Selection of Appropriate Sites for Structures of Water Harvesting in a Watershed using Remote Sensing and Geographical Information System

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Abstract - In the present study, an honest attempt has been made for selection of suitable site for water harvesting structures in Narli nala watershed, Gangapur, Aurangabad using Remote Sensing and Geographical Information System (RS & GIS). Delineation of catchment area is carried out using Survey of India toposheet after georeferencing them. The IRS-P6 LISS-III satellite imagery of Gangapur is used and landuse/landcover classes have been derived from it. A soil map of 1:50000 scale is obtained from National Bureau of Soil Survey and Land use Planning, Nagpur and surface drainage map is prepared. To indicate the rate of infiltration, soil and surface drainage are classified into Hydrologic Soil group. The various thematic maps such as land use map, group map, hydrological soil slope map and drainage map are laid over each other and five check dams are proposed for construction according to guidelines for selecting suitable site for construction of water harvesting structure as per Integrated Mission for Sustainable Development (IMSD). Geographical Information System is the technique which is used for preparation of thematic maps and combining all the layers and performance analysis.

Keywords - Suitable water harvesting structure, Geographical Information Systems, Remote Sensing Systems.

I. INTRODUCTION

Water harvesting structures are extremely important to conserve precious natural resource like, soil and water, these are depleting day by day at faster rate. 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 (Anon.,2002), India will be stress zone by the year 2025 and water scare zone by 2050. The land availability level is reducing day by day. The per capita land availability is in reducing trend and it is estimated that only 0.1 hectare per capita land will be available by the end of 2025 (Sarangi et.al.,2005). The water table is rapidly depleting with unregulated over exploitation of groundwater. Statistics on water budget indicates that our country gets about 400 Mha.m. of precipitation annually, out of which 200 Mha.m. is lost in evapo-transpiration.

About 135 Mha.m is available on the surface and remaining portion of precipitation joins groundwater through percolation. As per estimate about 92 Mha.m of the available surface water ultimately goes to the sea despite of construction of large dams, reservoirs, check dams, water harvesting structures etc. The precipitation in India is highly variable over time and space due to monsoon climate and land-mountain topography. Spatially it ranges from 100 mm in Rajasthan to 11000 mm in Mausingram, Meghalaya (Sharma and Paul, 1998). Over the time about 80% of the annual rainfall received within three monsoon months and rest of the 20% in nine dry months with a lightly scattered distribution. In order to conceptualize the runoff occurring from the humid regions, Zade et.al.(2005) used the remote sensing images and Natural Resources Conservation Services (NRCS) curve number approach to estimate the annual runoff from 12 major river basins of India. The rainwater harvesting systems are relatively equivatable and environmentally sound. The participatory management approach of harvested water resources ensures effective use, upholding and sustainable operation of the system. It has a great potential of improving land and water resources by integrating recent developments with the traditional knowledge. The need and importance of water harvesting and water conservation has been given weightage in national water policy and national agricultural policy of government of India. The various rainwater harvesting structures viz., check dams, farm ponds, nala bunds, percolation tanks etc are constructed at appropriate site that check flood and provide irrigation to downstream. This holistic approach within a watershed in conserving soil and water resources by selecting the suitable site specific soil and water conservation structures will not only conserve soil and water resources but also enhances the crop yield. Thiruvenkatamany (1982) has reported the effect of contour bunding on ground water recharge and found that 14.3% increase in water yield in wells due to contour bunding. Sarangi et.al.,(2004) have developed a decision support system for soil and water conservation practices on agricultural watersheds, which generates alternative scenarios for selection and targeting of different vegetative and mechanical measures for conservation of soil, water and reduction of sediment loss.
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. Appropriate structures are needed to avoid excessive surface runoff, help in flood control in lower catchment, improving soil moisture availability and to increase the water table in the watershed. These structures may differ with different parameters viz., location, slope of land, soil type, intensity of rainfall, land cover and settlement. Depending on these parameters, the construction of check dams, gully plugging structures, percolation tanks and farm ponds are to be decided. Check dams are constructed across the ephemeral streams to intercept runoff from local catchments and store it for optimum utilization (Khan, 1992). The small dams retain excess water flowing during monsoon rain in a small catchment area behind the structure. Needeenchezhian et.al. (2001) conducted study on artificial recharge mechanisms when natural recharge is not sufficient for sustainable groundwater levels. They studied the efficiency of some artificial recharge structures (percolation pond and check dam) constructed by TWAD board of Tamilnadu helped very much to recharge the ground water. Kalra (2005) made a case study on making of rainwater harvesting structures to check depletion of groundwater table in Saurashtra, Gujarat. The check dams and percolation ponds were found to be more effective to combat draughts and water storage. The farmers have constructed large numbers of check dams, percolation tanks and farm ponds within a short span of time, contributing their own money and labour under his guidance. The state Government launched a Sardar Patel Participatory Water Conservation programme based on success of rainwater harvesting movement.

The literature on water harvesting structures revealed that there are huge research and development works since 60s but few research works are carried out using information technologies (RS and GIS) for selecting suitable sites for water harvesting structures in the watershed. Thus 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.

II. MATERIALS AND METHODS

2.1 Description of Study area

The study area is a watershed Narli Nala which lies mostly in Gangapur tehsil in Aurangabad district.

This study area lies between 19°30’ and 20° North latitudes and 75° and 75°15’ East longitudes. Total area of the catchment is 106.47 sq.km. The area is falling under toposheets bearing no. 47 M/1 and 47 M/2 published by Survey of India (SOI) on a 1:50000 scale. Primary crops of this area is Sorghum, Bajra, Maize etc. The mean annual air temperature of the district varies from 25-27 degree celsius. Aurangabad features a semiarid climate. Most of the rainfall occurs in the monsoon season from June to September. Thunderstorms take place between November to April. The average annual rainfall is about 710 mm. The city is frequently cloudy during the monsoon season and the cloud cover may remain throughout the days. The daily maximum temperature in the city often drops to around 22 °C due to the cloud cover and heavy rains. The entire area is covered by the Deccan trap lava flows of Upper Cretaceous to Lower Eocene age. Whereas the lava flows are overlain by thin alluvial deposits along the Kham and Sukhana river. Soil categories found in the study area are clay and loam and three classes of vegetation are found in this region viz., sparse vegetation, dense vegetation and vegetation with a less amount of barren land. 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. Depending on these parameters, the construction of check dam, percolation tanks and farm ponds are to be proposed at appropriate sites in Narli Nala watershed. 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 Narli Nala watershed with the help of emerging technologies viz., Remote Sensing (RS) and Geographical Information System (GIS).

III. METHODOLOGY

The maps of Narli nala watershed were delineated from Survey of India topo-maps, supplied by SOI Pune. The base map was prepared through visual interpretation of satellite data, showing various permanent structures, delineating watershed boundary, drainage network, etc. The digital analysis was carried out using GIS and Image processing software (Arc GIS Ver 10.1). The stepwise method for preparation of various maps is presented through flowchart.
3.1 Decision rules for site selection of water harvesting structures

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.

**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.

**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.

3.2 Geo referencing and digitization

Geo-referencing of scanned maps was carried out in Arc GIS using control points already established on the base map. The four latitude and longitude values of the control points located on top left, top right, bottom left and bottom right corners of the map were assigned corresponding latitude/longitude values are later converted into polygonic projected system using Arc/Info GIS software after performing rectification. 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 etc in respective thematic maps.

3.3 Thematic maps

**Land use map**

Land use map (Fig 2) was prepared using IRS/P6 LISS-III satellite data considering nine different classes of land use. (i) Waterbody (ii) Scrub land (iii) Settlement (iv) Sparse vegetation (v) Dense vegetation (vi) Barren land (vii) Vegetation (viii) Bush (ix) Rock. Land use map was further classified based on suitability for different water harvesting structures.

**Drainage Map**

Drainage map was prepared by digitizing drainage from SOI toposheet as shown in Fig 3

**Hydrological soil group map**

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

**Slope map**

The slope map was prepared from contour and elevations extracted. The contours are extracted from Digital Elevation Model (DEM) map (Fig 6) then elevations at different points randomly are extracted and using both TIN map is extracted. In another technique slope map is extracted (Fig 7) from DEM. The slope designated in value domain was prepared using filtering technique. The slope map was further classified for exploring potential suitable sites for several water harvesting structures.

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Fig 1: Flowchart for preparing site suitability map
Fig 2: Land use map of Narli nala watershed

Fig 3: Drainage map of Narli nala watershed

Fig 4: Soil map of Narli nala watershed

Fig 5: Hydrologic soil group map
The cross operation was performed using classified land use map and Hydrological Soil Group map. In the next iteration suitable landuse 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. The site suitability map (Fig 8) for water harvesting structures was then obtained.

### IV. Results and Discussion

The suitable sites for water harvesting structures were identified with the application of remote sensing and GIS. The contour map, watershed boundary map, drainage map, land use map, soil map and DEM were prepared using satellite imagery and SOI toposheets of Narli nala watershed. The nine classes of land use/land cover and hydrological soil map were prepared. The overlay operation of land use map, hydrologic soil group map, stream order map and slope map was carried out for water harvesting structures and presented through site suitability map.

#### 4.1 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 Narli nala watershed were found to be suitable for check dam but as per ground truth and experience 5 suitable sites were proposed to construct the check dam. Since it is located in suitable land class (scrub land, barren land), 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 kharif/rabi crop may be cultivated.

4.2 Suitable sites for percolation tanks

As per IMSD guidelines the suitable sites for percolation tanks are not found, due to soils with low runoff potential were not found.

V. SUMMARY AND CONCLUSIONS

Water harvesting structures are extremely important to conserve precious natural resources like, soil and water, which is depleting day by day at alarming rate. The Ganagapur area of Maharashtra, possesses soil and water management problems. The good cultivable areas are being converted into waste and degraded lands due to over exploitation of land and water resources. Keeping this in view, Narli watershed is selected for planning suitable sites for construction of water harvesting structures using remote sensing and GIS techniques. The potential sites for water harvesting structures in Narli watershed were identified through emerging technologies of remote sensing and GIS and 5 check dams at appropriate sites are proposed. Sites are not suitable for percolation ponds due to less soil thickness and high runoff velocity.

REFERENCES


