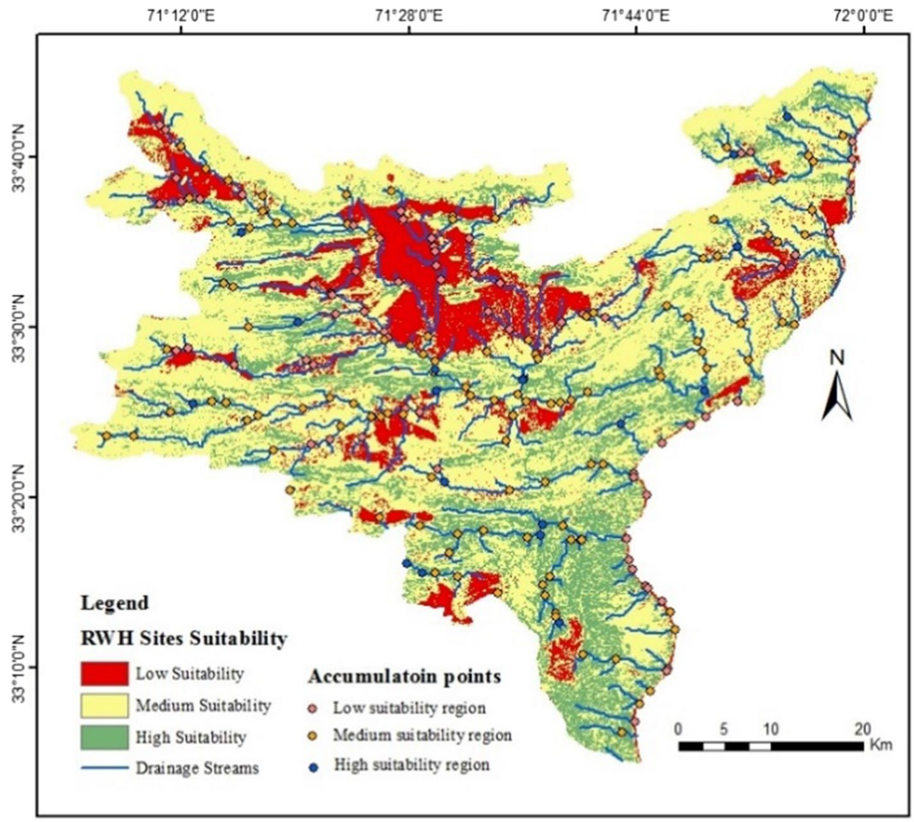


Fig. 7 Spatial distribution of RWH potential sites and suitable accumulation points

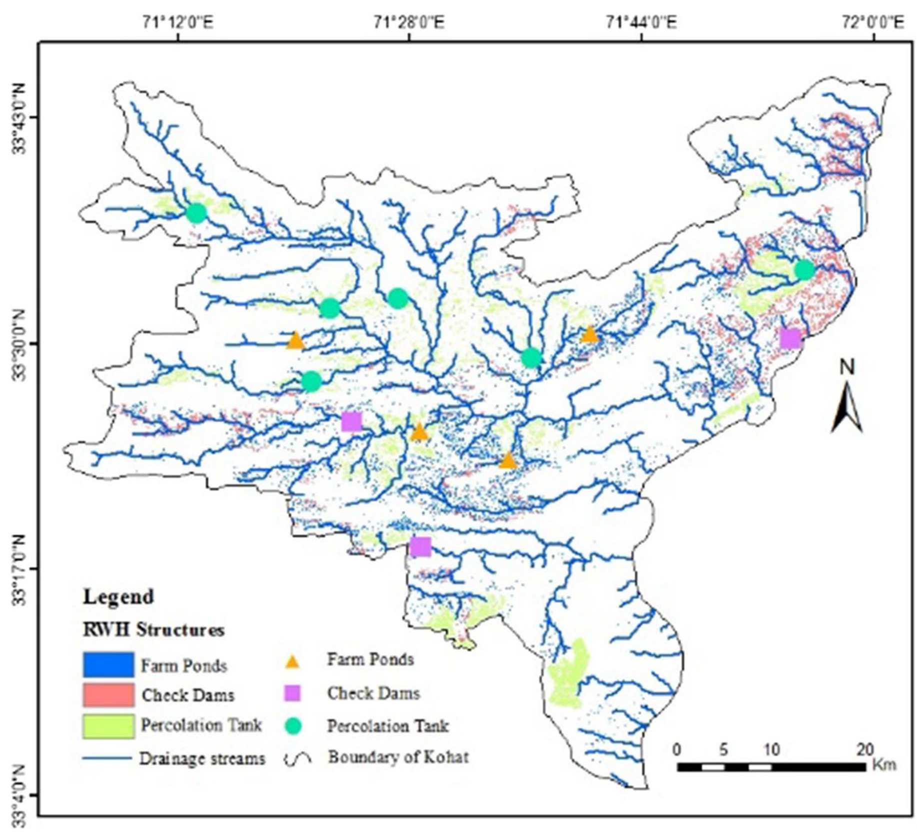


Fig. 8 Artificial structures for RWH

for development of application specific infrastructure to the decision makers in the region. These three types of structures need specific soil type and runoff depth.

Though the critical analysis 3.21% of the study area is found suitable for farm ponds that needs slope range of 0–5%, runoff depth lies from moderate to high and soil type as sandy clay loam. About 3% of the study area satisfies the conditions for the development of check dams with slope between 5 and 15% and runoff depth and soil type same as for farm ponds. The third structure is percolation tank with a suitability area of about 4.5% of the total, which can be installed in the regions where slope value is less than 10%, runoff is low and soil type is clay. Over this area allocation, the possible locations of individual structures, with maximum benefits, have also been pointed out and are shown in Fig. 7.

Well-distributed six locations have been marked for percolation tanks, four for the farm ponds concentrated mainly in the center of the region, and three for check dams. Installation of percolation tanks has been marked with four points at upstream of the main residential region of Kohat with two points as a facility to relatively low populated areas in the east and west of it. All the farm ponds suggestions have been emerged from periphery of the residential area where most of the farm land and farming business is concentrated. Three check dam suggestions are also providing a perfect distribution in the downslope of main Kohat and will be of great benefit for southern settlements to this main population zone. Overall the arrangement of potential sites for RWH system has come out with maximum potential benefits proving the use techniques as the perfect solution for planning such a system and the chosen area as the perfect fit of a pilot project for the RWH.

Conclusion

The aim of this study was to identify the suitable sites for harvesting rain water in the region of Kohat, Pakistan. The study area has been found having a natural setup to support RWH as an alternate for fulfilling water requirements at different scales. If the rainwater is harvested, filtered, stored and managed properly, the water scarcity problem can be fixed to considerable extent in the area. This research successfully develops the suitable sites in the area where rainwater can be harvested with the installation of different artificial RWH structures. Geographical multicriteria evaluation process has been successfully utilized for analyzing site suitability that is based on various methods of GIS and SRS. These methods have been put together in such a sequence that suits with natural settings of the phenomenon. The used thematic layers in the analysis are slope, land cover/land use, runoff depth, and drainage density that were combined using weighted overlay process in GIS environment. The study has provided many insights into the spatial distribution of RWH controlling parameters.

About 0.65% of the study area is covered by water that is absolutely not suitable for building any RWH structure and major land cover is barren that comprises about 58% of the area. The most appropriate soil type has a spread, covering of 70% and 98% of the area having a runoff greater than 300 mm, needed for building a RWH system. Similarly, maximum of the area has a suitable slope value of 0–10% and drainage density of all the individual watersheds is also fit for planning a RWH system. Although individual parameters have suitable scenario over major portion of the area, a geographical mismatch of their combination has somehow decreased this area to suitability. Even then the final suitability map has come out with only 17% of the area that is not suitable. Still 83% of the study area is supporting development of RWH system in the region with 21% area as highly suitable. So overall the study area is naturally blessed with all the ingredients needed for the development of sustainable and efficient RWH systems.

The area in immediate surroundings of Kohat city lies in the low suitable region while most of the highly suitable sites lie in the center and the southern parts. Conclusively, the generation of accumulation points at the end of down streams proved that there are enough points of accumulation throughout the region where different artificial recharge/storage structures can be installed in the selected sites which can prove to be greatly helpful in conserving water in water deficit areas.

In addition to this general suitability of RWH, sites for specific structure have also been determined. The area of suitability found for farm ponds is 3.2% with four construction sites, for check dams it is 2.9% with three construction sites and for percolation tanks it is 4.5% of the total with six construction sites. Overall the arrangement of potential sites, both general and specific, for RWH system in the area is proving beneficial in two ways. At first, emergence of these patterns with large rainwater collecting areas as the most suitable sites and distribution of these resource points throughout the area both are leading to highly efficient system in terms of water storage and utilization. This is an advantage of the region, making the area naturally blessed with high potential of success rate as a pilot project of RWH. At second place perfection in the output with maximum potential benefits has proved the used techniques as the preferred solution for planning such a system.

The SCS-CN approach adopted for the study has been proved to be a better technique not only for determining best sites for RWH system but also to assess natural settings of an area for the purpose. This approach can be implemented as it is to almost all the hilly areas. As the approach provides pre-assessment of RWH potential so when combined with some existing ranking criteria like one proposed by Mahmood et al. (2017b) can lead toward a better and beneficial resources allocation for such systems in the world.

Authors contribution All the authors are genuine contributor of the research work.

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Availability of data and material The used data is available with Soil Survey of Pakistan, Lahore, Pakistan, meteorological data with Pakistan Meteorological Department and used satellite images with Copernicus Open Access Hub. Additionally, all this data is also available with authors.

Compliance with ethical standards

Code availability Not applicable.

Conflict of interest There is no conflict of interest.

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