# Site Suitability Analysis for Surface Rainwater Harvesting using Remote Sensing and GIS

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*Abstract*— Delhi region is facing the problem of scarcity of water throughout the year. To check this problem, various efforts have been made. Rainwater harvesting is such an effort which can be used to address the problem of shortage of water effectively. This can be done by constructing check Dams, Percolation Tank, Bore well, Dug well, Dug cum bore well, Farm Pond, etc. In the present dissertation, Selection of suitable rainwater harvesting site are carried out with the help of GIS and remote sensing in Delhi region. In this study suitability of rainwater harvesting sites is carried out by GPS, Survey of India toposheets on scale of 1:250,000, SRTM data for creation of DEM and satellite imagery of LANDSAT ETM+ (30mt. spatial resolution). This study therefore focused on the development of suitability level for most important factor and parameters for identification of such sites. These factors include rainfall, soil texture, drainage, topography and land use / land cover and integration of these factors using weighted overlay analysis with the help of ArcGIS software provide suitable sites for rainwater harvesting. These sites are then classified into various suitability levels, namely, 1, 2, 3, 4 and 5, 5 suitability level is the most suitable region and 1 suitability level is the least suitable region for rainwater harvesting. By applying above process, the results shows that in Delhi region there are several suitable sites with highest suitability level which can be used for Rainwater harvesting. Hence, the conclusion of the study is that site suitability analysis for surface rainwater harvesting using GIS and remote sensing is the better technique for finding rainwater harvesting suitable site with quite appreciable accuracy.

***Keywords:*** Landsat-7 ETM, DEM, Topo sheets, Land Use / Land Cover (LULC), Reclassify, Weighted Overlay, Global Land Cover Facility (GLCF), Survey of India (SOI), Geological Survey of India (GSI) ,ArcGIS10.2 and ERDAS IMAGINE 9.1

## I. INTRODUCTION

Water is an essential requirement for economic and social development of any locality. The population and economy of India is growing thereby resulting in the growth of water demand for domestic, agricultural and industrial use. Reduction of surface runoff can be achieved by construction of suitable structures. These structures also helps to manage the other natural resources like soil, slope, and Land use/Land cover as the watershed condition affect these recourses. Water is important for all life and used in many different ways. It also is a part of the larger ecosystem on which reproduction of the biodiversity depends. Fresh water scarcity is not limited to the arid climate regions only, but in many areas with good supply the access to safe water has become critical problem. Deficiency of water is caused by minimized water storage capability, low infiltration, larger inter annual and annual fluctuations in precipitation due to monsoon rains and high evaporation losses.

The concept of Rainwater harvesting (RWH) is both simple and ancient. Rain water harvesting primarily consists of the collection and storage of rainwater for subsequent use as source of water. The harvested water can be used for Both potable and non-potable applications. There are many examples of rainwater harvesting systems which provide water for domestic, commercial, institutional and industrial purposes as well as agriculture, livestock, groundwater recharge, flood control, process water and as an emergency supply for firefighting (Gould & Nissen-Peterson, 1999). RWH systems can be small and basic, such as attachment of a tank to rainwater downspout, as well as large and complex, such as those that collect water from many hectares and serve large numbers of people. Before the latter half of the twentieth century, RWH systems were used predominantly in areas lacking additional forms of water supply, such as Kutch region of India. Some ancient rain water harvesting system can also be seen in Tamil Nadu, Maharashtra, Madhya Pradesh, Chhattisgarh and Rajasthan states of India.

The flowchart below demonstrates the fundamental process of rainwater harvesting.


Fig. 1: Flow chart illustrating the fundamental rainwater harvesting processes

The depth of ground water table has lowered in recent years in the Delhi region. Therefore, It is necessary to search for systems storing the water from the rainfall and permanent streams runoff to be used as supplementary resources in the dry spells or to provide systems for recharge of ground water.

## II. REQUIREMENT OF RAINWATER HARVESTING

Out of the total water source 91% is ocean water and only 2.5% is potable fresh water and balance 6.5% is in other forms. The ground water table has depleted abruptly due to urbanization causing scarcity of water. Rains provide a large amount of fresh water which can be easily harvested by surface or subsurface storage. So rainwater harvesting is the need of the coming years.

### A. *Why more Suitable for Metro City*

Over exploitation and heavy withdrawal of ground water in metros has led to declination of water level at an alarming rate making Rainwater harvesting for metro cities a necessity. Rain water can be collected and stored in lakes or tanks. Storing the rainwater in sub surface aquifer is another solution to solve the water supply problems. The process of artificial recharge to ground is fast and it is possible to recharge more than 90% of rainwater to ground system.

## III. AIMS AND OBJECTIVES

### A. *Aim:*

The aim of this study is to produce a groundwater recharge potential map using GIS.

### B. *Objectives*

1) To demarcate the ground water recharge potential zones using GIS technique.
2) To analyze DEM Model and to generate Slope Map and Aspect Map from DEM model for locating rainwater harvesting site.
3) To Identify and map out the potential rainwater harvesting sites for Delhi region along with recommendation for suitable hydrological structure.

## IV. STUDY AREA

The region selected for the present study is Delhi region. It is located between 28$^0$24’15’’ and 28$^0$53’00’’N latitudes and 76$^0$50’24’’ and 77$^0$20’30”E longitudes occupying an area of 1483.0 sq. km. The total population of NCT Delhi, as per the census 2011 is 167.53 lakhs with a density of 11297 persons/sq.km area. The normal annual rainfall of Delhi region is 611.8mm. The rainfall increases from the South-West to the North-West. About 81% of the annual rainfall is received during the monsoon months July, August and September. The rest of the annual rainfall is received in the form of winter rain. The Gangetic Plain and the Aravalli Ridge converge at Delhi, giving mixed geological character with alluvial plains as well as quartzite bedrock. Delhi region is divided into 9 districts and 27 sub-division. (CGWB, New Delhi).

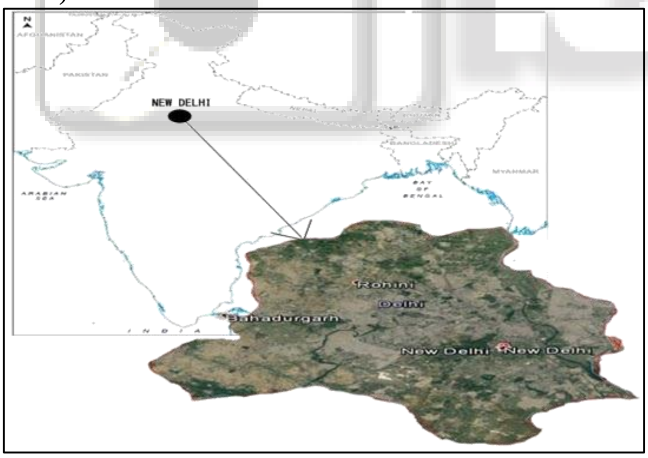



Fig. 2: Location map of the study area (Source: Google earth)

### A. *Software Used:*

ArcGIS 10.2 and ERDAS IMAGINE 9.1 was used for geo-processing and image processing respectively.

## V. METHODOLOGY FOR PRESENT STUDY

In this dissertation, the study has been conducted for the site suitability analysis for surface rainwater harvesting using GIS and remote sensing. The methodology divided in two parts is discussed separately.

To analyze DEM Model and to generate Slope Map and Aspect Map from DEM model for locating rainwater harvesting site.

A digital elevation model (DEM) is a digital model representation of a terrain's surface commonly for a planet including Earth, moon, created from terrain elevation data. In the present study, analysis of DEM Model is done. DEM Model is generated from SRTM data and slope map and aspect map are generated using ERDAS Imaging software. For this, with the help of preprocessing of DEM model, projection is changed according to the unit of the coordinates of the study area.

### A. *Slope Map Preparation*

The DEM obtained is used for the generation of slope which classifies the entire study area in different categories of slope ranges. The ranges so classified will help in calculating the space of the water flow in that particular region. This information is useful in the categorization of the type of structure to be built in that particular zone.

### B. *Aspect Map*

The compass direction that a topographic slope faces, usually measured in degrees from north. Aspect can be generated from continuous elevation surfaces Find all north-facing slopes on a mountain as part of a search for the best slopes for ski runs. Identify areas of flat land to find an area for a plane to land in an emergency.

### C. *Stream order map*

Stream order is a measure of the relative size of streams. This is also the outcome of the DEM generation using SRTM data. The smallest tributaries are referred to as first-order streams, while rivers are higher order waterway. Drainage/stream ordering represent the number of streams presents in each order defined i.e. 1, 2, 3, 4, 5 and 6 stream orders. 2nd, 3rd or 4th order streams are suitable for Storage Tank and Percolation Tank. 4th, 5th or 6th order streams are suitable for Check Dams. 3rd or 4th order streams are suitable for Stop Dams. In mathematics, the Strahler number or Horton–Strahler number of a mathematical tree is a numerical measure of its branching complexity. This can be obtained by Spatial Analyst of ArcGIS software Tools which is done by setting the input surface raster as DEM and output surface raster as Stream order.

### D. *To identify and map out the potential rain water harvesting sites for Delhi region.*

The process of identifying and mapping of potential rain water harvesting sites is based on weighted overlay analysis. In this analysis, the integration of the Land use/Land cover map, Slope map and Stream order map is done for carrying out site suitability analysis for rain water harvesting sites. The flow chart for this objective is given in Figure 3 and discussed below –

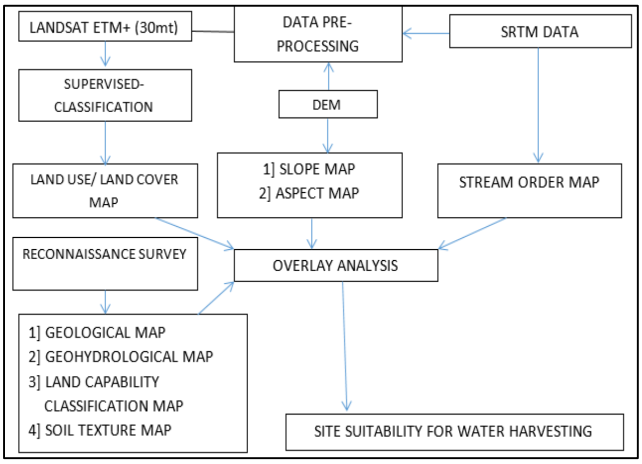



Fig. 3: Methodology for preparing site suitability map for RWH structures.

## VI. WEIGHTED OVERLAY ANALYSIS

The purpose of the weighted overlay analysis is to apply a common scale of values to diverse and dissimilar data input to create an integrated analysis. ArcGIS is used to implement Weighted Overlay Analysis. The weights calculated for each factor using

$$S = \text{SUMMATION } Zi * Xi$$

Where Zi is the weight of indicator i and Xi is the criteria score of the indicator I.

To implement the rules laid by integrated mission for sustainable development (IMSD) guide lines, number of information layers is prepared by overlaying the Land use, slope, stream order to match the criteria laid. A Multi Criteria based analysis is used for the identification of the site suitability map for various Rainwater Harvesting structures for water storage. The generated layers are in vector format, for Weighted Overlay Analysis the "Rasterization" of each layer is performed. The first step of data conversion is "Rasterization" for converting different lines and polygon coverage into raster data format. After this, reclassification of all the raster files is processed along with providing the scale value of each unit. A scale value in the range 1 to 3 is used in which "1" is for least suitable, "2" is for moderate suitable and "3" is for highly suitable. All the layers are given ranking based on their influence on the study applying equal weightage to all the parameters which means all parameters are of equal importance. Further, in the Spatial Analyst Tool, Weighted Overlay Function has been processed for identification of the suitable area. Based on the Weighted Overlay Function a site suitability map and most suitability map is prepared and is shown in figure.

### A. *Soil Texture map*

In this dissertation, Soil texture map taken by Soil survey of India Delhi (2012). Soil texture is an important soil characteristic that will be taking into consideration of suggesting water harvesting structures .The study area is having different types of soil texture as sand, clay loam, sandy loam, loamy sand, silty loam, loam, silt clay loam, sandy clay loam and clay.

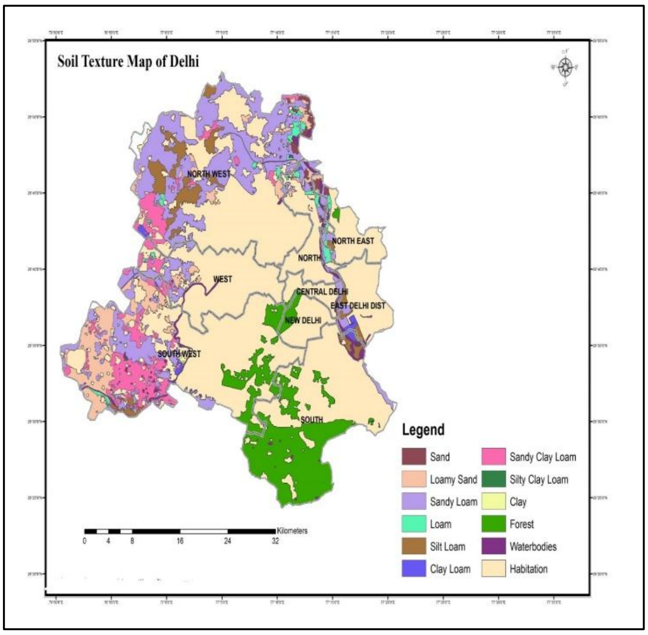
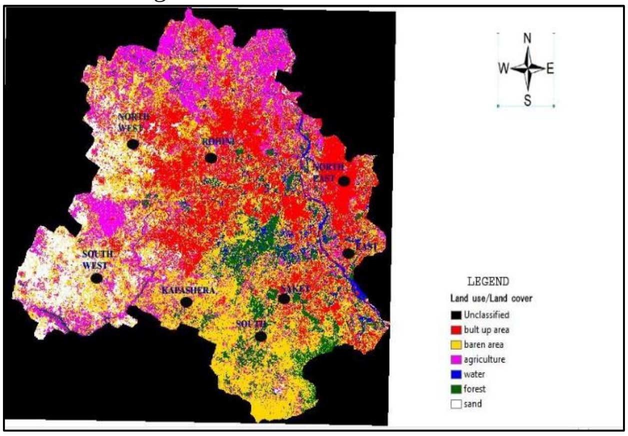



Fig. 4: Soil texture map Delhi. Source: Soil survey of India Noida

### B. *Land use/ Land cover map*

ERDAS IMAGINE 9.1 Software was used to mosaic the collected satellite images. The cluster Supervised classification tool and maximum Likelihood classification function in the ERDAS IMAGINE 9.1 Software were used for the supervised classification of Land use/Land cover data or Landsat ETM+ image for carrying out Land use/Land cover map. Training samples collected were used to create spectral signature for the supervised classification to identify what the cluster represent (i.e. water, bore earth and sand). Land Use/ Land Cover shows six main classes, namely (Built up area, Barren Area, Agriculture, Water, Forest and Sand).Beside land use/ Land cover map, Slope map and stream order map, soil texture map is also the important factor in deciding the outcome of the site suitability analysis for rain water harvesting.




Land use/Land Cover map presents multiple levels of land cover classifications for the continental Delhi States based on Landsat TM 2000 satellite imagery.

Fig. 5: Land use/Land Cover Map of Delhi region. Source: (Global Land Cover- Facility Site)

A digital elevation model (DEM) is a digital model representation of a terrain's surface commonly for a planet including Earth, moon, created from terrain elevation data. In the present study, analysis of DEM Model is done. DEM Model is generated from SRTM data and slope map and aspect map are generated using ERDAS Imaging software. For this, with the help of preprocessing of DEM model, projection is changed according to the unit of the coordinates of the study area.

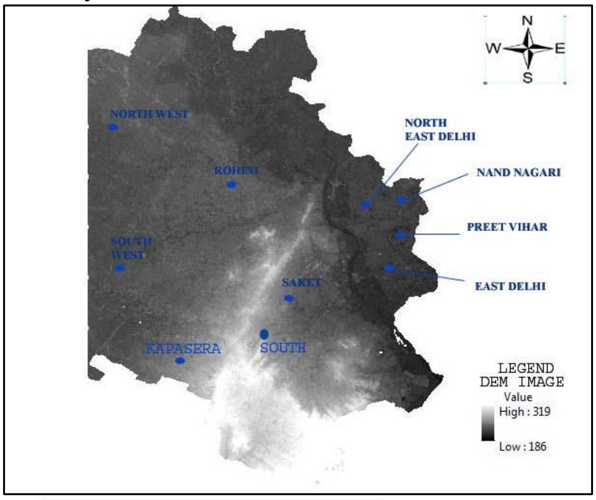



Fig. 6: Delhi Digital Elevation Model (Lat 28º24’15N’- Lon 77º20’30”E)
Source: (Global Land Cover Facility Site).

## VII. Result and Discussion

In the present study, DEM is constructed from SRTM raw data and Land use/land cover map is constructed from LANDSAT ETM+ raw data. With the generation of DEM, Slope map and stream order are fabricated using ArcGIS 10.2. Land use/Land cover map is obtained by using ERDAS Imagine 9.1.

### *A. Stream Order:*

Assigns a numeric order to segments of a raster representing branches of a linear network. The output of Stream Order will be of higher quality if the input stream raster and input flow direction raster are derived from the same surface. If the stream raster is derived from a rasterized streams dataset, the output may not be usable because, on a cell-by-cell basis, the direction will not correspond with the location of stream cells.

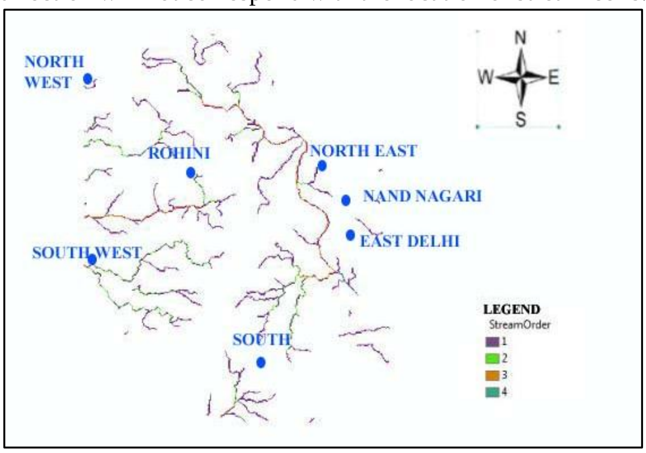



Fig. 7: Stream order map of Delhi region.

Stream order map was prepared with the help of DEM analysis in ArcGIS. Spatial analyst tool is being applied for extracting the stream lines and stream order tool is utilized to derive the order of the stream lines. As per the GIS analysis stream order ranges from 1st order to 7th order. Drainage ordering represent the number of streams presents in each order defined i.e. 1, 2,3,4,5 and 6 stream orders. 2nd, 3rd or 4th order streams are suitable for Storage Tank and Percolation Tank. 4th, 5th or 6th order streams are suitable for Check Dams. 3rd or 4th order streams are suitable for Stop Dams.

| Sl No | Stream Order |
|---|---|
| 1 | 1st Order |
| 2 | 2nd Order |
| 3 | 3rd Order |
| 4 | 4th Order |

Table 1: Stream order

### *B. Watershed Output Map*

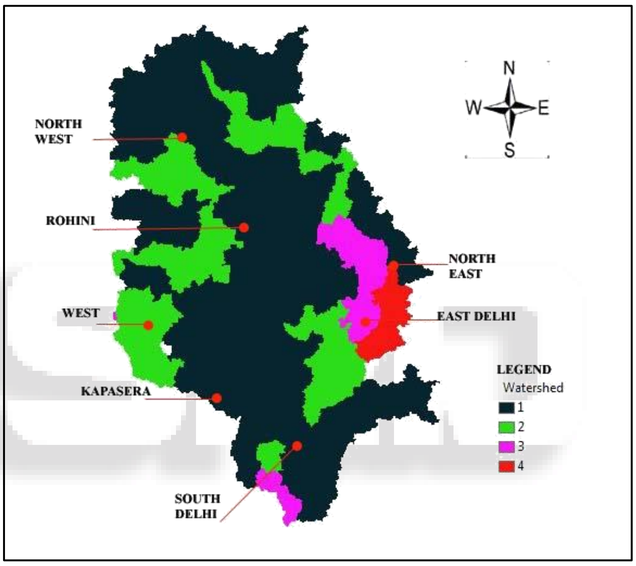



Fig. 7: watershed map of Delhi region.

### *C. 12 Most Suitable Site:*

Finally most suitable area shown in figure below. In this study, five most suitable area and two suitable areas are found. All suitable and most suitable area shown in figure.

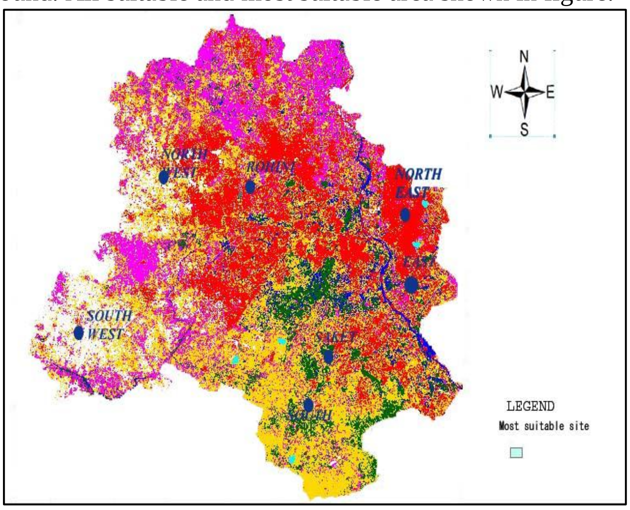



Fig. 8: Most Suitable Map of Delhi region.

## VIII. Conclusion

The multi-layer integration through Land use /Land cover, slope, stream order, gave the suitability of sites for identifying the rainwater harvesting sites. These layers were combined in ArcGIS using weighted overlay tool. A final map was generated which provide us the suitable and most suitable location for rainwater harvesting sites, as per the criteria laid by IMSD. Show the most suitable map for location of rainwater harvesting sites. There are about 2 suitable and 5 most suitable numbers of sites identified, which are highly suitable for creating water storage structures. Suitable and most suitable areas identified in Delhi region are located at south Delhi, North east Delhi, East Delhi and South west Delhi.

As per the slope and soil texture map following suggestions are made for rain water harvesting structures at the suitable sites of Delhi region.

### *A. North East Delhi*

Loni is the most suitable site in this region. It is suggested to construct Farm ponds, bore wells and dug wells at this location. The soil here is sandy loam and due to low slope it is more suitable for construction of farm ponds/percolation tank.

### *B. South Delhi*

Aya Nagar extension is the most suitable site in this region. Due to presence of sandy clay loam soil, low slope of <10% and high ground water depth. As the area is barren land it is suggested to construct check dams and dug wells in this area.

### *C. South West Delhi*

Samalkha and Jindal Colony, Kapasera is the most suitable site in this region. Construction of dug wells is suggested in this area. Due to low slope and presence of sandy loam soil it is found suitable for dug wells.

### *D. East Delhi*

Kiran Vihar and Karkardooma is the most suitable site in this region. It is suggested to construct dug/bore wells in this area. The presence of sandy loam soil and gentle slope (<10%) this area is found suitable for dug/bore wells.

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