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Site Selection of Water Conservation Measures by Using RS and GIS: A Review

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Abstract

There are many areas which has sufficient amount of rainfall but entire quantity of water runs off. It can be stored in order to avoid water scarcity problem by constructing water conservation measures like check dam, percolation pond, farm pond, contour bunding and contour trenching. We can decide the best location for these measures by using traditional methods which are more tedious. To speed up the activity and optimize the work new technology called as remote sensing integrated with GIS can be used. For this purpose, maps having different theme should be prepared. These maps can be combined after assigning weightages to each map and ranks to each parameter in GIS environment. While assigning ranks, we can classify particular theme in different types. SCS-CN method is available to find out runoff potential. Suitable criteria is applied to get locations of water conservation measures.

This paper gives the overall idea to improve water resources availability by using RS and GIS techniques. Actual locations on the field can be found out by using GPS and location map.

1. INTRODUCTION-

In a densely populated country like India, water resource is in high demand. Continuous failure of monsoon, increasing demand and over exploitation leads to depletion of water level, which in turn tends to increase both the investment and the operational costs [4]. In rain-fed areas, a small additional increment of water can dramatically increase crop yields and lower the risk of crop failure [5]. Sometimes, it can make a difference between crop and no crop in drought areas. There are various measures using which we can locate sites for the purpose of water harvesting. Using methods that are accurate and efficient for attaining precise result is extremely important.

Recent advances in remote sensing and GIS provide very useful information in undertaking the integrated resource analysis. Satellite remote sensing provides reliable and accurate information on natural resources, which is pre-requisite for planned and balanced development at watershed level. These two new technological tools have emerged to meet ever-increasing demand for more precise and timely information [2]. The overall methodology involves extraction and generation of various thematic maps either through satellite images or through existing records and field survey maps. The next step deals with classification of all these parameters into 'suitable' classes and assignment of 'suitable' ranks to these classes, weights to the parameters, and finally integration of all the ranked and weighed parameters in a GIS environment. Subsequently, the area is classified into poor, moderate, good and excellent sites suitable for the rainwater harvesting [4].

Our study area will be Warvadi village situated in Pune, Maharashtra, India. We would apply a technique where, potential runoff generating sites, and thus priority areas for runoff harvesting will be identified with the use of GIS. To achieve this objective it is necessary to identify and obtain the relevant data, develop the required databases and specify how these data are to be utilized in a GIS working environment, in order to meet the goal of reflecting the spatial extent of runoff and to priorities sites for runoff harvesting.

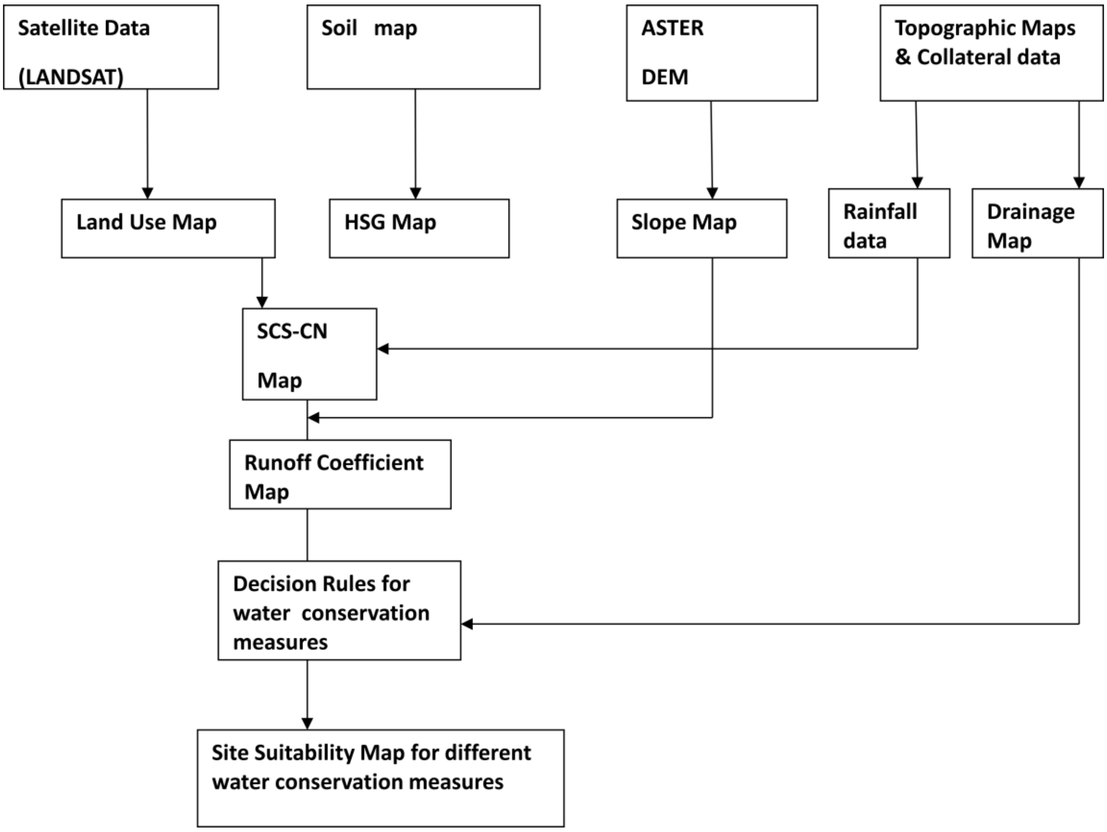
2. STUDY AREA-

Warvadi village is located in Purandhar Tehsil of Pune district in Maharashtra, India. It is situated 18km away from sub-district headquarter Sasvad and 22km away from district headquarter Pune. Thapewadi is the gram panchayat of Warvadi village.

The total geographical area of village is 556.62 hectares. Warvadi has a total population of 620 peoples. There are about 140 houses in Warvadi village. Sasvad is nearest town to Warvadi which is approximately 18km away.

3. METHODOLOGY-

Flowchart :



The methodology used for site selection in this paper is the SCS Curve Number Method. The Soil Conservation Services (SCS) method is the most widely used technique for estimating surface runoff for a given rainfall event from small catchments. The SCS method considers the relationship of land cover (cover type, land treatment and hydrologic condition) and hydrologic soil group, which together make up the curve number [6]. Land cover- Land cover data documents how much of a region is covered by forests, wetlands, impervious surfaces, agriculture, and other land and water types. Water types include wetlands or open water. Hydrological soil group is classification of soils by the NRCS into A, B, C, and D groups according to infiltration characteristics. The curve number is an index expressing a catchment's runoff response to a rainfall event and therefore indicates the proportion of rain- water that contributes to surface runoff. Curve numbers vary from 0 to 100 where greater curve numbers represent a greater proportion of surface runoff. Concepts used for deriving curve numbers that are developed within the SCS method provided the basis for mapping runoff potential in this study.

The SCS method requires information on soil form and family to classify the hydrological soils groups (A, B, C, and D). Curve numbers can be calculated for each of the hydrological soils groups when combined with the various land covers. A map of curve numbers will be generated based on the hydrological soil groups and land cover grid surfaces.

The SCS-CN method explaining the water balance equation can be expressed as below:

$P = Ia + F + Q$ - (1)

$Q / P - Ia = F / S$ - (2)

$Ia = \lambda S$ - (3)

Where,

- P is the total precipitation (mm)
- Ia the initial abstraction (mm)
- F the cumulative infiltration (mm)
- Q the direct runoff (mm)
- S the potential maximum retention (mm)
- λ the initial abstraction coefficient (0.3)

The SCS-CN equation, as expressed below is derived from the combination of the first two equations:

$Q = (P - Ia)2 / (P - Ia + S)$ -(4)

In practice, S is derived from a mapping equation expressed in terms of the curve number (CN):

$S = (25400 / CN) - 254$ - (5)

The CN (dimensionless number ranging from 0 to 100) is determined from a table, based on land-cover, HSG, and AMC.

In this study, the curve numbers are weighed with respect to the micro-watershed area using the following equation: [3]

$CNw =$ Summation of $(CNi * Ai) / A$ - (6)

4. DATA COLLECTION-

In this study, the input data required to characterize the biophysical and socio-economic parameters of the catchment will be derived using available data as well as information obtained from infield surveys .An elevation dataset obtained for the catchment will be derived from a Digital Elevation Model(DEM) generated in ASTER. The DEM has a resolution of 90m. Landsat images of the village are of 28.5m resolution. The DEM has been resampled to 28.5 m resolution. The rainfall data of 10 years return period has been obtained from IMD office. The soil groups in the soil map have been obtained by performing sieve analysis test for soil which will at depths of 5cm, 10cm and 15cm.

5. DISCUSSION-

Grouping of polygons of high ranks of all the thematic layers will help in delineating the sites that are excellent for construction of water harvesting structures. Thematic maps show parts of the study area are most suitable for construction of rainwater harvesting structures [5].

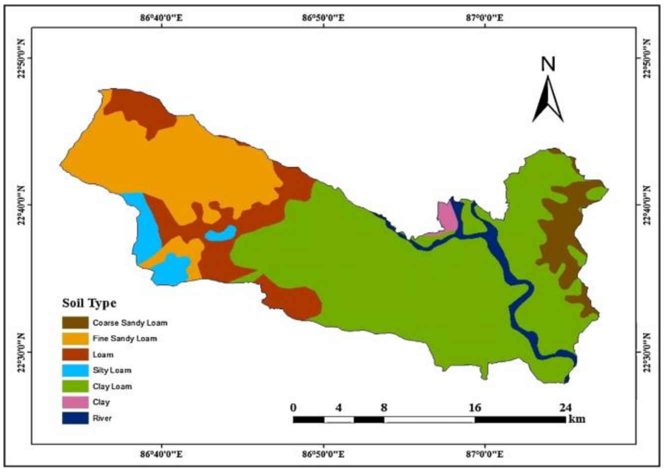
Amongst the various parameters taken into consideration in order to locate potential water harvesting sites these are the following few which are of utmost importance.

5.1 Land use/ Land cover-

The land use gives the information of purpose of land and land cover denotes natural cover. Land is classified as forest, urban, agriculture, barren and water body.

5.2 Soil map

The soil map of study areas would reveal major soil classes: coarse, sandy, loamy, fine and very fine etc. In the soil maps, various soils classes are identified and their area is found in the form of percentage to map these soils [1]. Soil maps are very important to know factors like imperviousness, infiltration, porosity, etc. An example of a soil map is depicted in the figure below,



5.3 Hydrological Soil Groups-

Soils are classified into four classes A, B, C and D based upon the infiltration and other characteristics:

Group A (Low runoff potential)- Soils having high infiltration rates even when thoroughly weighted and consisting chiefly of deep, well to excessively drained sands or gravels. The soils have high rate of water transmission. Example- Deep Sand and Deep Aggregated Silt.

Group B (Moderately low runoff potential)- Soils having moderate infiltration rates when thoroughly weighted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse texture. These soils have moderate rate of water transmission. Example- sandy loam and red sandy soil.

Group C (Moderately high runoff potential)- Soils having a low infiltration rates when thoroughly wetted and consisting chiefly or moderately deep to deep, moderately well to well-drained soil with moderately fine to moderately coarse texture. These soils have moderate rate of water transmission. Example- Shallow Sandy Loam and Mixed Red and Black Soils.

Group D (High runoff potential)- Soils having very low infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with permanent high water table, soils with a clay pan, or clay layer at or near the surface, and shallow soils over nearly impervious material. Example- Heavy Plastic Clay and Deep Black Soils [7].

5.4 Slope-

The slope map gives a lot of information on the steepness of the area, hence giving us an idea of the runoff generated in that area. The slope of the area can be divided into six slope classes: (a) ‘nearly level’ (0–1%), (b) ‘gentle’ (1–3%), (c) ‘moderately gentle’ (3–5%), (d) ‘steep’ (5–10%), (e) ‘moderately steep’ (10–15%), and (f) ‘very steep’ (15–30%). The slope classes ‘nearly level’ and ‘gentle’ are considered more suitable for rainwater harvesting.

5.5 Runoff potential map

Slope, derived from the DEM, will determine the run off potential. Conforming to the slope- based criteria for surface runoff generation, the slope categories will be ranked from least suitable to most suitable ,where the steeper the slope category, the higher the potential runoff generation. The runoff potential in the study area for the normal rainfall years can be grouped into three classes: (a) ‘moderate’ (200–300 mm), (b) ‘poor’ (100–200 mm) and (c) ‘very poor’ (<100 mm).

5.6 Runoff coefficient map

Based on the spatial distribution of runoff coefficient values, the study area can be divided into four classes: (i) ‘high’ runoff coefficient (>0.4), (ii) ‘moderate’ runoff coefficient (0.3–0.4), (iii) ‘low’ runoff coefficient (0.2–0.3), and (iv) ‘very low’ runoff coefficient (<0.2 [6].

The runoff potential map and runoff coefficient map help in identifying potential water harvesting sites accurately and efficiently, as the maps delineate precise information on that area.

5.7 Drainage network-

Mapping of depression storage in the form of lakes, ponds and reservoirs gives information on surface storage, ground water storage, storm water flow, etc. Stream ordering is done for proper planning of conservation measures in terms of storage and capacity [6].

5.8 Suitability modeling

The final step is to combine the various maps in order to identify the most suitable sites for runoff harvesting. Suitability maps will be generated by applying criteria. This suitability modeling approach is encouraged due to its simplicity. Numeric values, such as the suitability rankings are assigned to the classes within each map layer in order to facilitate the suitability analyses. The values from each map layer are ranked on a scale of most suitable to least suitable based on the criteria of each data set, with each layer being assigned an equal weighting [1].

Decision rules for water conservation measures-

Sr.No.	SWC measures	Slope(%)	Permeability	Runoff coefficient	Stream order
1.	Farm pond	0-5	low	Medium/high	1
2.	Check dam	< 15	low	Medium/high	1-4
3.	Percolation pond	<10	high	low	1-4

Sr. No.	SWC measures	Sub-type	Slope(%)	Rainfall (mm)	Suitable area
4.	Bunding	Contour	<6	<800	light/medium textured soil
		Graded	2-6	>800	Fine textured soil
5.	Trenching	line	10-25	<800	Hilly area
		staggered	10-25	>800	
6.	Terracing	Bench	20-30	500-1000	Hilly area

6. CONCLUSION-

On the whole, it can be inferred that there is an ample scope for using rainwater harvesting technology in the study area so as to ensure long-term water security for domestic and irrigation purposes. The rainwater harvesting potential zone maps and the map showing suitable sites for rainwater harvesting structures can be used for the efficient planning and management of water resources in the study area, which in turn can ensure sustainable water supply in the face of looming climate change.

In this study the importance of parameters like land use, slope, soil map, drainage networks etc. are highlighted. The efficiency and accuracy of SCS- Curve number method is also expressed where two main factors of landuse and soil maps are combined to identify potential water harvesting sites. Here, we learn how to perform water management using the most advanced and user-friendly approach. Hence, proving that sustainable water management strategies are crucial for ensuring ‘water security’, ‘food security’, ‘energy security’ and ‘environmental security’, which are the major global challenges of the 21st century.

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