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Selection of Suitable Sites for Water Harvesting Structures in a Flood Prone Area Using Remote Sensing and GIS – Case Study

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Abstract
Water harvesting structures are extremely important to conserve precious natural resource like soil and water which is deteriorating due to the uncontrolled flood flushes that caused damages, in time where it could be very useful if suitable technical methods were applied to keep it. Check dams are one of these structures that could be very useful if certain conditions were available in the flood area. In this study Ali Al Gharbi which is located in the southeast part of Iraq near to the Iraqi- Iranian borders, is chosen as an area that suffered from frequently flood flushes that come from the Iranian land. Those floods damaged all the infrastructures like bridges, roads and also the farms and villages in its way. Remote sensing and GIS technologies were the appropriate tools to choose the suitable sites for check dams in the area. The various thematic maps such as Land use, Drainage, HSG, Slope and DEM maps were prepared for selecting suitable sites for construction of check dams. Four check dams and four percolation tanks were proposed for the construction that may serve the purpose of soil and water conservation to help in sustainable development of the catchment area. The proposed check dams can be very useful to supply water for irrigation in dry seasons.
Keywords: Water harvesting, Check dams, Ali Al Gharbi, Missan Governorate, GIS, Floods, Remote sensing.

1. Introduction

Water is essential for all life forms and is used in different ways such as food production, drinking, domestic, industrial, power generation and recreational use. Out of 2.5% global fresh water only 1% is available for human consumption. According to the World Bank report (Al Abadi, et al., 2017), Decades of war and mismanagement, increased demand due to population growth, water policies at Iraq's upstream neighbors (Turkey and Syria), and the worst droughts in recent years have made water a scarce commodity in Iraq, particularly in southern part of the country. Severe water scarcity in the region has forced thousands of marshland residents to abandon their homes in recent years. The trend is very likely to grow as the drought continues in Iraq. There is an urgently need of alternative planning to mitigate the water scarcity. water harvesting (WH) is considered as one of the most effective options for irrigation in dry areas. In the arid regions, like southern Iraq, WH could be an efficient approach to harness the excess runoff that is often lost, and hence can be used during water deficit (Yousif &Bubenzer,2015). WH helps to increase the amount of water per unit cropped area and improve groundwater levels (Sur, et al.,2001), and thus help to mitigate water shortage problems especially for agricultural and domestic uses (Cook,2000).

2. Location and Characteristics of the Case Study Area

Floods are among the most frequent and devastating natural hazards which cause severe damage to both life and property every year across the world (Jonkman et al,2012; Ajin et al.2013). It is ranked as the top among all natural disasters in terms of both number of affected people and economic losses incurred globally. The study area Ali Al Ghurbi is located in the northeastern part of Missan governorate, south of Iraq between latitude 32°03'25.52" – 32°30'30" and longitude 47°05'21.16" – 47°40'53.52" (Fig.1). It covers an area of 2098 km2 with elevation ranges from 0 to 266 m. The land surface is relatively flat in the central part of the area and is bounded by Hemrin hills in the northeastern and Band hill in the north. In general, the elevation of the study area decreases from northeast to southwest. Two intermittent streams originated in Iran flow through the study area. The Teeb stream enters the territory of Iraq through the Teeb town located in the north of the study area and runs from north to south until it ends in Al-Sanaf marsh outside the study area. The other stream is Dewereg which enters Iraq through Fauqi area and runs from east to northwest until it finishes in Al-Rais marsh. The total lengths of Teeb and Dewereg streams within the study area are 63 and 35 km, respectively. Most parts of the area is covered with different types of Quaternary deposits mainly sand and alluvium deposits of recent and Pleistocene age. The Quaternary sediments are unconsolidated and usually fine grained, where alluvial fans, flood plain, depression fill, and aeolian deposits are the major units of the Quaternary deposits in the area (Khalaf et al., 1985 in Jassim and Goff, 2006).One of the common landforms in the area and very effective one is the existence of Wadies (valleys) , which are filled with water after heavy rain and significantly contribute in groundwater recharge. Wadies can be classified into two types depending on their occurrence; mountain or flat area. Wadies in mountain area are very rugged and dissected due to action of strongly water coming from Iran. Shallow wadies in flat area are simple depression with gentle slope and commonly terminate in marshes and they consist of a mixture of gravel, sand, and silt sediments.

3. Water Harvesting Strucures

The present study envisages the potential suitability for different water harvesting structures in the watershed with the help of information technology viz., Remote Sensing and Geographical Information System.

Cities in southern Iraq have been suffering from floods coming from Iranian lands. In 7 May 2013, heavy rainfall was unexpected by many, and certainly wasn't anticipated to continue for so long. In fact it comes after a significant period of drought. At least 70 towns and villages in the analyzed area are potentially inundated. Multiple sections of roadways are likewise potentially affected. It is likely that flood waters have been systematically underestimated in highly vegetated areas, along main river banks, within built-up urban areas, and in sparse areas of cloud shadow. The same disaster was repeated again in 2014 and 2016 (Plate 1).

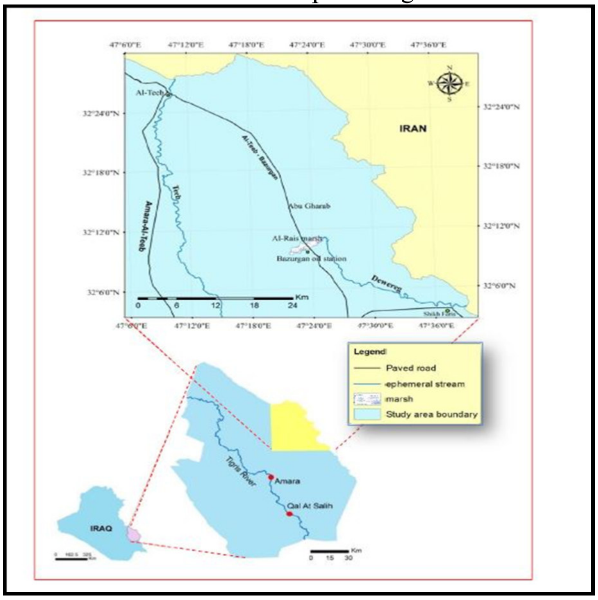

Figure 1. The Location Map of the Case Study Area

Plate1. Photos from the Flood-Stricken Areas in Ali Al-Ghurbi, Missan Governorate (May, 2013)

The maximum runoff water goes down without being used for any purpose due to steep slope and stones in the soil causing soil erosion and converted into degraded land. Due to steep slope water gets down with very high speed and it cannot be directly stored in the reservoirs. The surface runoff can be checked by constructing structures like check dams, farm ponds, nala bunds, percolation tanks etc. These structures may differ with different parameters viz., location, slope, soil type, rainfall intensity, land cover and settlement (Bamne et al., 2014). Depending on these parameters, in addition to benefiting from the presence of gravel and sand quarries in the nearby area, the construction of check dams, percolation tanks and Nala bunds are to be proposed at appropriate sites in Ali Al-Ghurbi watershed.

4. Methods

The planning about the required number and type of water harvesting structure to be constructed in watershed and making decision on them is extremely important to avoid large investments on unproductive structures. The present study envisages the potential suitability for different water harvesting structures in Ali Al-Ghurbi watershed with the help of emerging technologies viz, Remote Sensing (RS) and into GIS using weighted linear combination method. The stepwise method for preparation of various maps is presented through flowchart (Fig. 2). The following criteria have been followed for making decision on selecting suitable site for various water harvesting structures as per Integrated Mission for Sustainable Development (IMSD) guidelines (Bamne et al., 2014):

4.1 Check dams

i. The slope should be less than 15 per cent.

ii. The land use may be barren, shrub land and riverbed.

iii. The infiltration rate of the soil should be less.

iv. The type of soil should be sandy clay loam.

4.2 Percolation tanks and nala bunds

i. The slope should be less than 10 per cent.

ii. The infiltration rate of the soil should be moderately high.

iii. The land use / cover may be barren or scrub land.

iv. The type of soil should be silt loam.

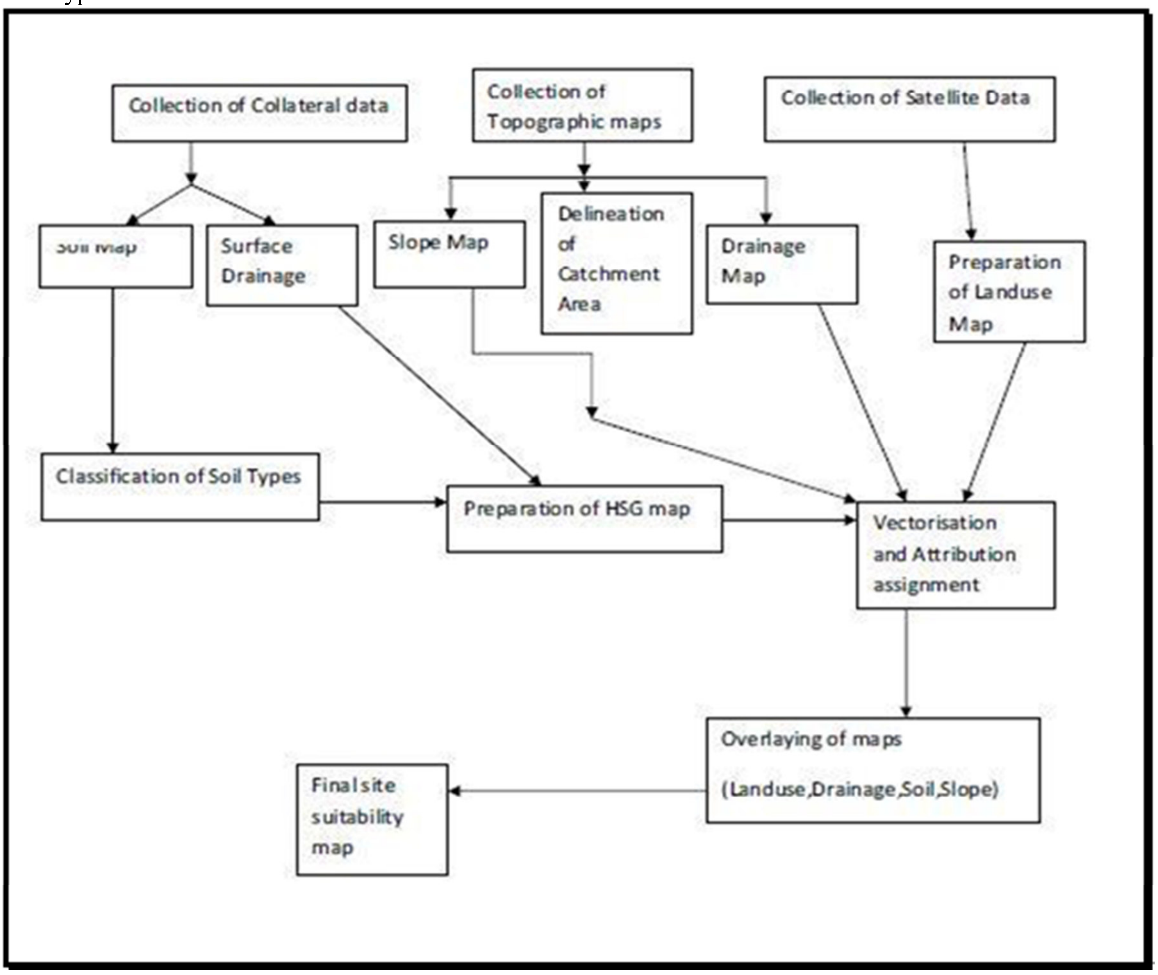

Figure 2. Flowchart for Preparing Site Suitability Map

5. Materials

Geo-referencing of scanned maps was carried out in this study in a raster format with a resolution of 30 m using ArcGIS 10.2 software using control points already established on the base map. The raw data was re-projected to Universal Transverse Mercator (UTM) coordinate system [World Geodetic System (WGS) datum, 38 N], the sinks were filled, and clipped with the study area polygon (Al-Abadi, 2016). On screen digitization of scanned maps was performed in Arc GIS software and editing was done accordingly to remove errors incurred during digitization.

After finalizing the error free coverage, attributes were assigned to units belonging to different categories of the land use, drainage and soils in respective thematic maps.

Thematic raster layers of topographic factors, i.e. elevation, slope, were prepared from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) data. The ASTER-GDEM data of 30 m resolution is available from web site (http://gdem.ersdac.jspacesystems.or.jp/search.jsp).

5.1 Thematic Maps:

The following thematic maps are needed for locating the water harvesting structures in the area:

5.1.1 Land Use Map

Land use map (Fig. 3) was prepared using satellite image data considering five different classes of land use. (i) River, Canal (ii) Mixed dry farming land with graze land(Agricultural land) (iii) Date palm and Orchard (Agricultural land) (iv) Abandoned and perennial fallow land (Agricultural land) (v) Mixed range land. Land use map was further classified based on suitability for different water harvesting structures.

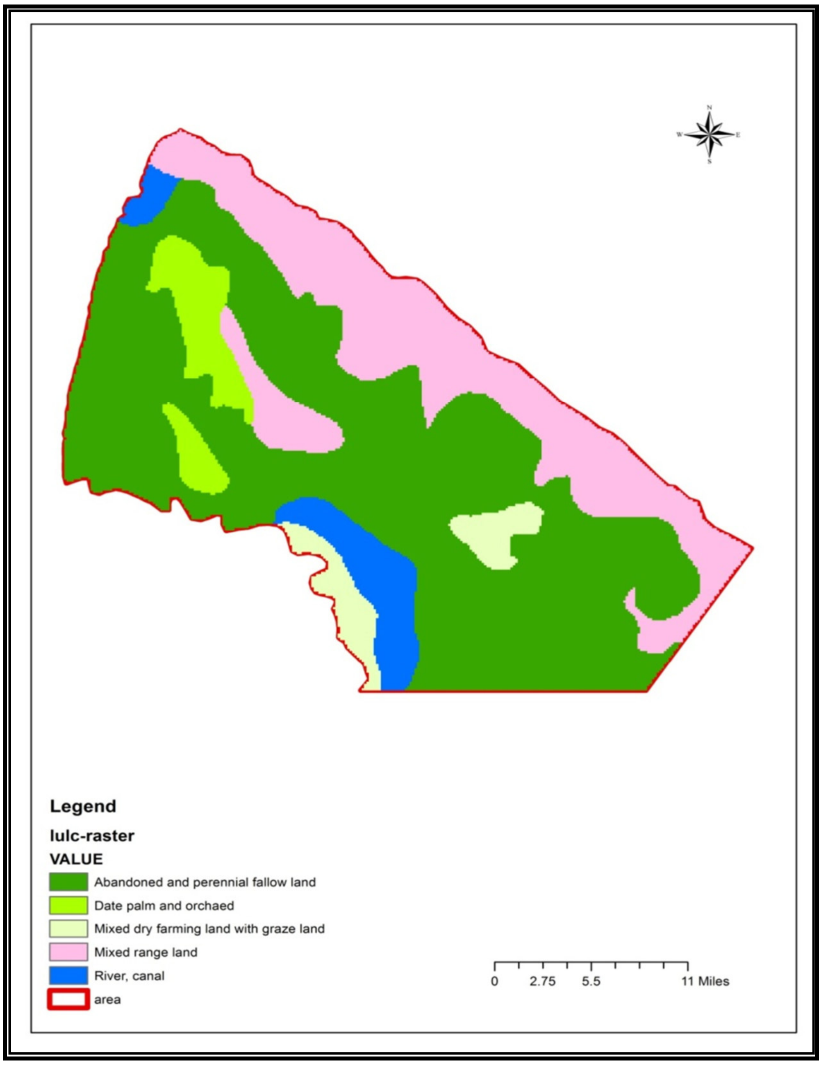

Figure 3. Land Use Map of Ali Al-Ghurbi Watershed

5.1.2 Drainage Map

Drainage map was prepared by digitizing drainage in ArcGIS using Arc hydro tools as shown in (Fig.4).

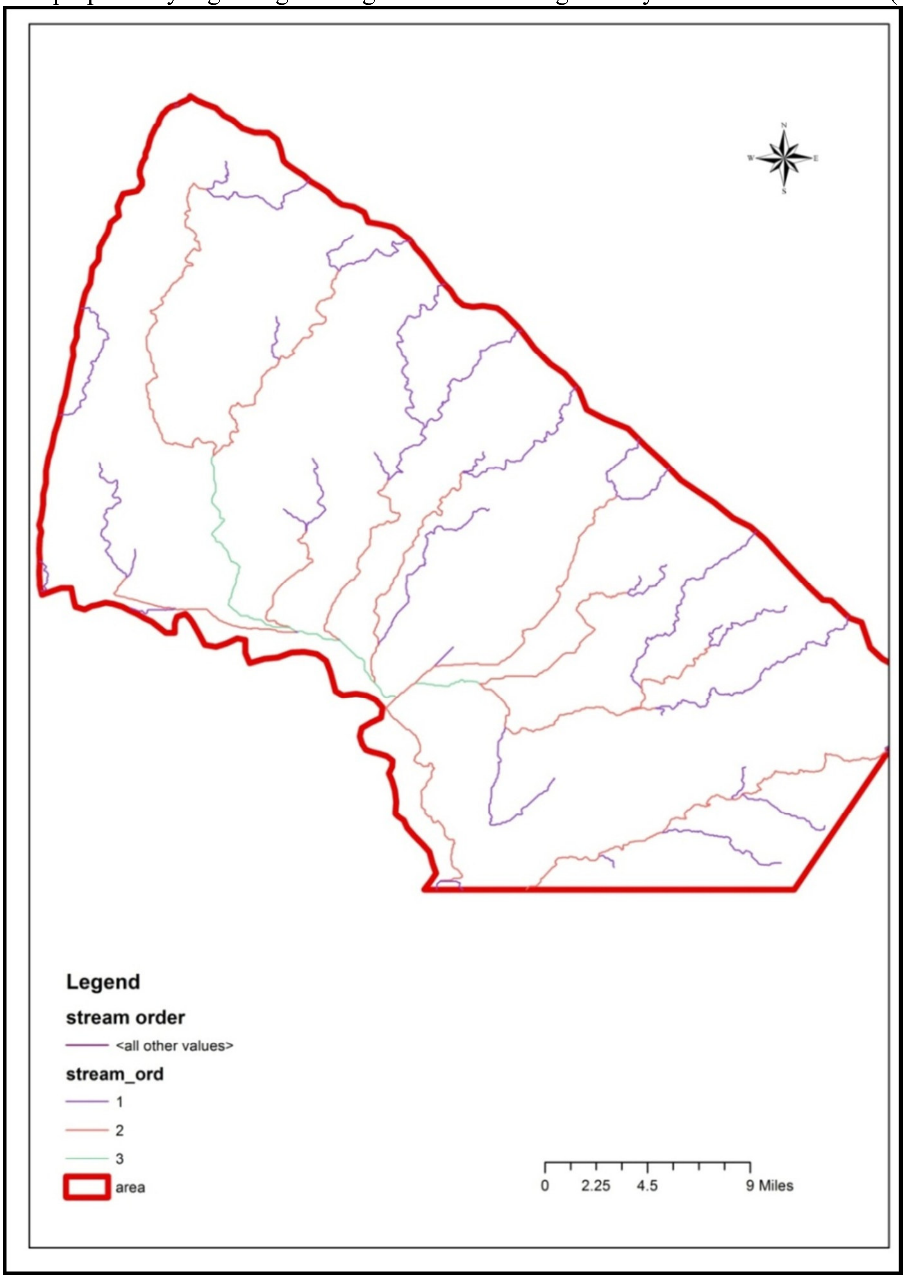

Figure 4. Stream Order Map of Ali Al-Ghurbi Watershed

5.1.3 Hydrological Soil Group Map

The soil map consists of four classes' viz., clay, sand silt and loam (Fig.5). The hydrologic soil group (HSG) map was prepared from soil map taking into account the infiltration rates of various soil textures (Fig. 6). Accordingly the soil classes were grouped under four categories viz. A, B, C and D. The classified HSG map was further grouped for the suitability of check dam, farm ponds and water harvesting structures.

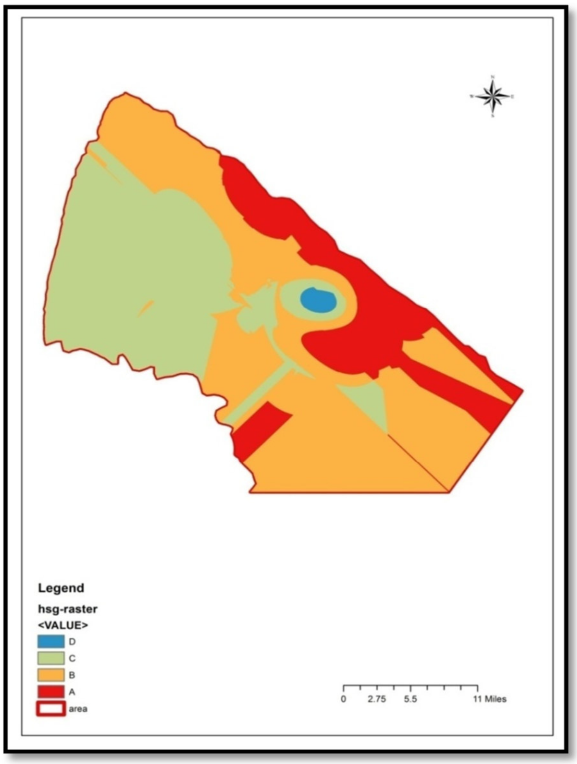

Figure 5. Soil Type Map of Ali Al-Ghurbi Watershed

Figure 6. HSG Map of Ali Al-Ghurbi Watershed

5.1.4 Slope Map

The slope map was prepared from elevation map extracted from Digital Elevation Model (DEM) (Fig. 7). The slope designated in value domain was prepared using filtering technique (Fig. 8). The slope map was further classified for exploring potential suitable sites for several water harvesting structures.

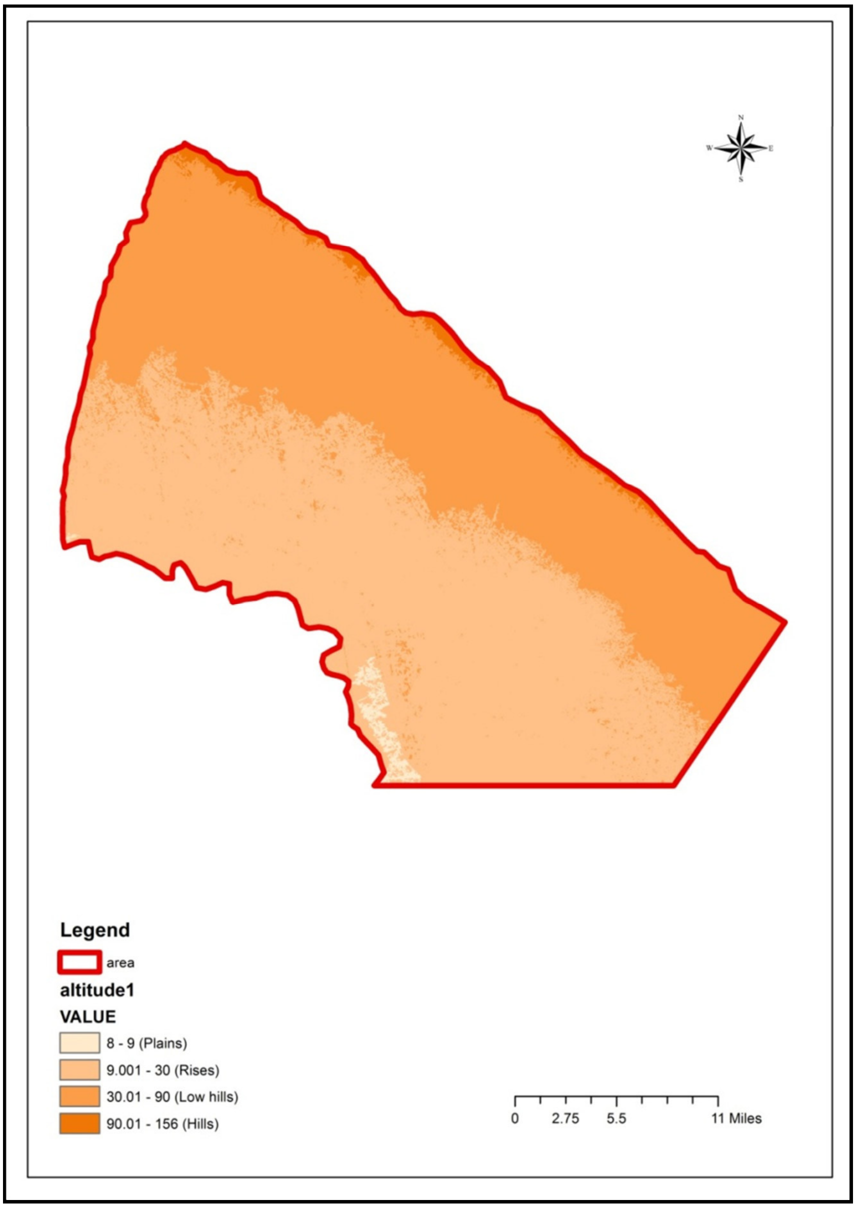

Figure 7. Elevation Map of Ali Al-Ghurbi Watershed

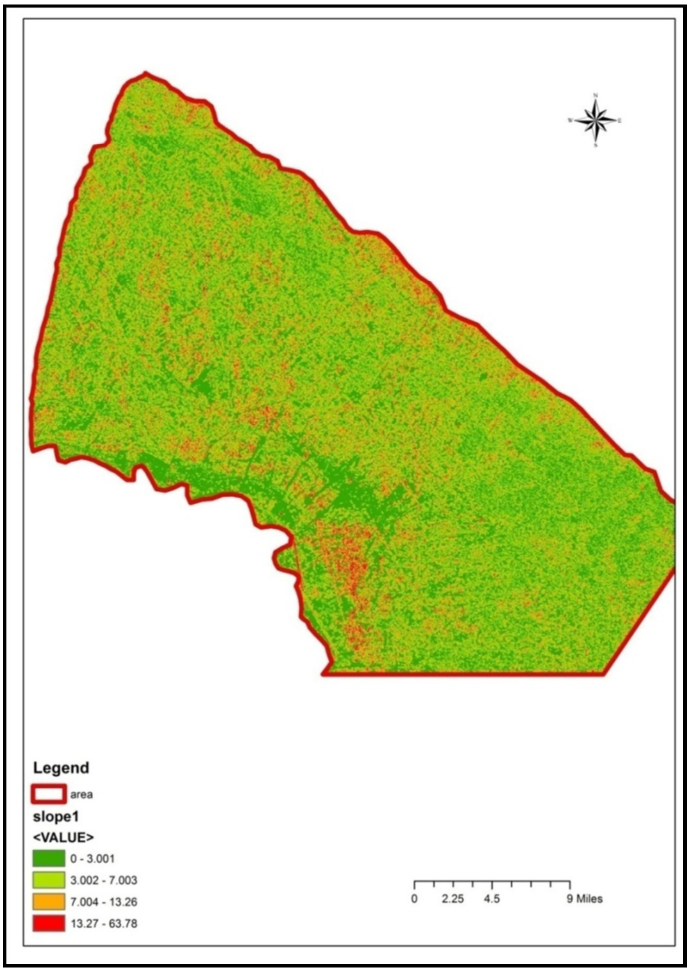

Figure 8. Slope Map of Ali Al-Ghurbi Watershed

6. Results and Discussion

The cross operation was performed using classified land use map and Hydrological Soil Group map. In the next iteration suitable land use and infiltration rate, suitable soil feature and suitable stream order are intersected and overlaid on slope map for locating suitable sites for water harvesting structures.

6.1 Suitable sites for check dams

The suitability of check dam sites can be confirmed as the site is located on second and third order drainage and satisfies the conditions of land use, soil type and slope as per IMSD guidelines. The most of the sites in Ali Al-Ghurbi watershed were found to be suitable for check dams but as per ground truth and experience, four suitable sites were proposed to construct the check dams (figure 9). Since it is located in suitable land class (agricultural land,water body), slope (less than 15%) and soil type (sandy clay loam) that serves the purpose of soil and water conservations and groundwater augmentation. The proposed check dams could be very useful as supplementing irrigation during the dry season, and suitable autumn/spring crops may be cultivated.

6.2 Suitable Sites for Percolation Tanks

The suitability of sites for percolation tanks can be confirmed, as it is located in soil having high infiltration rate and satisfying other conditions as per IMSD guidelines. The figure (9) reveals that few sites are found to be suitable for construction of percolation tanks in Ali Al-Ghurbi watershed and four sites were proposed for the construction. The proposed percolation tanks are located in a sandy silt loam soils which is highly suitable for recharging ground water. It is also located in agricultural land having slope less than 10% which satisfied the IMSD guidelines. Since, it is located in the second and third order drainage that saves the percolation tanks from the damage due to high runoff.

7. Conclusions

Water harvesting structure is one of the key components of watershed development. There are always strong links between soil conservation and water conservation measures. The reduction of surface runoff can be achieved by construction of suitable structures or by changes in land management. Additional, this reduction of surface runoff will increase infiltration and help in water conservation. Remote sensing and GIS technologies were used to determine the suitable positions to construct the proper water harvesting structures in the watershed which are check dams and percolation tanks or Nala bunds. Thematic maps of land use, drainage, hydrological soil group, and slope were used to produce the final map for site locations of check dams and percolation tanks. Check dam sites is located on second and third order drainage and satisfies the conditions of land use, soil type and slope as per IMSD guidelines. The most of the sites in Ali Al-Ghurbi watershed were found to be suitable for check dams but as per ground truth and experience, four suitable sites were proposed to construct the check dams. The suitability site for percolation tanks is located in soil having high infiltration rate and satisfying other conditions as per IMSD guidelines. Four sites were preposed for the percolation tanks, which are located in a sandy silt loam soils which is highly suitable for recharging ground water. It is also located in agricultural land having slope less than 10% which satisfied the IMSD guidelines. Since, it is located in the second and third order drainage that saves the percolation tanks from the damage due to high runoff.

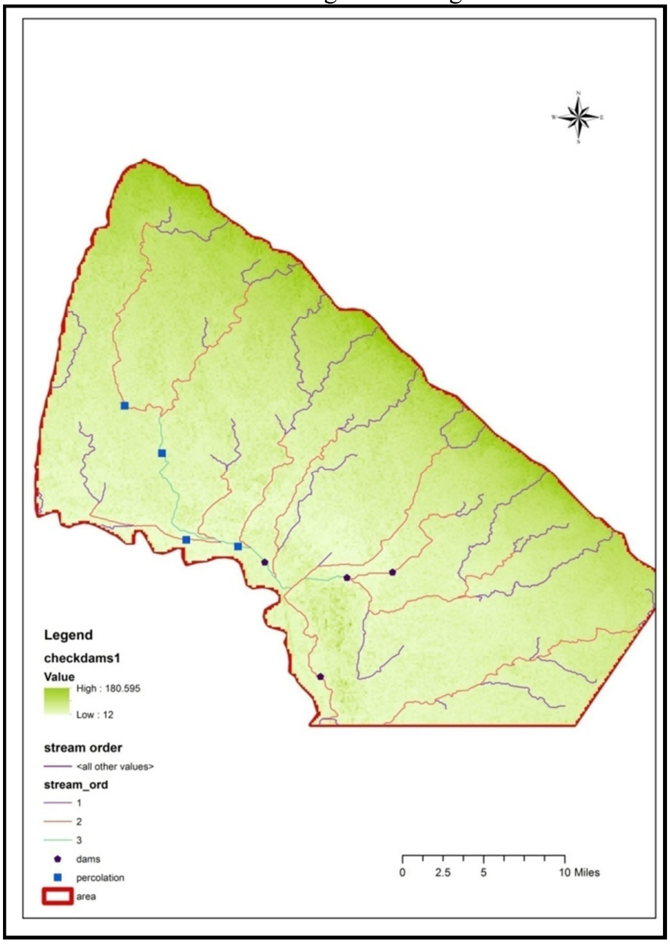

Figure 9. Site Suitability Map for Check Dams and Percolation Tanks of Ali Al-Ghurbi Watershed

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