International Research Journal of Natural and Applied Sciences
ISSN: (2349-4077)
Impact Factor 5.46 Volume 4, Issue 7, July 2017
Website- www.aarf.asia, **Email** : editor@aarf.asia , editoraarf@gmail.com

Site Suitability Analysis for Rain Water Harvesting Structures Using Remote Sensing and GIS

Dr. B. C. Jat, Sr. Lecturer in Geography,
Govt. P. G. College, Neemkathana (Rajasthan),India

Abstract

Site suitability studies for rainwater harvesting structures are an integral part of watershed management .It needs a large volume of multidisciplinary data from various sources. Remote sensing is of immense use for natural resources mapping and generating necessary spatial database required as input for GIS analysis. GIS is an ideal tool for collecting, storing and analyzing spatial and non - spatial data, and developing a model based on existing factors to arrive at a suitable natural resources development and management action plans. Both these techniques in conjunction with each other are the most efficient tools for selecting suitable sites for rain water harvesting structures. In the present study, an integrated remote sensing and GIS based methodology is adopted for identifying the suitable sites for rain water harvesting structures in the chosen study area located in the Solani watershed of Dehradun District, Uttarakhand, India. IRS-1D P6 - LISS III &IV precision geocoded FCC data on 1:50,000 scale and field observation data were used for extracting thematic information such as geomorphology, geological structures, soil, landuse landcover, well locations, drainage pattern etc. of the area. Slope map and flow accumulation maps were prepared using Survey of India toposheets on 1:50,000 scale. The various thematic layers and field observation data were integrated into GIS and various spatial and non spatial queries were performed. The suitable sites for installation of artificial recharge structures and water harvesting structures were identified.

Keywords: watershed, rain water harvesting, remote sensing, GIS,farm pond,check dam,DEM,stream order,barren land.

Introduction

Watershed management is an integrated effort for increasing production through better utilization of primary resources without causing any adverse effect on the ecological balance. The watershed approach has conventionally aimed at treating degraded lands with the help of low cost and locally accessed technologies such as in situ soil and moisture conservation measures, afforestation etc. and through a participatory approach that seeks to secure close involvement of the user communities. Watershed management has been defined as an integration of technologies within natural boundaries of a drainage area for optimum development of land and water resources to meet the basic minimum needs of the people in a sustainable manner. The concept of integrated treatment of all lands on watershed basis was adopted and implemented by the Damoder Valley Corporation in the areas of Bihar and West Bengal(Guy Honore 1999).Integration of remote sensing and geographical information system(GIS) provides a reliable ,accurate and update database on land and water resources which is prerequisite to identify suitable site for water harvesting such as farm pond, check dams ,percolation tanks and gully plugs(I.P.Abrol Dhurv Narayan et. al. 1997).

A large number of techniques have been recently evolved for the watershed management. After a considerable amount of experimentation and model building, it has been felt that these techniques have to be integrated in a comprehensive manner. Remote sensing and GIS technology provide a ground for integrating the various parameters over a geographical platform with high and analytical capabilities, like the location of feature over space and time, the patterns and trends of development and different analytical permutation and combination.

Remote sensing and GIS are valuable tools for generating and analyzing this thematic information (Ouattara et.al 2004). Harvested water can be used for variety of purposes when the common sources such as; springs or well fall. In addition to supplying drinking water for people ,livestock and wildlife; water harvesting system can provide supplemental water for growing food and fibre crops (Verma et.al.1995).Water harvesting can be done at domestic level it is a common practice to harvest rainwater from roofs, hillrock surfaces and store it in tanks or to recharge the groundwater. Jeykumar (2001),Hannah(2001, and Adhitayan (2001) discuss the methodology of roof water harvesting and its use. At society level, water harvesting can be done at large level to meet the local irrigation and drinking demand for some extent by constructing check dams and farm ponds and percolation tanks etc. Durgaroa et.al.(2001) demonstrated the role of remote sensing and geographical information system(GIS) in selecting suitable sites for water harvesting structures. Raju has proposed an innovative design for some water harvesting structures such as check dams and percolation tanks. Verma et.al.(1995) and IMSD(1995)suggested some guide lines for identifying suitable sites for water harvesting structures.

The use of remote sensing and Geographical Information System (GIS) methodology is well suited for the quantification of heterogeneity in the topographic and drainage features of a catchment (Shamsi, 1996; Rodda *et al*, 1999). The objectives of this project were to use Remote sensing and GIS for the site suitability for rainwater harvesting in Solani watershed depending on the physical characteristics of watershed as slope, land use and H.S.G. type, all of which affect to collect rainwater in various structures in the different sub-watersheds of a catchment.

STUDY AREA

The study area for the analysis is Solani watershed (Figure 3), which is a subwatershed of Ganga River – the largest river in India. Solani watershed is located between 29° 47' 57"-30° 16' 16" N and 77° 44' 05"-78° 04' 26" E latitude. The area is about 577 km². Elevation varies from 252 m (lower plat agriculture lands) to 908 m (upper hilly area). Administratively Solani watershed belongs to Uttarakhand and partly Uttar Pradesh.

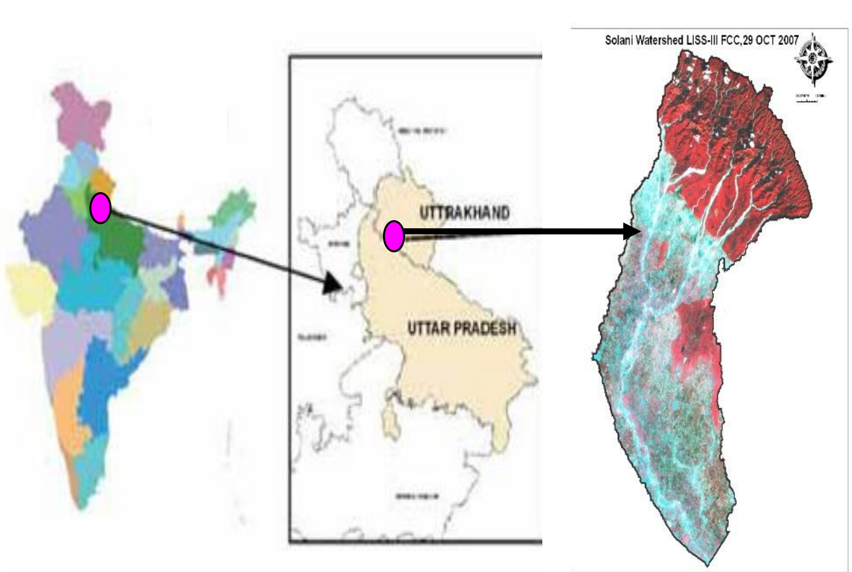


Figure 1 Location of Solani watershed

In terms of topography, Solani watershed has three major terrains: hill, piedmont and plain. The hills are Siwalik range, located northern margin of watershed; elevation ranges approximately from 252 to 908 m . The Siwalik range is composed of a gentle northern slope and steeper southern slope. The plains are bordered by the mountain which is major character of the watershed. Solani River emerges from the Siwalik range, length of the main river is 45 km. Kaluwala, Chillawal, Shahjahanpur and Mohan rivers are some of the major tributaries of Solani main river.

The study area experiences sub-tropical monsoonal type of climate. Most of the rainfall occurs during the period June-September (Indian monsoon season) and annual precipitation varies from 1200 to 1500 mm. About 84% of the season is associated with the western disturbances across the northern latitudes. The surface winds in winter are westerly to northern-westerly. Average maximum temperature varies between 20-40°C and relative humidity varies from 35 to 80%. On the basis of the existing weather conditions the area has been divided into four seasons: 1) winter (December-February); 2) summer (March-May); 3) south-west monsoon (June-September); 4) post-monsoon (October-November).

Objectives

The main objectives of the study is to GIS application for the location of suitable sites for construction of different water harvesting structures. The main objectives of the study can be delineated as under:

- Generation of various thematic parameters.
- Identification of suitable sites for farm pond.
- Identification of suitable sites for check dam.
- To develop a set of geodata-base for any watershed for testing the application in real world.

Methodology

In the present study, an integrated remote sensing and GIS based methodology is adopted for identifying the suitable sites for rain water harvesting structures in the chosen study area located in the Solani watershed of Dehradun District, Uttarakhand, India. IRS-1D P6 - LISS III &IV precision geocoded FCC data on 1:50,000 scale and field observation data were used for extracting thematic information such as geomorphology, geological structures, soil, land use land cover, well locations, drainage pattern etc. of the area.

The comprehensive methodology of this study can be described as in figure- 2

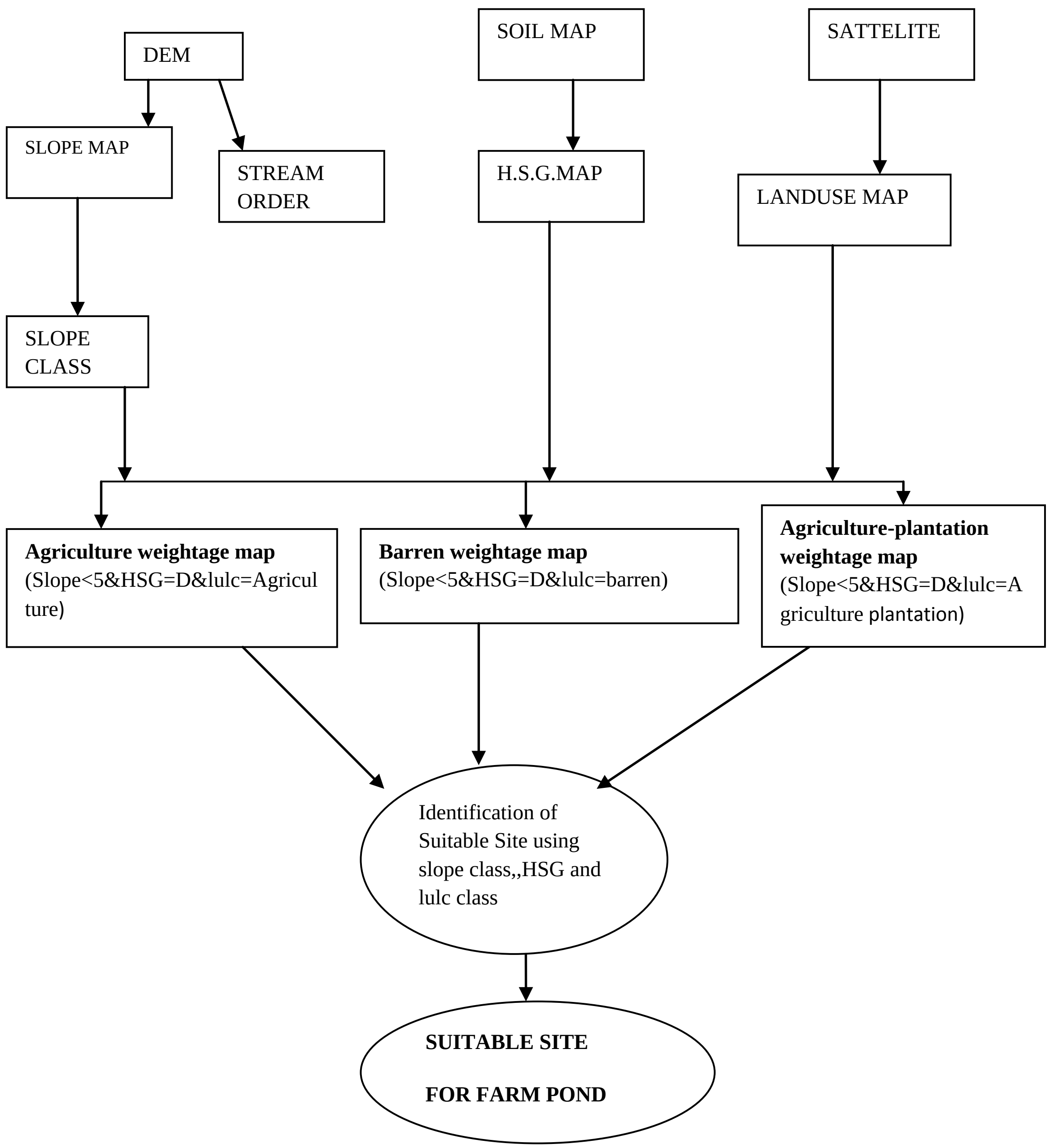


Figure-3,Flow diagram of site selection for farm ponds.

.

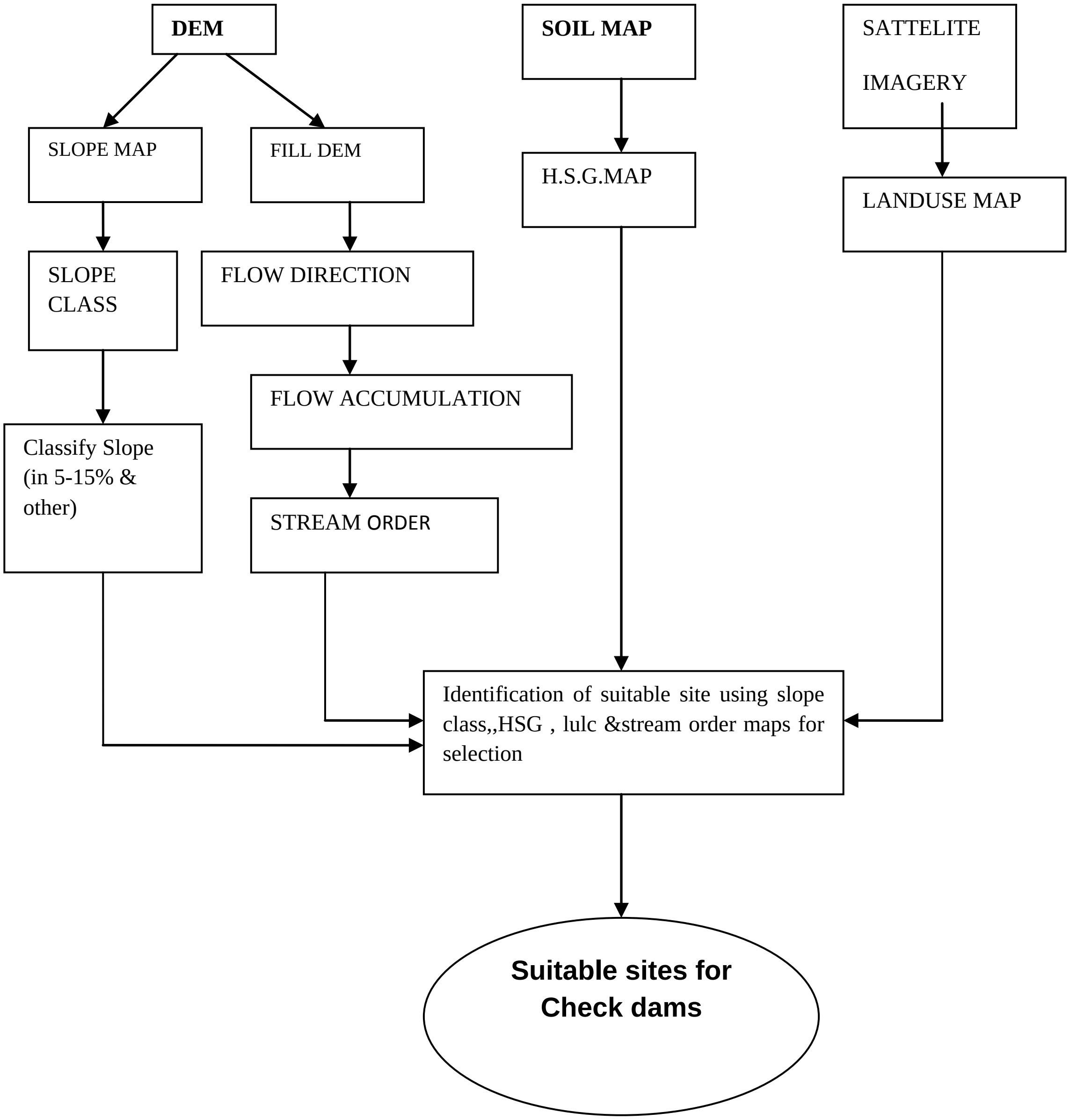


Figure-4: Flow diagram of site selection for check dams

The present study has been conducted by following a well defined methodology as given in Flow charts (Figure 1 and 2). One for the selection of suitable sites for farm ponds and the other for selection of suitable sites for check dams in the Solani watershed.

Selection of Suitable sites for water harvesting structures:

Technical guidelines for selecting suitable sites for conserving water is given by The Integrated Mission for Sustainable Development(IMSD), Technical guideline prepared by

National Remote Sensing Centre(NRSC) India and guideline given by "Indian Committee on Hydrology(INCOH).

Farm Ponds :

Farm Ponds are made either by constructing an embankment across a water course or by excavating a pit or the combination of both. Normally such structures are provided within individual farms. According to IMSD guidelines the main objectives of construction of farm pond are:

- To provide water storage for life saving irrigation in a limited area,
- To provide drinking water for livestock and human beings in arid areas,
- To serve as water storage for providing critical irrigation to limited number of fruit plants for establishment purpose and
- To moderate the hydrology of small watersheds.

Site conditions:

Dugout ponds are generally created by excavating pits in areas having flat topography and location having a low soil permeability. Design criteria can be decided by the concern user. Approximate locations can be selected based on remote sensing data interpretation and consultation of toposheet.

Check Dams:

In general they are constructed on lower order stream (upto third order)with medium slopes. They are proposed where water table fluctuation is very high and the stream is influent or intermittently effluent. The catchment area vary widely, but an average area of about 25 hectare should be there.The parameters to be considered are slope, soil cover, and thickness and hydrological conditions such as rock type, thickness of weathered strata, and fractures depth to the bedrock etc. There should be some irrigation well in the down stream of the proposed structure. The structure will serve for dual purpose. Firstly it reduces runoff velocity thereby minimizing erosion and secondly allows the retained water to percolate and thus results is increased recharge in the wells located down stream of the structure.

Stages:

The methodology can be divided into three different parts:

Formulation of different parameters for construction of water harvesting structures.

1. Generation of geo-data layers.
2. Generation of different thematic and derived maps.

Stage 1: Formulation of different parameters for construction of water harvesting structures.

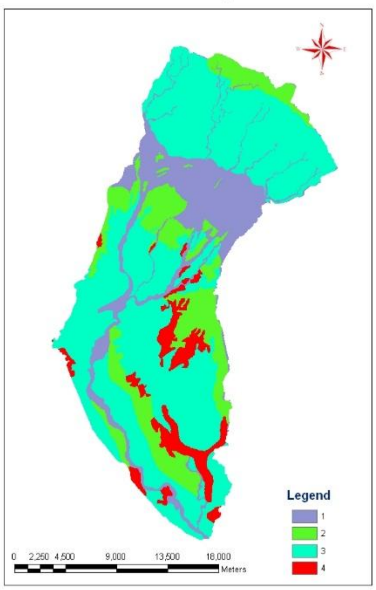
A set of criteria have been selected for the site suitability analysis for construction of water harvesting structures. Main parameters adopted in in all analysis are as follows:

Slope map: The main attribute characteristics with the slope of a region should be the slope type and percentage of slope.

The slope classes can be divide into following categories:

Sr. No.	Slope classes (in percentage)	Type
1	< 1	Nearly level
2	1-3	Very gently sloping
3	3-5	Gently sloping
4	5-10	Moderately sloping
5	10-15	Steep
6	15-35	Very steep
7	> 35	Extremely steep

HSG map



Land use map

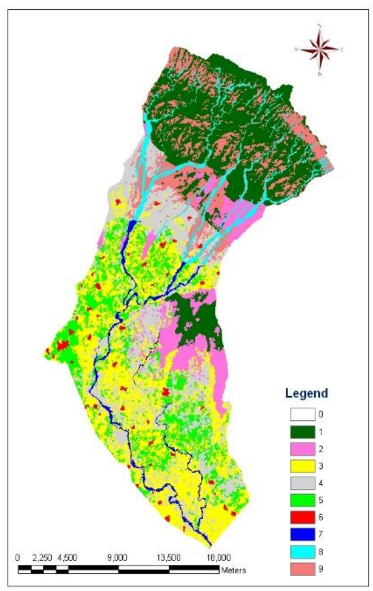


Figure 3.3 HSG and Land use maps of Solani Watershed

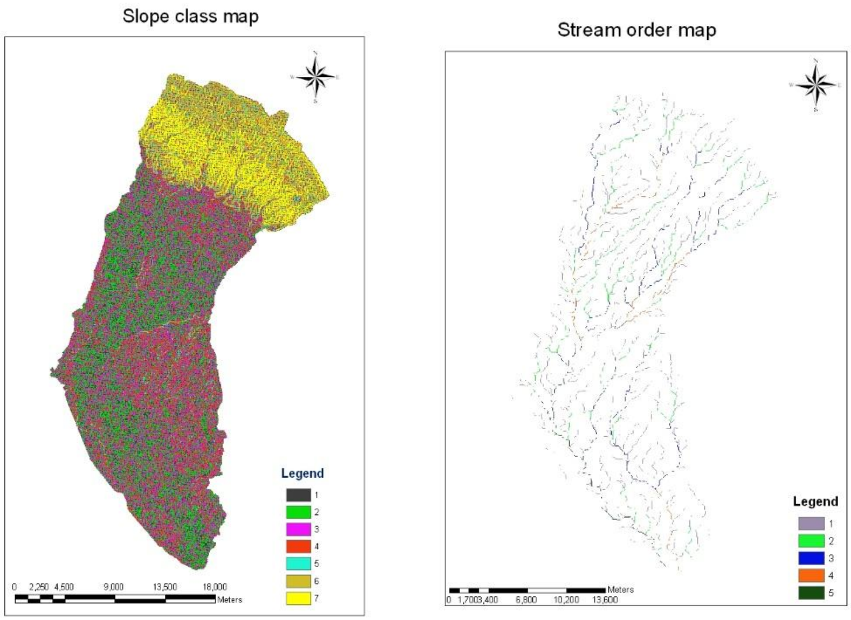


Figure 3.4 Slope class and stream order maps of Solani Watershed

H.S.G. map: HSG map is created from soil map. The main attribute characteristics with the HSG group of a region should be in four categories.

Sr. No.	**H.S.G. Group**
1	**A**
2	**B**
3	**C**
4	**D**

Land use/Land cover map:

The main attribute characteristics with the land use/land cover of a region should be the type.

- Dense forest
- Sparse forest
- Agriculture
- Fallow and barren land
- Agriculture-plantation
- Built up area
- River perennial
- River seasonal
- Scrub

Stream Order map:

Stream order map is created from flow accumulation map(Dem-Fill Dem-Flow direction-flow accumulation).The main attribute characteristics with stream order of a region should be the order:

- First order
- Second order
- Third order
- Fourth order
- Fifth order

Stage 2. Generation of geo-data layers:

The input for the geo- data base development:

1. **Dem:** The layers which are extracted from DEM for the study include the slope, and stream order.

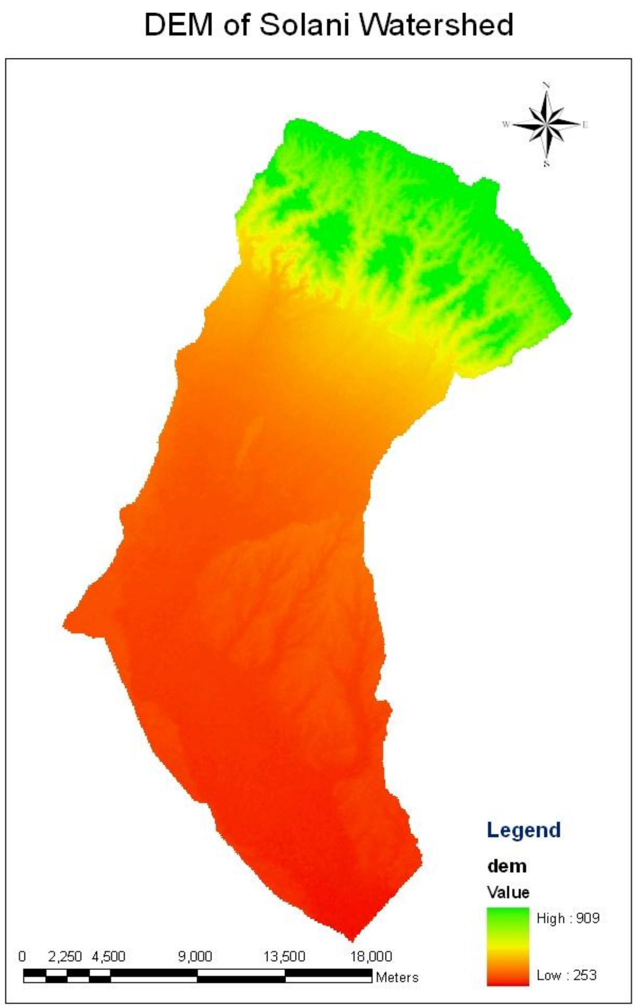


Figure 3.5,Dem of Solani Wateshed(source:WRD,IIRS,Dehradun)

2. LISS IV of IRS 1D (P6) data of March season (16.3.2009) used for creation of land use and land cover map.

3. Secondary data related to geological structure.

Stage 3. Generation of different thematic and derived maps:

Slope and stream order maps were generated from the DEM and land use/landcover map was generated from the satellite imagery (1D-P6) for the period of 16 march ,2009(LISS IV)using ERDAS Imagine software. HSG map was generated from soil map.

Selection of sites for **farm pond**: three maps were generated:

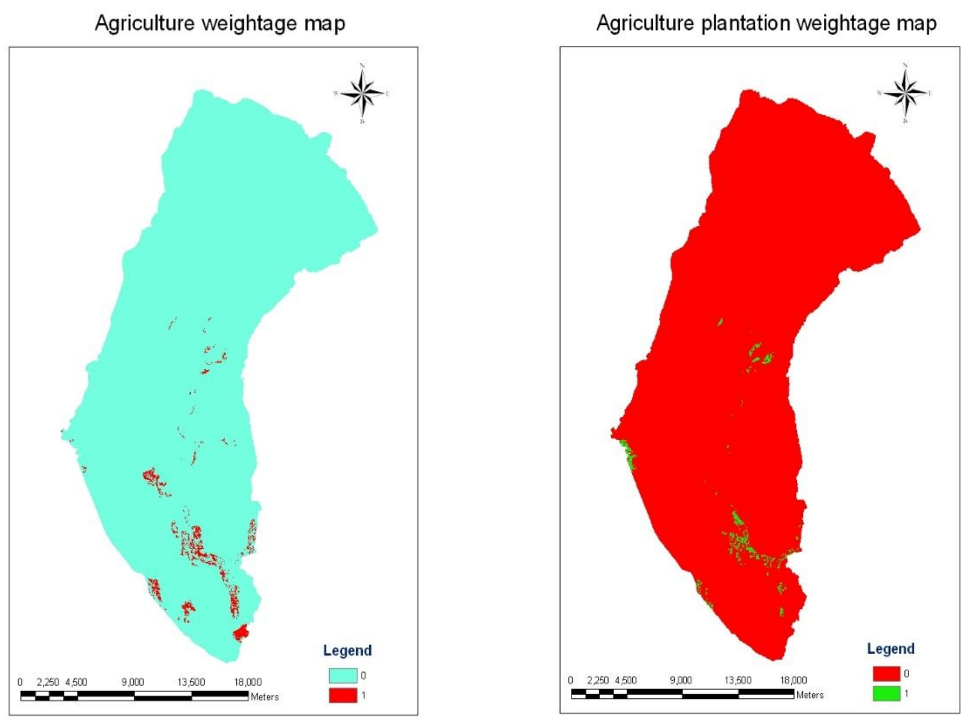


Figure 3.6 Agriculture and Agriculture-plantation weightage maps

1. Agriculture weightage map(agri_wtg.image)- condition in raster calculator is: con(slope=< 5 and HSG=D and lulc=Agriculture(no.from attribute table)).Fig.3.6

2. Barren weightage map(barren_wtg.image)- condition in raster calculator is: (slope=< 5 and HSG=D and lulc=barren land(no.from attribute table)). Fig.3.7

3. Agriculture-plantation weightage map(agri_plant_wtg.image)- condition in raster calculator is: con(slope=< 5 and HSG=D and lulc=Agriculture plantation(no.from attribute table)). Fig.3.6

After generation of these three maps in raster calculator following condition has been applied:

Con((agri_wtg.image)=1 or(barren_wtg.image)=1or (agri_plant_wtg.image)=1,1,0)

Finally map of suitable sites for construction of farm ponds was generated.(Fig.5.1)

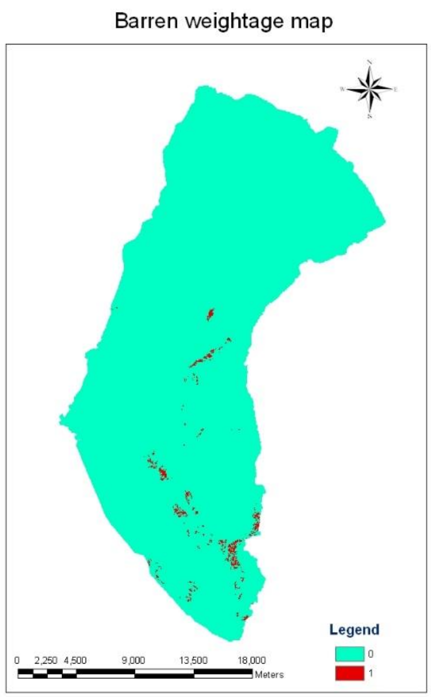


Fig.3.7,Barren weightage map

For Selection of site for **check dams** four maps were used in raster calculator:

Con((slope_per)=8&(lulc)=1&(HSG)=4&(stream order)=>3 ,1,0)

Slope map has been reclassified into two classes; first is 5-15% and given value -8(for selection of ideal site for check dam), second is other class (rest of all class).

Finally map of suitable sites for construction of check dams was generated (Figure 5.2).

A Monthly Double-Blind Peer Reviewed Refereed Open Access International e-Journal - Included in the International Serial Directories.

4.2. Remote Sensing And Other Data Used

Slope map, Land use map, HSG map, and stream order and geological and meteorological data are the main inputs for hydrological models. Followings are the main material used in this study:

- Slope map created from Aster-DEM .
- Stream order map created from Aster-DEM.
- HSG map: this map was prepared from Soil map.
- Land use map: This map was prepared using LISS-III images in the WRD IIRS and this was updated and validated through field observations during present study period.

4.3. Software Used

- ERDAS 9.2,
- Arc GIS 9.3,
- ILWIS 3.3
- Microsoft Office software.

RESULTS AND CONCLUSIONS

Selection of suitable sites for construction of farm pond and check dam was based on IMSD guidelines for water resources development and analysed using remote sensing and GIS technology. For construction of farm pond the suitable site were selected in agriculture, agriculture-plantation and barren land.

Farm Pond:

The decision rules applied for farm pond in GIS environment are :

- Agriculture weightage map(agri_wtg.image)- condition in raster calculator is: con(slope=< 5 and HSG=D and lulc=Agriculture(no.from attribute table)).Fig.3.6
- Barren weightage map(barren_wtg.image)- condition in raster calculator is: (slope=< 5 and HSG=D and lulc=barren land(no.from attribute table)). Fig.3.7
- Agriculture-plantation weightage map(agri_plant_wtg.image)- condition in raster calculator is: con(slope=< 5 and HSG=D and lulc=Agriculture plantation(no.from attribute table)). Fig.3.6

In Solani watershed those areas were selected for construction of farm pond where flat topography with less than 5 percentage of slope and location having low soil permeability. In this watershed 1587.59 hectare area was selected for construction of farm pond. Results are displayed on the map, as the sites where the farm ponds are to be constructed for water harvesting. (Fig. 5.1)

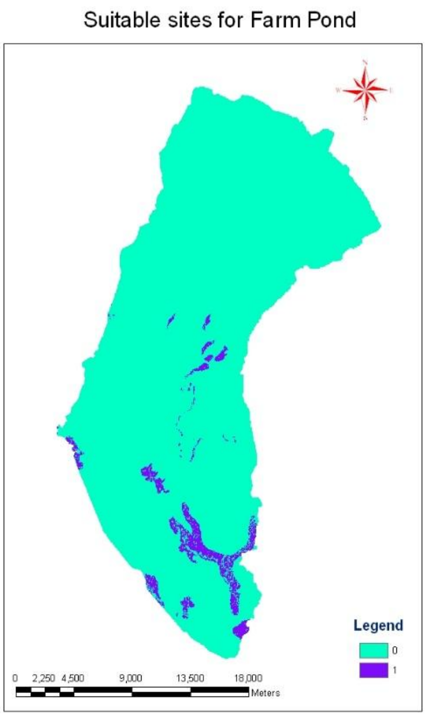
Check Dam:

The decision rule applied for farm pond in GIS environment is :

Con((slope_per)=8&(lulc)=1&(HSG)=4&(stream order)=>3 ,1,0)

Selection of suitable site for construction of check dams was also based on IMSD guidelines. The parameters to be considered are slope(in percentage),HSG,lulc and stream order. Those areas were selected for construction of check dams where slope was 5 percent to 15 percent(moderately sloping to steep)and location having low soil permeability(HSG-D) on first to third order streams. (Fig. 5.2)

In Solani watershed there were five sites selected for constructing check dams, from which two sites situated on second order stream and three sites situated on first order stream. Results are displayed on the map, as the sites where the check dams are to be constructed for water harvesting.



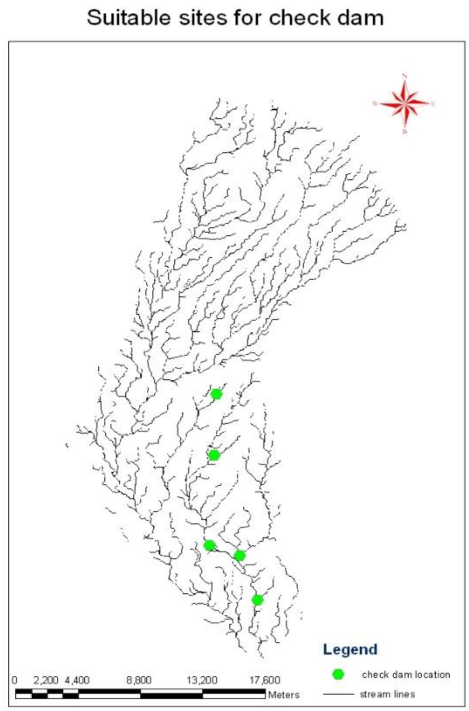


Fig.5.1: Suitable site map for farm pond

Fig.5.2: Suitable site map for check dam

5.2. Conclusions

In this study, the following conclusions were derived from this study:

- Out of total area of the watershed 1687.59 hectare area is found suitable for construction of farm ponds
- Five locations are identified for construction of check dams
- Remote sensing and GIS techniques helped in minimising the time required for locating suitable sites for water harvesting structures as compare to tradition method of selecting sites.Also is more scientific and precise method.

- Further these sites should be finalised based on conducting field visit, discussion with the beneficiaries and benefit: cost analysis.
- This approach could be applied easily for other watersheds for efficient and effective planning and implementation for locating suitable water harvesting structures.

    - analysis can be increased for more accurate location analysis for the structures.

.

REFERENCES

- Adams M.E. (1982): Agriculture extension in Developing countries. Mtl. Trop. Ag. Ser. Longman
- Agriculture extension and Research Project : Summary Report (1995) Department of Agriculture, Govt. of Rajasthan, Jaipur.
- Bennet,J.W.(1997):The ecological transition:cultural anthropology and Human adaptation.Paragamon Press New York.U.S.A.
- Berger,P.L.,T. Luckman(1966):The social Constrction of reality.The double day New York.Field,D.R.,and W.R.Burch,Jr.(1990):Rural Sociology and environment.Social Ecology Press,Madision,Wisconsin.U.S.A.
- Durga Rao,K.H.V.and Bhaumik,M.K.(2003):Spatial Expert support system in selecting site suitability for water harvesting structures-a case study of Song watershed Uttaranchal,Geocarto International,vol.18,no.4,December,2003,pp.43-50.
- Ramakrishan,D., Durga Rao,K.H.V.and Tiwari K.C.(2008):Delineating the potential sites for water harvesting structures through remote sensing and GIS techniques:a case study of Kali watershed ,Gujarat, Geocarto International,vol.23,no.2,April,2008,pp.95-108.
- Freedman,B.R(1989): Environmental ecology:the impacts of pollution and other stress on ecosystem structure and function,acaedemic press,San diego.
- Gahlawat, J.K. (1988): Strategies for Rural Development Ornald Publishers Mdio, New Delhi.
- Gurjar R.K and Jat ,B. C. (2001): Water Management Science , Pointer Publication, Jaipur .
- Jat,B.C. (2008): Watershed Management, Pointer Publication, Jaipur .
- Longman.K.A. and J.Jenik(1987)Tropical forest and its environment,Lonman,London.
- Mannion,A.M.(1995): Agricultural and Environmental change,Wiley,London.
- Mather,A.(1992): Global Forest Resources,Wiely,Londan.
- Odem,E.P. (1959): Fundamentals of Ecology,saunders,Philadelphia.

- Saha,S.K., and Shukla,M.K.(2003):Project report on “Customized GIS application development for site suitability for water harvesting and soil conservation structures” submitted to Indian Institute of Remote Sensing,Dehradun.
- Sahu S K(2006): Cost benefit analysis of watershed development programme: A study of Bichhiwada watershed project, Udaipur, Rajasthan, Social Science Electronic Publishing
- Singh S(2010): Comparative study of common guidelines for watershed development programme in india,Journal of Global Economy, Vol. 6, Issue 2, 137-148.