Peer Reviewed International Research Journal of Geography
Maharashtra Bhugolshastra Sanshodhan Patrika
ISSN : 0971-6785 {Impact Factor 3.687 (IIFS)} Vol. 34, No.2, Jul-Dec. 2017. pp 118-127

SITE SUITABILITY ANALYSIS OF SOIL AND WATER CONSERVATION STRUCTURES USING REMOTE SENSING AND GIS TECHNIQUES

P. C. Hakay Bhavana N. Umrikar Praveen Saptarshi

Abstract

The watershed development programs are focused on the collection, conservation and efficient utilization of water, increasing the recharge to aquifers, control the soil erosion and enhance the biomass. The water harvesting structures play an important role in watershed development process. The aim of the present study is to identify suitable areas for soil and water conservation structures (SWCS) in Shivari watershed of Pune district, Maharashtra by using Remote Sensing (RS) and Geographic Information System (GIS). The low rainfall, water scarcity in summer months and increasing groundwater demand for drinking and agriculture urgently need the identification of suitable sites for SWCS in the study area. With this intent, suitable zones for SWCS such as gully plugs, check dams and percolation tanks were identified using thematic layers namely digital elevation model (DEM), slope, drainage density, land use/ land cover and geology. The Integrated Mission for Sustainable Development (IMSD) specifications have been used for the identification of site suitability potential of the area.

Keywords: *soil and water conservation structures, site suitability, RS-GIS.*

Introduction

Groundwater is consistent, cost-effective and hidden natural source for drinking and agricultural purpose. Explosion of population, has led to increase in demand of various natural resources in general and water resources in particular resulting in overexploitation of this precious resource (Maggirwar and Umrikar 2009). Thus, a judicious use of water resources, especially in semi-arid and rural areas of India call for good watershed development practices and implementing it on a watershed/micro-watershed scale , . For the appropriate scheduling and management of water resources, watershed characterization and identification of suitable soil and water conservation (SWC) sites are indispensable task, which entail the high precision data input (Patel et al. 2013; Aher et al. 2014; Jaiswal et al. 2015; Alvarado et al. 2016). Many watershed based studies have discussed the rainwater harvesting techniques to enhance the water resources as well as soil conservation, preserving high nutrients in soil for increasing crop productivity and reduce the soil erosion rate . There are various methods used to obtain direct or indirect information about soil water conservation and its potential occurrence, out of which hydrogeological and geospatial analysis is the most used and popular one.

Geospatial and hydrogeological analysis include several spatial layers of other associated topographies which affect soil water conservation structures such as slope, soil, drainage density, land use and lineament, etc. (Kadam et al. 2012; Das 2000; Tomas et al. 2009). Remote sensing (RS) and GIS tools are widely used for the development and management of various natural resources (Dar et al. 2010; Ganapuram, et al. 2008; Muralidhar etal. 2000). The present study aims in identifying the soil and water conservation sites based on the superimposition of various thematic layers such as digital elevation model, slope, geology, drainage density and land use/land cover in GIS environment.

Study area

Shivari village is in Purandar Taluka which is one of the 13 Talukas of Pune District. Purandar Taluka is surrounded in the north by Haveli, Daund Taluka in the East, in the South by Satara District and on the West by Bhor Taluka. The climate of Purandar Taluka is hot and dry. The Shivari village is located about 40 km towards South from Pune and about 9 km from Purandar taluka. The study area lies between 74°03'30" to 74°06'30" East longitudes and 18°16'30" to 18°19'30" North latitude, (Fig. 1).

The study area is represented in Survey of India (SoI) toposheet number 47J/3 on 1:50,000 scale. The study area receives an average annual rainfall of about 710 mm from June to September. The study area is having semi arid climate with average temperature ranges from 39°C during April and May to about 15°C during December.

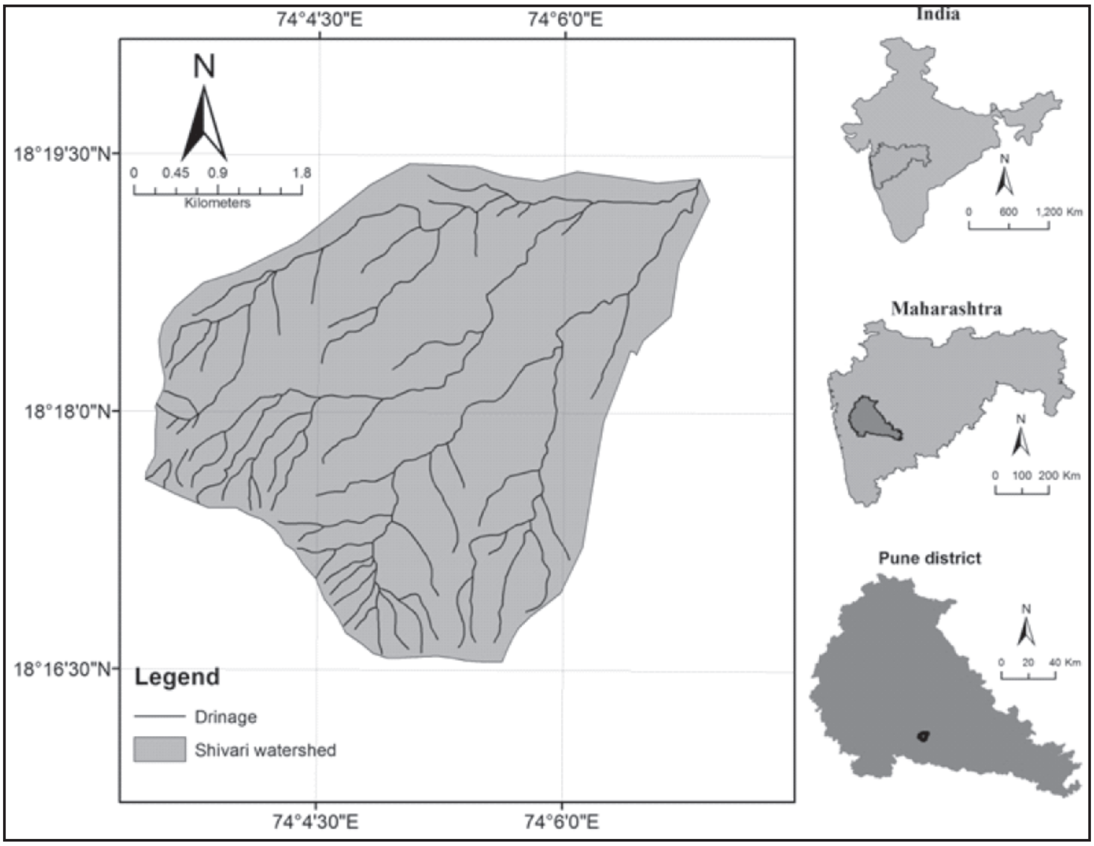


Fig. 1. Location map of Shivari watershed.

Material and methodology

For identification of suitable sites for soil and water conservation structures (SWCS), overlay analysis in Arc GIS 10.2 has been performed which integrated different layers like base layer, derived and thematic layers. The base layers such as drainage network and contours were used in collaboration with derived layers like drainage density, digital elevation model (DEM) and percent slope for generating prioritized rank map and identification of suitable SWC sites.

The land use reference layer was used to generate the settlement buffer, identification of present land use pattern and recognize the existing SWC structures. The priority is given to the areas which have the combination of low compound parameter constant i.e. which show low drainage density, gentle slope, and a higher infiltration rate . Figure 2 depicts a detailed illustration of the methodology.

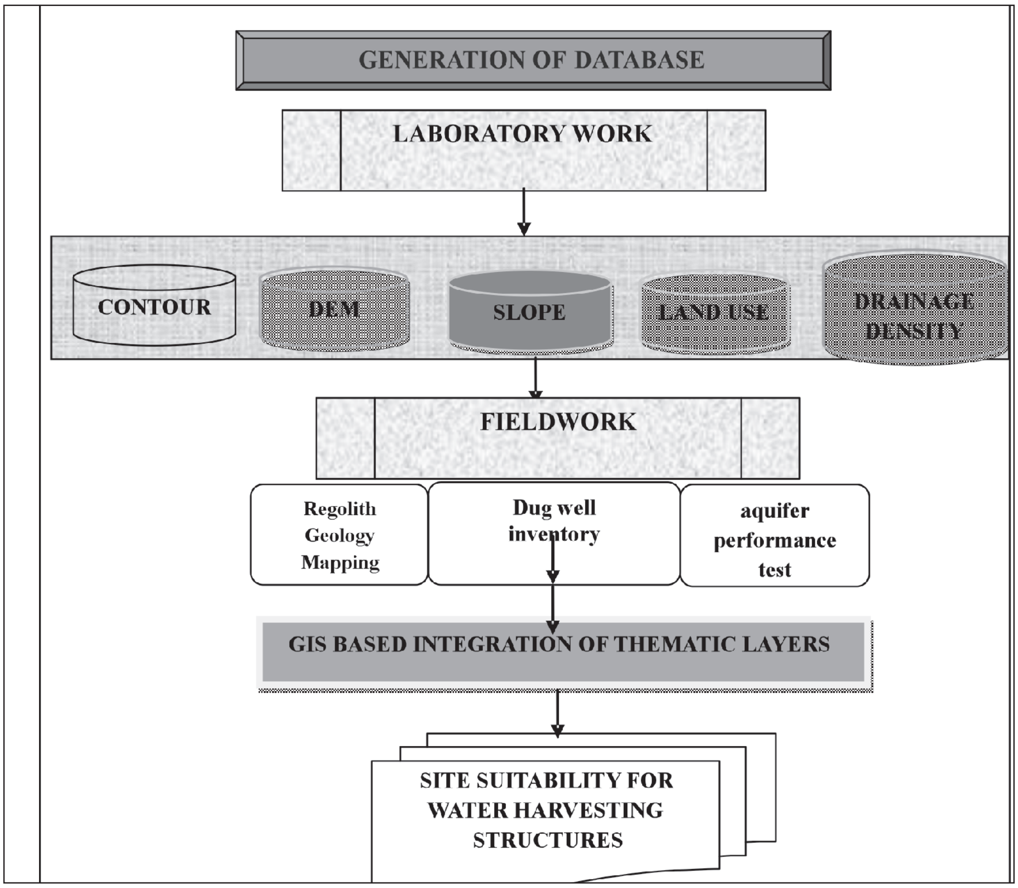


Fig. 2: Flow chart of methodology adopted in the present study.

Identification of potential soil water conservation sites

In the present study, the integrated mission for sustainable development (IMSD), Department of Space, Government of India specifications were used for identification of potential soil water conservation sites namely gully plugs, percolation tanks / farm ponds and check dams (Table 1).

The intersect overlay analysis was performed on thematic layers viz. geology, land use/land cover, slope, and drainage density based on IMSD specifications. The ground truth data was used to validate the resultant map.

Table 1: Adopted specifications for potential soil water conservation sites

Parameter	Slope (%)	Porosity and permeability	Landuse/ landcover	Runoff potential	Stream order	Catchment area (ha)
Check dam	<15	Low	Scrub land/ River bed	Medium/ high	1-3	> 25
Percolation tank	<10	High	Waste land	Low	1-4	25-40
Gully Plug	>35	Low	Open forest	High	1-3	> 20

Results and discussion

Digital Elevation Model

The digital elevation model has been prepared using ASTER - GDEM data and it is observed that the elevation ranges between 702 m and 944 m in the study area (Fig. 3). Highly elevated areas are seen in the periphery of watershed which act as drainage divide of the watershed.

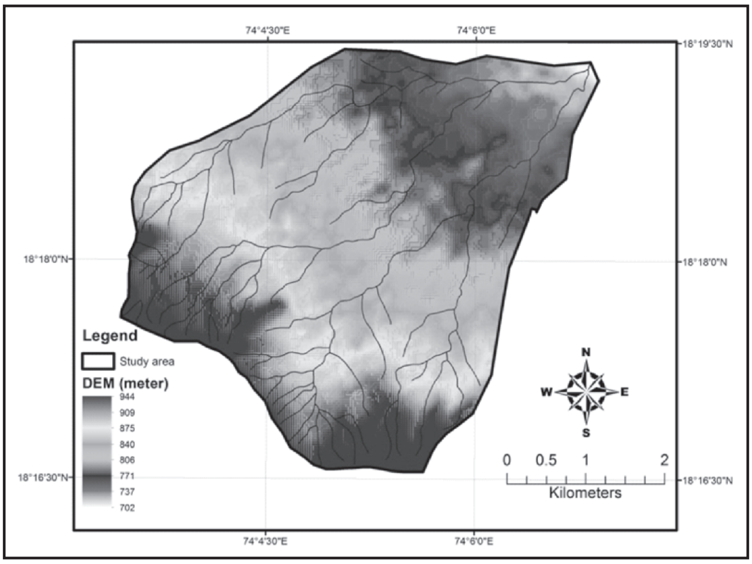


Fig. 3: Digital Elevation Model of Shivari watershed.

Slope

The runoff/recharge of rainwater is primarily the function of slope followed by geology, soil cover, landforms and land use pattern . The study area is divided into seven slope classes following the norms of integrated mission for sustainable development (IMSD 1995). The category with least slope represents un-dissected topography, and relatively low surface runoff indicative of plain surface (Fig. 4).

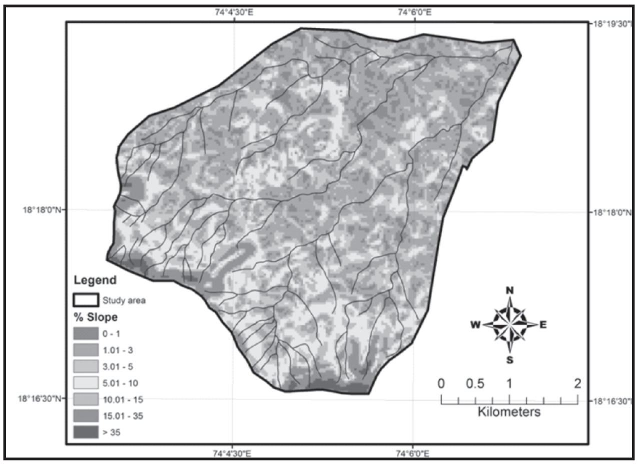


Fig. 3: Digital Elevation Model of Shivari watershed.

Slope

The runoff/recharge of rainwater is primarily the function of slope followed by geology, soil cover, landforms and land use pattern . The study area is divided into seven slope classes following the norms of integrated mission for sustainable development (IMSD 1995). The category with least slope represents un-dissected topography, and relatively low surface runoff indicative of plain surface (Fig. 4).

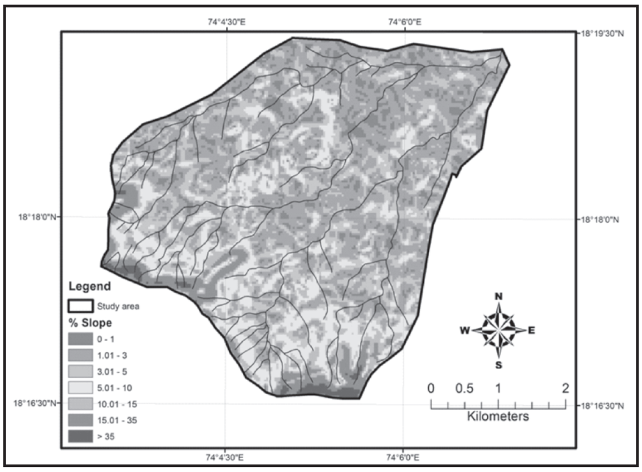


Fig. 4: Slope map of the study area.

Drainage density

Topography, relief, landforms, geology, soil, and land-use pattern reveal the drainage density of any terrain (Horton 1945; Strahler 1964). Drainage density is the fraction of total stream length of all stream orders divided by the entire area of the basin. It shows how closely spaced stream channels are present within a watershed . Surface runoff is directly related where as recharge is inversely proportional to drainage density. The drainage density is categorized into three classes namely low, moderate and high (Fig. 5).

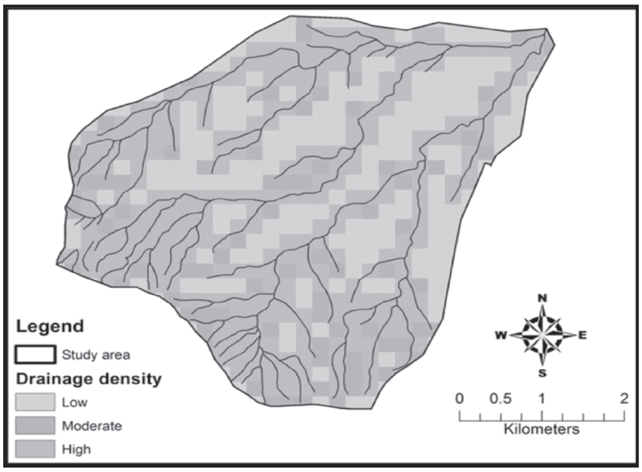
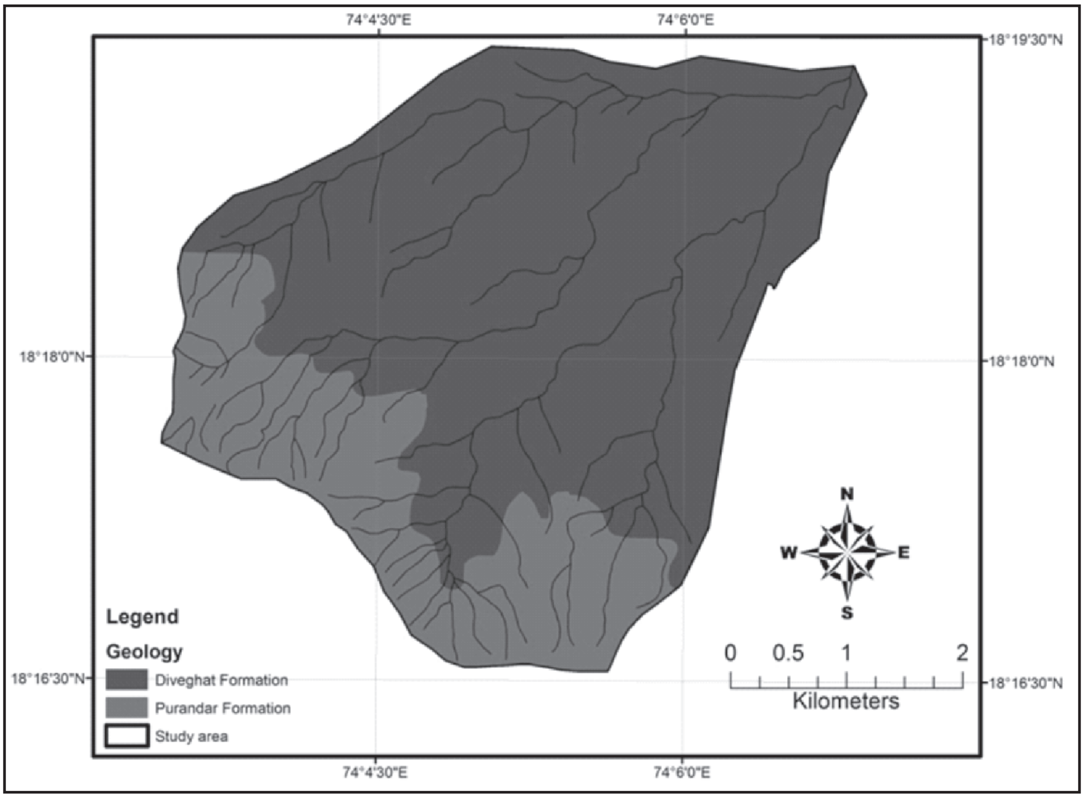


Fig. 5: Drainage density map of Shivari watershed.

Geology

The feature layer of geology was prepared by integrating the field traverses taken along the streams, road cuttings, and ghat sections with the map published by Geological Survey of India (scale 1:250,000). The Deccan Volcanic Province (DVP), representing basaltic flows of Cretaceous to Eocene age, is a unique geological formation in Peninsular India.

The study area is dominantly constituted of basaltic rocks. The basalts occur in the form of horizontal flows having variation in the thickness and are seen to extend for a considerable distance. A typical spheroidal weathering pattern is very common all over the Deccan volcanic Province. These hard rocks possess low porosity and hydraulic conductivity (Beane et al. 1986). The study area depict Purandar formation and Diveghat formation of Deccan Volcanic Province. On the gentle hill slopes, they are covered by residual and/or colluvial soils (Fig. 6).



Land use /land cover

The study area is having sparse vegetation and land with scrub as major land use type followed by agricultural land (Fig. 7). Land use pattern describes the (high / low) generation of surface-runoff, soil erosion and suitable type of rainwater harvesting structure .

The study area is covered by waste land and sparse vegetation at the periphery which demands construction of gully plug and check dams for soil and water conservation. Further, agriculture land is good for construction of percolation tank, farm pond and check dam and there is ample scope for such activities which was observed during the field visits.

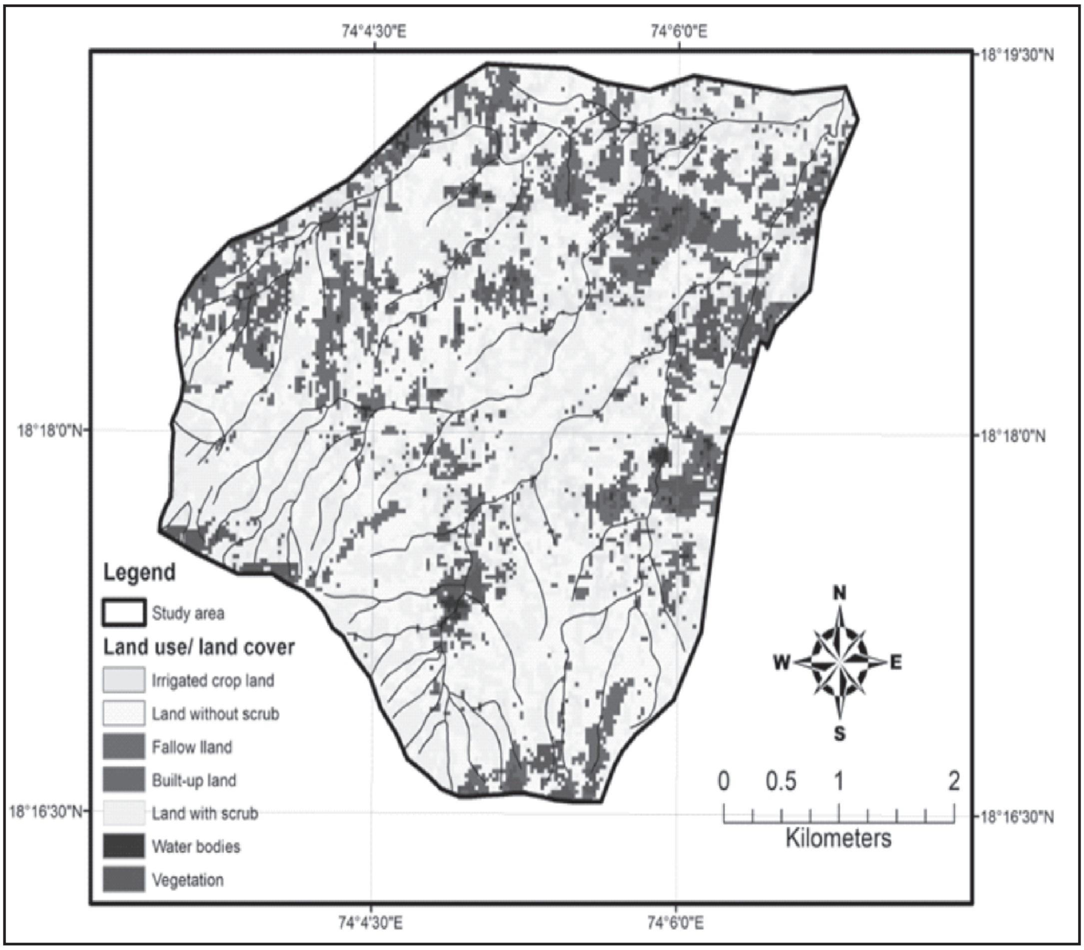


Fig. 7: Land use/land cover of study area

Site selection for SWC structures

Thematic layers generated for the study area namely DEM, slope, geology, drainage density and land use/land cover, were integrated as per IMSD specifications in GIS environment to identify suitable sites for check dam and percolation tanks. The site suitability map depicts the spatial distribution of potential zones suited for various water recharging structures (Fig. 8). The areas suitable for check dams are widely present in the outer part of the study area. However, suitable zones for percolation tanks are scattered in the middle and lower part of the study area having moderate to gentle slope. Hence, it can be inferred that there is an ample scope for construction of rainwater harvesting structures in the study area.

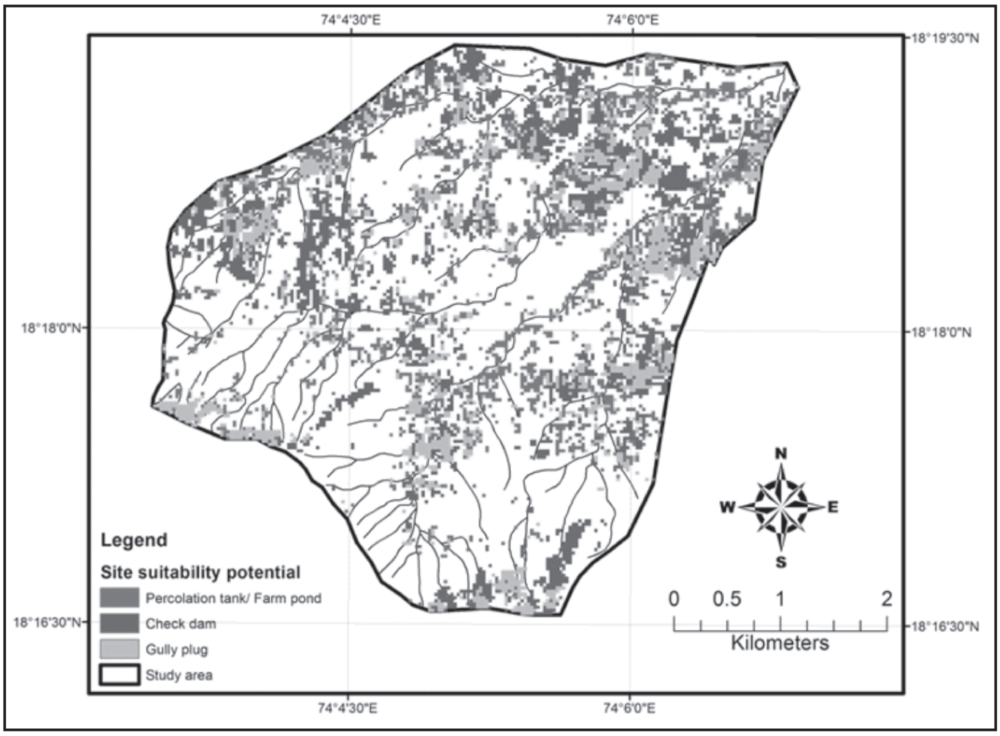


Fig. 8: Potential zones for soil and water conservation structures.

The field study has been done to verify potential identified sites in order to check the accuracy and precession of applied modified method. The sites identified with existing sites (photo plate 1) showed 80% matching with the potential site of a percolation tank and 85 % accuracy with sites of the derived map for check dam. There is huge scope for construction of check dam and percolation tank in the study area.

Photo plate 1: Soil and water conservation structures in Shivari watershed

Conclusion

Soil and water conservation structures play the crucial role in augmenting these valuable resources. These structures when properly placed (considering the slope, drainage network, geology, soil and land use pattern) serve their best in crisis. However, identification of suitable sites in the field is a decisive task which demands the verification of topographic aspects. The present study demonstrates the RS-GIS based method by using various thematic layers result into the accurate identification of SWC zones. In addition to this, field investigations of soil type and depth are also a prerequisite to authenticate the sites suitable for soil and water conservation structures.

References

* Adgo E, Teshome A, Mati B (2013) Impacts of long-term soil and water conservation on agricultural productivity: The case of Anjenie watershed, Ethiopia. Agricultural Water Management 117:55-61. doi: 10.1016/j.agwat.2012.10.026
* Adimassu Z, Langan S, Johnston R (2016) Impacts of Soil and Water Conservation Practices on Crop Yield, Run-off, Soil Loss and Nutrient Loss in Ethiopia: Review and Synthesis. Environmental Management 1-15. doi: 10.1007/s00267-016-0776-1
* Aher PD, Adinarayana J, Gorantiwar SD (2014) Quantification of morphometric characterization and prioritization for management planning in semi-arid tropics of India: A remote sensing and GIS approach. Journal of Hydrology 511:850-860. doi: 10.1016/j.jhydrol.2014.02.028
* Alvarado A, Esteller MV, Quentin E, Expósito JL (2016) Multi-Criteria Decision Analysis and GIS Approach for Prioritization of Drinking Water Utilities Protection Based on their Vulnerability to Contamination. Water Resources Management 30:1549-1566. doi: 10.1007/s11269-016-1239-4
* Beane JE, Turner CA, Hooper PR, Subbarao KV, Walsh JN (1986) Stratigraphy, Composition and form of Deccan Basalts, Western Ghats, India. Bull Volcanol 48: 61-83.
* Dar IA, Sankar K, Dar MA (2010) Deciphering groundwater potential zones in hard rock terrain using geospatial technology Environmental Monitoring and Assessment, 173, pp. 597-610
* Das D (2000) GIS application in hydrogeological studies. Available from: http://www.gisdevelopment.net/application/nrm/water/overview/wato0003.htm
* Ganapuram S, Kumar G, Krishna I, Kahya E, Demirel M (2008) Mapping of groundwater potential zones in the Musi basin using remote sensing and GIS Advances in Engineering Software, 40, pp. 506-518
* Horton RE (1945) Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. Bull Geol Soc Am. 56:275-370.
* IMSD (1995) Integrated Mission for Sustainable Development technical guidelines, National Remote Sensing Agency, Department of Space, Govt of India.
* Jaiswal RK, Ghosh NC, Galkate RV, Thomas T (2015) Multi Criteria Decision Analysis (MCDA) for Watershed Prioritization. Aquatic Procedia 4:1553-1560. doi: 10.1016/j.aqpro.2015.02.201
* Jha MK, Chowdary VM, Kulkarni Y, Mal BC (2014) Rainwater harvesting planning using geospatial techniques and multicriteria decision analysis. Resources, Conservation and Recycling. doi: 10.1016/j.resconrec.2013.12.003
* Kadam AK, Kale SS, Pande NN (2012) Identifying Potential Rainwater Harvesting Sites of a Semi-arid, Basaltic Region of Western India, Using SCS-CN Method. Water Resources Management 26:2537-2554. doi: 10.1007/s11269-012-0031-3
* Maggirwar BC, Umrikar BN (2009) Possibility of artificial recharge in overdeveloped

miniwatersheds: RS-GIS approach., e-Journal, Earth Science India., ISSN No. 0974-8350, Vol.2 (II), pp. 101 - 110 (http://www.earthscienceindia.info)

* Muralidhar M, Raju KRK, Raju KSVP, Prasad JR (2000) Remote sensing applications for the evaluation of water resources in rainfed area, Warangal district, Andhra Pradesh. The Indian Mineralogists, 34, pp. 33-40
* Pandey A, Chowdary VM, Mal BC, Dabral PP (2011) Remote sensing and GIS for identification of suitable sites for soil and water conservation structures. Land Degradation and Development 22:359-372. doi: 10.1002/ldr.1012
* Patel D, Gajjar C, Srivastava P (2012) Prioritization of Malesari mini-watersheds through morphometric analysis: a remote sensing and GIS perspective. Environ Earth Sci. 69:2643-2656.
* Patel DP, Gajjar CA, Srivastava PK (2013) Prioritization of Malesari mini-watersheds through morphometric analysis?: a remote sensing and GIS perspective. Environ Earth Sci (2013) 69:2643-2656. doi: 10.1007/s12665-012-2086-0
* Samal (2015) GIS based drainage morphometry and its influence on hydrology in parts of Western Ghats region , Maharashtra , India. Geocarto International 37-41. doi: 10.1080/10106049.2014.978903
* Sajinkumar KS, Anbazhagan S (2015) Geomorphic appraisal of landslides on the windward slope of Western Ghats, southern India. Natural Hazards, 75, 953-973, doi: 10.1007/s11069-014-1358-2.
* Sarma S, Saikia T (2012) Prioritization of sub-watersheds in Khanapara-Bornihat area of Assam- Meghalaya (India) based on land use and slope analysis using remote sensing and GIS. J Indian Soc Remote Sens. 40:435-446
* Singh A, Narayanan K (2015) Impact of economic growth and population on agrochemical use: evidence from post-liberalization India. Environment, Development and Sustainability 1-17. doi: 10.1007/s10668-015-9618-1
* Singh LK, Jha MK, Chowdary VM (2017) Multi-criteria analysis and GIS modeling for
i dentifying prospective water harvesting and artificial recharge sites for sustainable water supply. Journal of Cleaner Production. doi: 10.1016/j.jclepro.2016.11.163
* Strahler AN (1964) Quantitative geomorphology of drainage basin and channel network. In: Handbook of applied hydrology, pp 39-76
* Thomas BC, Kuriakose SL, Jaydev SK (2009) A method for groundwater prospect zonation in data poor areas using remote sensing and GIS: a case study in Kalikavu Panchayath of Malappuram district, Kerala, India. Int J Digit Earth 2(2):155-170
* Yadav SK, Singh SK, Gupta M, Srivastava PK (2014) Morphometric analysis of Upper Tons basin from Northern Foreland of Peninsular India using CARTOSAT satellite and GIS.

***P. C. Hakay,**
Department of Environmental Science,
Savitribai Phule Pune University, Pune

****Bhavana N. Umrikar**
Department of Geology,
Savitribai Phule Pune University, Pune

*****Praveen Saptarshi**
Department of Enviromental Sciences,
Savitribai Phule Pune University, Pune