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AN INTEGRATED REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS APPROACH FOR THE SELECTION OF WATER HARVESTING STRUCTURES IN DOON VALLEY, DEHRADUN, U.P., INDIA

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ABSTRACT

Remote Sensing and GIS were found effective in preparing and maintaining databases and carrying out analysis related to natural resource management. The present work is an attempt to build a micro level database using Remote Sensing and GIS technology as a significant step towards the site selection studies in watershed management. The advancement in Remote Sensing technology with the advent of Geographical Information System (GIS) made it possible for integrated study of the multiple themes to drive the required information in the desired format. Remotely sensed data can be utilised to provide information on space in a hydrological unit. There is a growing demand for the construction of water harvesting structures not only in drought prone areas but also in semi-humid and humid areas to meet the requirements of irrigation at critical stages for survival of crops and drinking water supply. The paper discusses the detailed procedure involved in an RS-GIS integrated study and demonstrates the integration of soil texture, thickness, landuse, slope of the area, for the selection of suitable sites for the construction of water harvesting structures viz., Bundis, Farm Ponds, Check Dams and Percolation Tanks and ground water recharge.

INTRODUCTION

Water is an important natural resource of the earth and plays a vital role in every aspect of life. With increasing demand on water by growing world population, it has become necessary for the mankind to look for additional sources, as well as to conserve the available resources. Water harvesting has been defined as the practice of collecting water from an area treated to increase runoff from rainfall for beneficial use (Boera, 1979) but now a days it became a general term for collecting and storing of precipitation and runoff resulting from rainfall or snowmelt in soil profile and reservoirs. Earlier rainwater harvesting was used for arid and semi-arid areas, but recently their use has been extended to sub-humid and humid regions too (Verma and Tiwari, 1995). Water harvesting techniques are used for augmenting the water quantity in soil profile and also to reduce the runoff at downstream end. The structures help not only to conserve water in the upstream side when water is plenty (i.e. during monsoon) but also will increase the water holding capacity of soil profile. Conserving the soil from being eroding away and reaching the reservoir as silt, is an another major advantage of water harvesting structures. IMSD (1995) formulated guidelines for surface water harvesting structures namely Farm Ponds, Minor Irrigation Tanks, Check Dams, Water Harvesting Bundhis, Nala Bunds and Percolation Tanks. The site selection criteria for these structures are proposed based on type of landuse, slope, soil texture, soil depth, catchment area, geology, lineament density and water table. Selection of a suitable site for erecting these structures requires considerable skill, innovation, effort and expenditure in addition to an update database terrain conditions.Several attempts have been made in the past in various study areas and the efforts have given successful results (ADRIN,1997; Ramsawamy and Anbazhagan, 1996; Ram kumar, 1998). Integration of remote sensing technology and Geographic Information System techniques with other resource data provides a reliable, accurate and up-to-date database on land and water resources. The present paper discusses the techniques of RS and GIS in selection of sites for water harvesting structures.

STUDY AREA

For the present study the Doon valley and its environs (extending between 30° 15' 00" to 30° 30' 00" North latitude and 77° 55' 00" to 78° 20' 00" East longitude) covering an estimated area of 790 sq.km has been chosen(Fig.1). The area falls under subtropical monsoon type of climate receiving about 2320mm of average rainfall with a mean annual temperature of 24.1°C. The area depicts a rugged terrain consisting of structural hills, denudational hills, gently sloping piedmont zone, valleys, recent flood plains and river terraces. The

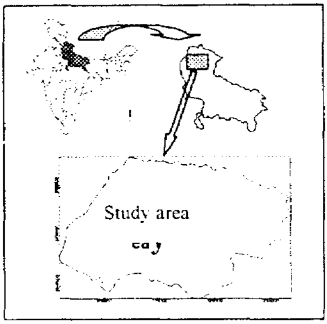


Fig. 1 Location Map

elevation of the study area varies from 540m to 2700m. The drainage of study area is a part of Ganga River system. Song is one of the major tributaries to Ganga and Bandal River is the tributary of Song River. The rivers show a braded pattern and the overall drainage pattern is dendritic.

Doon valley residual hills support good Sal forests. Mixed vegetation is found in lower Himalayan zone, which are sparsely distributed at higher reaches. The sun facing south slopes have scanty shrub types mixed vegetation. The northern slopes are better forests of Deodar and Oak. Riverine forest species like Khair and Sissoo are found on the terraces of rivers where adequate water is available. Orchards of Mango, Litchi, Grapes are present with patches of forest. Valley flats are largely cultivated crops like Wheat, Paddy, Maize, and Sugar cane with seasonal vegetables grown in patches.

Geologically, the Doon Valley is an intermountain valley flanked on NE by the Lesser Himalayas and Siwalik foothills and in the SW by the Outer Himalayan Siwalic range. The oldest to the youngest formations are the Pre-Tertiary Meta sedimentary rocks. Subathu (Lower Tertiary) and Siwalic sedimentaries of Upper Tertiary age. These are overlain by old and youngest Doon Gravel (sub-recent and recent sediments). Various geomorphic units (viz. structural hills, residual hills, denudation hills, dun fan gravels, Sub-recent fan terrace and recent alluvium) have been recognized

MATERIALS AND DATA USED

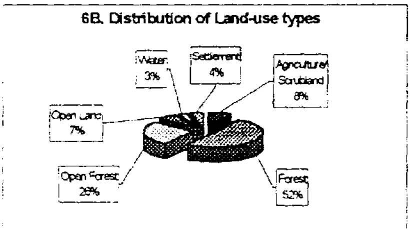
The materials and data sources used in the study are Satellite Data (IRS- 1C, LISS III geocoded FCC imagery (96/49, 96/50) of date 14th October 1996 and IRS-1C, LISS III geocoded digital data of 11th Feb. and 9th Oct, '97), Ancillary Data (SOI Topo maps No. 53 F/15, F/16, J/3 and J/4 on scale 1: 50000). The methodology adopted for the preparation of various thematic maps and the procedures for their integration using GIS technology is shown in Fig.2. Different thematic maps namely drainage map, contour map, landuse map, geology and geomorphology maps were prepared using topo maps and remotely sensed data. The image features on the FCC of the study area were interpreted for land use/land cover using the standard interpretation keys. oordinate system for the study area was created with UTM projection for zone 44, using Everest (India, 1956) ellipsoid and Everest (India, Nepal) datum bundled with ILWIS© package. The digitized contour and spot height (100m.interval at hilly region and at 20m intervals at piedmont areas) information were used to obtain the DEM with '*Interpolseg*' module of ILWIS. Elevation zones, slope classes and slope-aspect for mountainous area were derived from DEM using appropriate modules and filters available in ILWIS.

Physiographic elevation classes namely High Mountain region above 1500m. (+MSAL) and low mountain region below 1500m were identified and chosen for the study. The FCC and SOI topo sheets have been observed for visual interpretation of land-cover followed by limited field checks. The unsupervised and supervised classification schemes of ERDAS-IMAGINE software have been performed for a meaningful classification of land-cover/landuse map(Fig.3). The elevation class map depicting mountainous region and different piedmont zones were obtained by reclassifying the DEM. The slope map was worked out by running directional-gradient-filters. The gradient maps were ratioed and transformed to obtain the slope map (Fig.4). Different slope classes were delineated by reclassification. The slope and aspects were calculated using neighborhood connectivity operators and mapped as northern and southern aspects. These two maps were fused to arrive at the various Physiographic-soil-units of the study area. The Physiographic-soil-units are reclassified based on texture and soil units are classified as fine loam, coarse loam and skeletal loam (Fig.5).

Considering the guidelines prepared by Integrated mission for Sustainable Development (IMSD), technical guidelines given by National Remote Sensing Agency (NRSA) and National Committee on Hydrology (INCOH), decision rules were determined for selection of sites for various water harvesting structures. The objectives and site conditions for these structures and selection criterion used in the study to identify suitable sites is given in Table-1.

RESULTS

The elevation in the study area ranges from 540m to 2700m above mean sea level. Very steeply sloping terrain covers an area of 25824.8 ha. Followed by area under very gently slope (13289.79 ha.), steep slope (11293.68 ha.), nearly level land (9554.43 ha.), gentle slope (6908.81 ha.) and area under strongly steep slopes (4066.00 ha.) regions (Fig6.6A).



6B. Distribution of Land-use types

Based on land use / land cover the study area has been divided into six classes (Fig. 3). These classes are Forest, Open forest, Agriculture/ Scrubs, Open land, Settlements and water bodies(Fig.6A) Forest occupied the major proportion to the extent of 40538.85 hectares area, which are about 52.0 percent of the total study area. The other classes, open forest, agriculture/ scrub land, open land, settlement and water bodies covering the area 20913.49, 6367.66, 5321.65, 3466.97 and 2433.97 hectares respectively (Fig.6B).

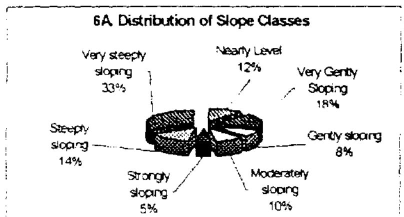
Physiographic soil classes (Fig-5) were obtained by considering aspect and landuse in mountainous region and slope in piedmont regions. Skeletal loam is the major soil class covers an area of 55742.50 hectares, while coarse loam and fine loam covers an area of 17121.76 and 6177.74 ha. Respectively (Fig.6C).

SELECTION OF SUITABLE SITES

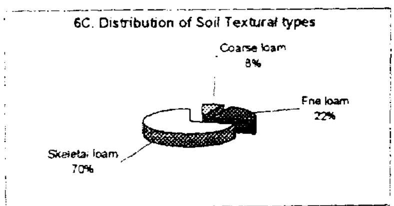
Table- 2 Suitable sites for different structures

S. No.	Type of Structure	Number of Locations
1.	Bundis	39
2.	Farm Ponds	298
3.	Check Dams	7
4.	Check Dams	4
5.	Percolation Tanks	3
6.	Ground Water Recharge Sites	261

By integrating the Landuse, soil and slope maps and applying the decision rules possible locations for different water harvesting structures are identified (Fig.7). A buffer zone of 500m. distance around agriculture and settlement areas was created and overlayed on site suitability map. The locations within the buffer zone were considered. Number of locations identified for different structures is shown in Table-2. Selected sites have been investigated confirm the analytical results and the same were found to be satisfactory. These sites may further be taken up for detailed field studies and final selection for execution of work may be made according to the priority regions and depending on socio-economic considerations in the area.



6A. Distribution of Slope Classes



6C. Distribution of Soil Textural types

SUMMARY & CONCLUSIONS

Supplement Irrigation is sometimes essential for survival of horticulture and agriculture crops in drought prone areas having undependable and erratic rainfall. For this purpose excess rainwater has to be conserved / stored in different structures and can be directed to artificially recharging the ground water for its use later. In recent past there is a growing demand for the construction of water harvesting structures not only in drought prone areas but also in semi-humid and humid areas to meet the requirements of irrigation at critical stages for survival of crops and drinking water supply. Department of Space has designed certain guidelines for the site selection criteria for different water harvesting structures.

The present study aimed at the selection of suitable sites for water harvesting structures in Dehradun and its environs using an integrated approach of Remote Sensing and GIS technology based on the Decision rules designed by the NRSA. Using SOI Topo maps and Remotely Sensed Data different thematic maps such as drainage, contour, geology, geomorphology, soil, and landuse were prepared. Using contour map Digital Elevation Model was developed. The DEM was utilised for the generation of slope, aspect and soil maps. Integrating soil texture, thickness, landuse, slope of the area, suitable sites were identified for Bundis, Farm Ponds, Check Dams and Percolation Tanks. Also area suitable for ground water recharge was demarcated.

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Table 1: Site characteristics of harvesting structures (Source: IMSD, 1995)

	Structures	Objectives & Site Characteristics	Site selection criteria used in the present study				
			Slope	Land use	Soil type	Lineament density	Catchment area
1	**Check Dams**	To reduce runoff velocity and erosion as well as to retain more water in soil. Lower order streams , medium slopes, highly fluctuating water table, influent or intermittently effluent streams, >25 ha catchment area with flat to gentle slope	Nearly level to gentle	River and streams	Fine loam	Nil to low	> 25 ha
2	**Farm Ponds**	Water storage for life saving or critical irrigation and domestic purpose and to moderate the hydrology of small watersheds. Flat topography, low soil permeability and areas >1 ha near a farm or settlements.	Nearly level	Agriculture	Fine loam	Nil to low	> 1 ha
3	**Bundis(bunds)**	Collection and storage of runoff to facilitate more infiltration and raise ground water in zone of influence of bandi as well as for providing irrigation in close proximity. Pervious soil, government open land with adequate cultivated land at the down stream of bandis.	Moderate	Open lands	Coarse loam skeletal loam	Nil to low	> 1 ha
4	**Nala bunds and Percolation Tanks**	To check velocity in nala for increasing percolation and soil moisture and to raise ground water level. They also reduce the silt loads to reservoirs and maintain their life. Relatively flatter nala reach (slope within 2 percent) with a catchment area not less than 40 ha . Nala bed with good permeability and fracture development .	Nearly level to Very gently	Open land and rivers.	Skeletal loam	High	> 40 ha
5	**Ground Water Recharge**	To improve ground water recharge through artificial methods like ponding in burrow pits, open wells, inverted wells and cavity wells. Geological conditions should be available to take recharge in and able to provide supplies in scarcity period for domestic or irrigation purpose. Permeable strata with nearly level slope in open lands having catchment area more than 40 ha is preferred.	Nearly level to very gentle	Open lands	Coarse loam Skeletal loam	High	> 5 ha

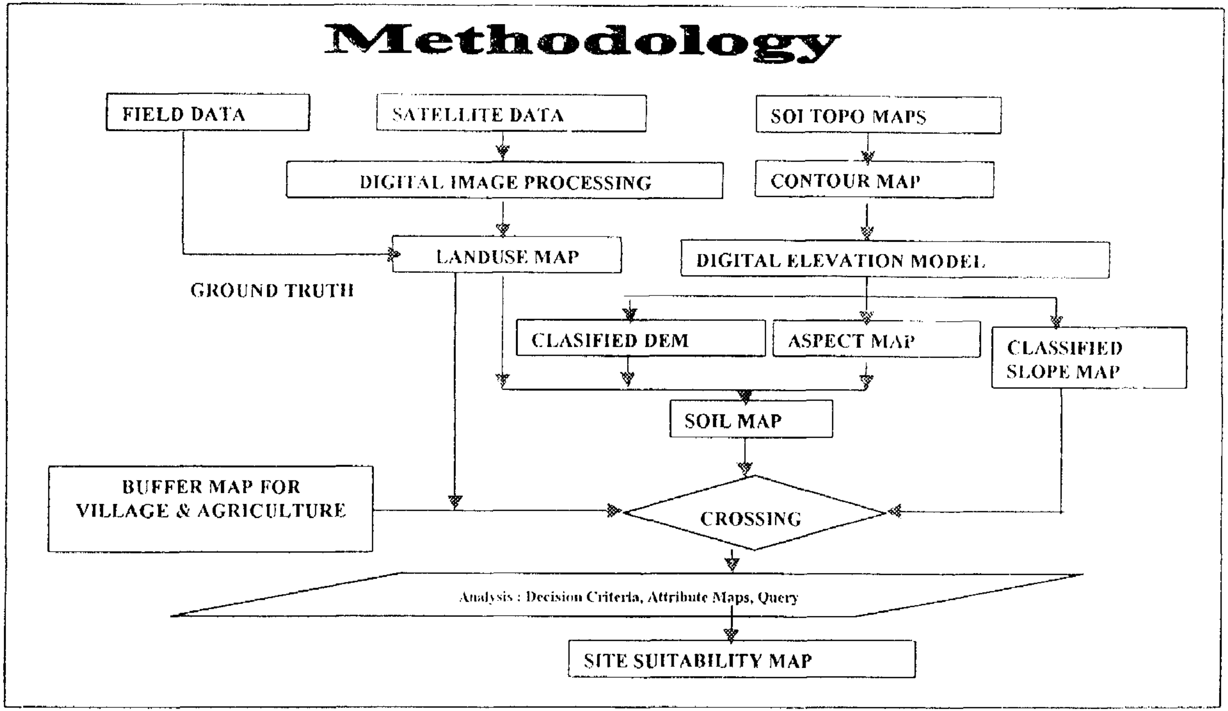


Fig. 2 Methodology adopted in the present study.

Fig. 3

Fig. 4

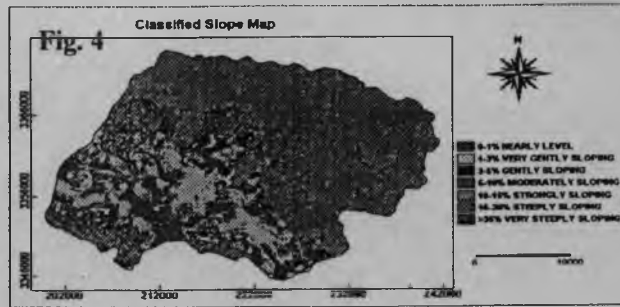
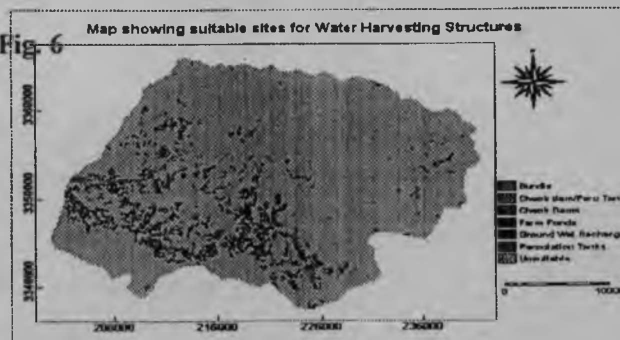


Fig. 5

Fig. 6



Thematic maps. Fig.3 Landuse Map Fig. 4 Classified Slope map. Fig. 5 Classified Soil map. Fig. 6 Map showing suitable sited