SITE SUITABILITY ANALYSIS FOR GROUND WATER RECHARGE IN DUDHGANGA BASIN, INDIA - A GEOINFORMATIC APPROACH

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ABSTRACT

Groundwater is a precious resource with limited extent. In many parts of the world rapid growth in population, agriculture sector and industrialization have increased the demand for ground water. With the increasing use of water for various activities, ground water declines at an accelerated rate. In order to prevent the fast depletion of ground water levels, artificial recharge is required. Various artificial recharge and water harvesting structures are required to allow the movement of rainwater from the catchment surface into the underground formations. Selection of suitable sites for artificial recharge and water harvesting structures needs a large volume of multidisciplinary data from various sources. The main objective of the present study is to identify the suitable sites for artificial recharge of ground water in Dudhganga basin of Maharashtra. Integration of remotely sensed data and field survey data on a GIS platform provides convergent analysis of diverse data sets for decision making in ground water management. For the present investigation Landsat 5 Satellite image of ETM+ sensor is used to assess land use/ land cover conditions by supervised classification technique. In conjunction with that SRTM dataset is used to evaluate the slope conditions. Strahler's method of stream ordering has been applied to assess fluvial morphometry. Buffer analysis has been carried out to analyse proximity conditions. The integrated effect of all the parameters is evaluated by applying weighted intersect overlay technique of GIS to find suitable sites for artificial ground water recharge. The analysis reveals that forty two sites are suitable for check dams and eighteen sites for percolation tanks in the study region.

Key words: Watershed, Overlay, Site suitability.

I. INTRODUCTION

Water is an indispensable constituent of everyday life and it is widely distributed in nature so that it may be available quickly and easily. However, with increasing population and rapid urbanization along with advent of modern technologies, water use has increased tremendously. Hence, there is a need for an early rational and practical policy for development of water resources, water use and its conservation i.e. optimal use of available water resources is essential for development of the country. Rainfall is the major source of ground water recharge, which is supplemented by other sources such as recharge from canals, irrigated fields and surface water bodies. The amount of ground water withdrawal and situation of low rainfall are factors responsible for overall stress on ground water. Ground water resources development and related engineering activities have gained paramount importance as the risks from pollution to resource have increased year after year. As a result, the interferences are becoming more and more pronounced which brings about a growing need for integrated management of the ground water resources. Progress in water resource sciences and improved computational facilities have paved the way to an integrated approach. Management of groundwater resources, projecting the future development possibilities and socio-economic as well as environment impact assessment, can be achieved through effective implementation of water harvesting and artificial recharge measures. The need of the hour therefore is a long term planning for effective and efficient management of this precious resource as well as to bring in additionally to depleting water resources by adopting a holistic approach. Ground water management deals with a complex interaction between human society and physical environment and presents a difficult problem of policy design. Aquifers are exploited by human decisions and over exploitation cannot be always defined in technical terms. For the present study, the main objective is to identify the suitable sites for artificial rain water harvesting by applying GIS techniques.

Ashok Kumar (1997) has carried the study to determine watershed wise detailed sub-surface aquifer geometry. Also, evaluated geo-morphology and terrain modeling and identified the groundwater recharge sites, check dam / water harvesting sites on the basis of geo-hydrological, hydro-geophysical and digital basement terrain model (DBTM) for the area located in the upper reaches of Siwane basin, part of Hazaribagh Upper Plateau. Jothiprakash et. al (2003) have also delineated the potential zones for artificial recharge of ground water in Agniar - Ambuliar-Southvellar river basins of Tamilnadu, India by using GIS techniques.

II. STUDY REGION

The region selected for the present study is Dudhganga basin of Maharashtra. It is located between 16° 7′ to 16° 37′ north latitudes and 73° 53′ to 74° 20′ east longitudes. The region has diversified physiography, whose western border is demarcated by Western Ghats. The soil vary from laterite patches in the west to deep medium black alluvial of the river tracts in the central part and poor grey soil in the east. The monsoon climate dominates the region. The region receives rainfall mainly from south west monsoon, ranging between 3700 mm in the west to 1000 mm in the east. The total area of the study region is about 52849 hectares.

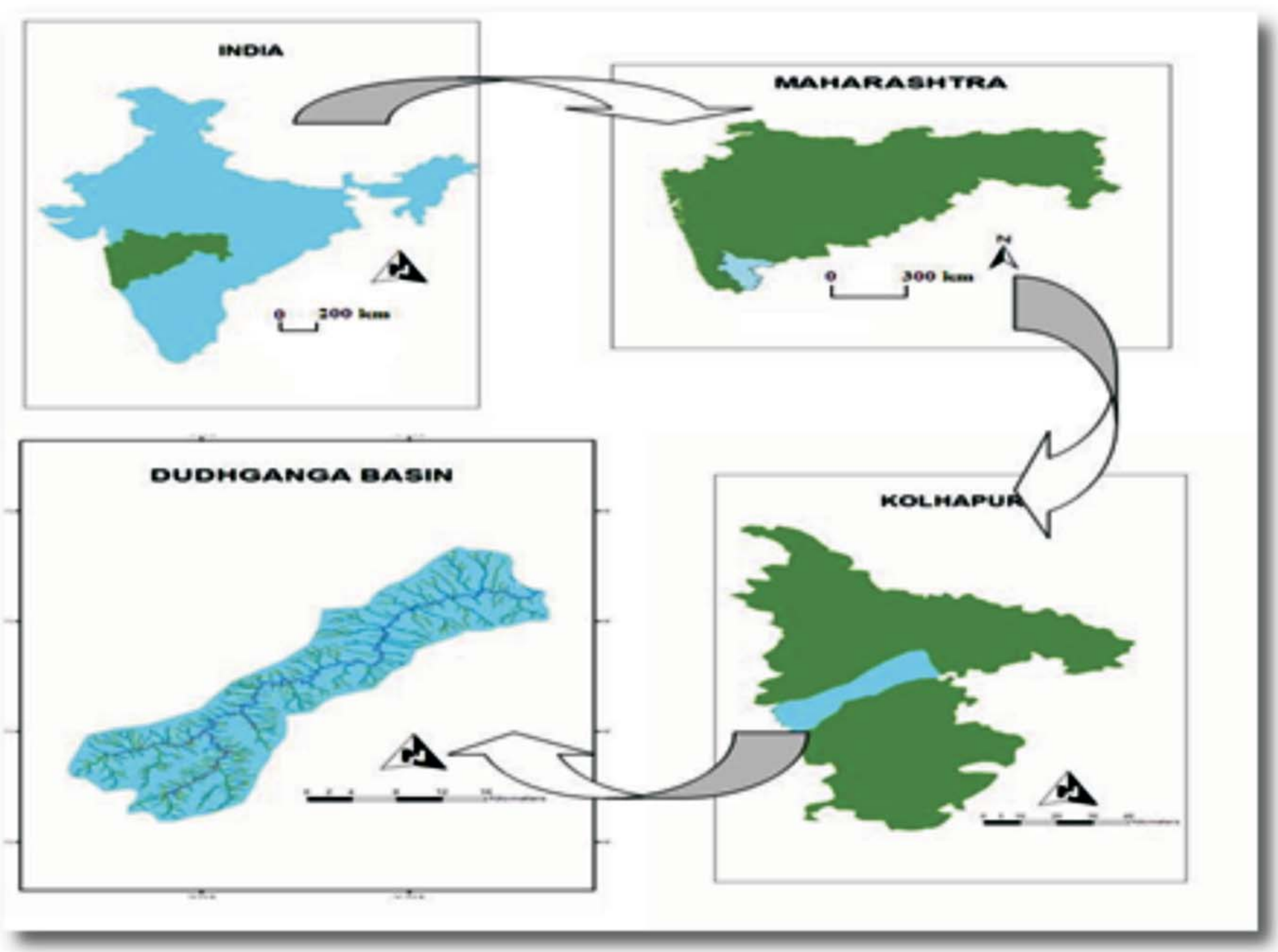

Fig. 1 Location Map

III. METHODOLOGY

Remote sensing and GIS plays an important role in the study of natural resources and helps in planning water resources development. One of the greatest advantages of using remote sensing data for hydrological investigations and monitoring is its ability to generate information in spatial and temporal domain, which is very crucial for successful analysis, prediction and validation [3]. Remote sensing provides multi-spectral, multi-temporal and multi-sensor data of the earth's surface. However, the use of remote sensing technology involves large amount of spatial data management and requires an efficient system to handle such data. An integrated study covering the aspect of groundwater recharge is a crucial requirement of the present day [4].

In this study, analyses were performed to identify suitable sites and to determine their degree of suitability for artificial ground water harvesting by applying geoinformatic approach. For site suitability analysis, the parameters like Land use/land cover, Geohydrology, slope, stream order and village /agricultural location are mostly considered. For land use and land cover mapping, four images of landsat satellites of ETM sensor are mosaiced by using Erdas Imagine 9.3 software. As the image covers adjacent areas, a subset image has been taken out for further analysis. Six classes are identified by applying supervised classification technique.

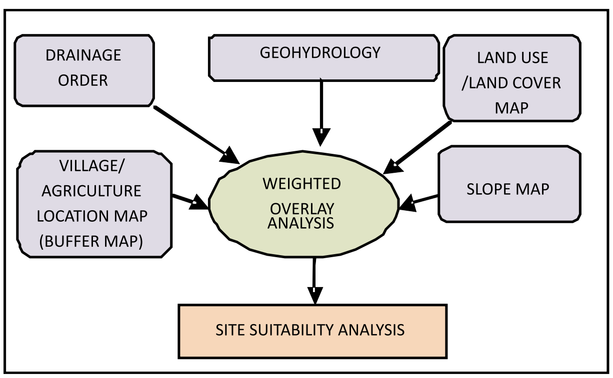

Fig. 2 Methodology Flowchart

A DEM of Dudhganga basin was generated by using SRTM data set and used for the estimation of slope. To assess geohydrology of Dudhganga watershed, thematic maps of Geological survey of India have been used in ArcGIS domain to create the digital database for further GIS analysis. The basin morphometry includes the analysis of the characteristics of linear, areal, and relief aspects of the fluvially originated drainage basin. For calculating stream order, Strahler's scheme of stream ordering has been employed. The buffer zone of 700m is created by considering village/ Agricultural location.

The present study clearly utilizes the power of GIS for priority site suitability analysis, which is otherwise not possible by conventional techniques where many analytical computations of various parameters are required to be done for a solution. In the present study the sites for surface rainwater harvesting are selected after evaluating various characteristics like geohydrology, slope, land use/land cover, drainage order and village/agricultural buffer map. The Weighted Overlay Analysis has been used by taking various thematic maps as a separate priority layer to suggest suitable sites for rain water harvesting and watershed management.

A. Data set:

(i) Landsat 5 image of ETM sensor (14 February 2008)

(ii) SRTM data of C-band and X-band (Year 2000)

(iii) District Resource Map of Kolhapur (GSI, 1998)

B. Softwares used:

(i) Erdas Imagine 9.3

(ii) ArcGIS 9.0

IV. PARAMETERS

By following the guidelines given by Government of India (1995), criteria table has been framed and following parameters have been considered to identify suitable sites for ground water recharge.

Table I: Criteria Table for Site Suitability Analysis

Structure	Area	Permeability	Stream order	Buffer for Village and Agriculture	Slope
Check Dam	>25 Ha.	Low	1st / 2nd order	700 m	Nearly level to gentle
Percolation tank	>40 Ha.	Medium to High	3rd order	-	Flat to gentle

Source: GOI, 1995

A. Slope:

Slope analysis (Fig.3) reveals that gradient is highest in south western part and middle hilly areas and lowest gradient can be observed at the lower end of Dudhganga River towards north eastern part of the basin. Sites for artificial ground water recharge are much more influenced by gradient. Hence, it is important input for site suitability analysis.

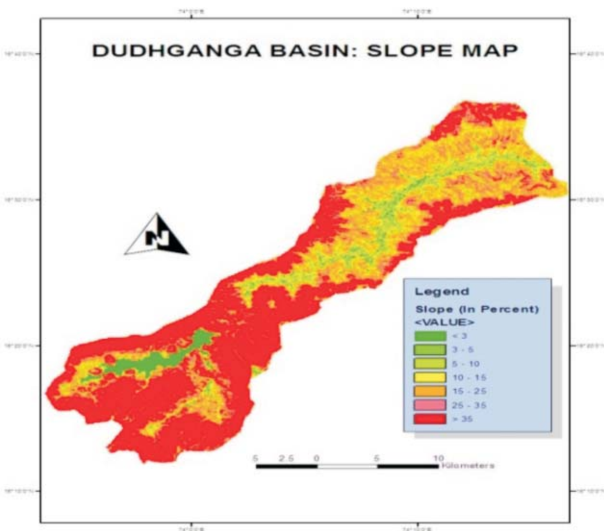

Fig. 3. Slope Map

B. Geohydrology:

The entire basin is underlain by Deccan Trap basaltic lava flows of late Cretaceous to Palaeogene age. Deccan basalts are hydro-geologically inhomogeneous rocks. The massive portion of basaltic flows are devoid of water, but when it is weathered, fractured, jointed or contain weaker zones, ground water occurs in it. Although the rocks are generally inhomogeneous, the zone of weathering and structures in the basalt, such as sheet joints and vertical joints, serve as zones of groundwater flow.

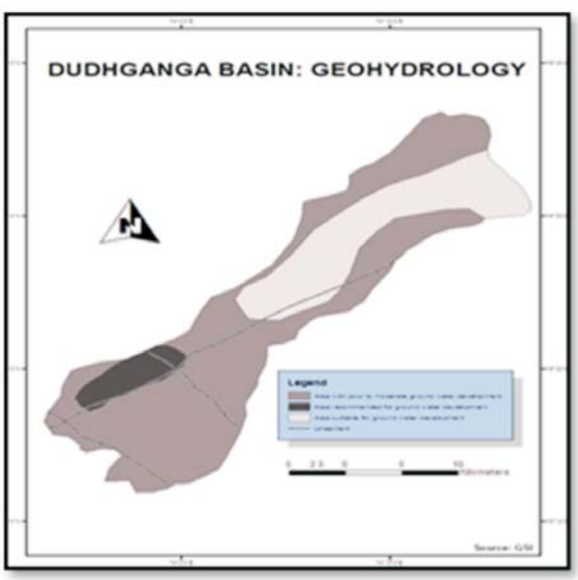

Fig. 4. Geohydrology Map

The lower reaches of Dudhganga basin are quite suitable for ground water development as compare to hilly areas of upper reaches of the basin.

C. Stream Order:

A river basin consists of its several branches having different positions in the basin area and they have their own morphometric characteristics and therefore, it becomes necessary to locate the relative position of a branch in the basin, so that the hierarchical organization of a stream segment is visualized. Thus, stream order is defined as the measure of the position of a stream in the hierarchy of tributaries [7]. For calculating stream order, Strahler's scheme of stream ordering has been used. This watershed is large basin with sixth order as the higher order stream indicates larger basin and lower order stream indicates smaller basin. The total no of streams in the Dudhganga basin accounts for 2236, out of those 1693 streams are of first order. Second and third order streams are 419 and 102 respectively. Stream number analysis (Table II) reveals that as the stream order increases, no of stream decreases. There is negative correlation between stream order and stream numbers which justifies Horton's law of stream order.

Table II: Total Stream Numbers of Dudhganga Basin

Stream Order	Stream Numbers	In per cent
First	1693	75.70
Second	419	18.70
Third	102	4.76
Fourth	17	0.70
Fifth	4	0.10
Sixth	1	0.04
Total	2236	100

D. Land Use / Land Cover Analysis:

According to supervised classified images, six classes can be identified in the year 2006. Out of the total geographical area of the basin, about 36.2% was

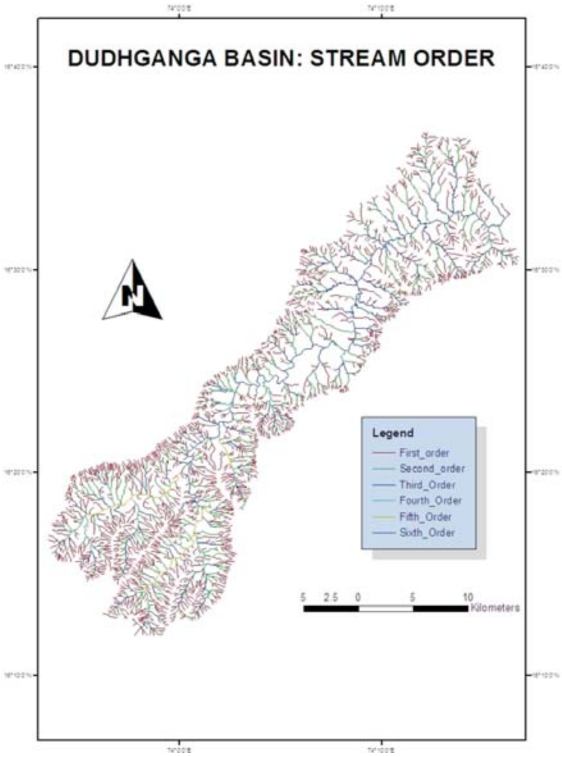

Fig. 4: Stream Order

under cultivation (Net sown area and fallow land). The area under fallow land is 15.80 per cent.

Table III: Land use / Land cover Analysis

Class Name	Area in hectares	Area in %
Grass land	9494	17.90
Barren land	8661	16.40
Forest	11930	22.60
Water bodies	3614	6.80
Agricultural fields (Sown area)	10850	20.50
Total	52849	100

The lower reaches of Dudhganga basin is having high proportion of sown area and low proportion of fallow land and the vice-versa situation is observed in the upper reaches of south western high altitude areas of the basin. The south western part of the region is dominated by Western Ghats. It is having dense forest and grassland. The actual dense forest remaining now is about 22.5 per cent only. The share of barren land is about 16.3 per cent. High proportion of this category is basically confined to hilly and plateau areas of Karveer tahsil and north eastern part of Kagal tahsil. The proportion of water bodies, which includes dam, tank and rivers account for 6.8 per cent.

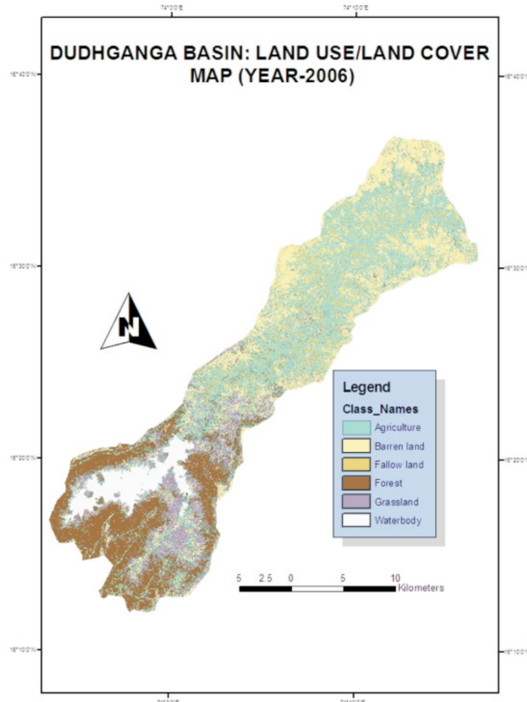

Fig. 5: Land Use/ Land Cover Map

V. DISCUSSION AND RESULT

The Integrated Mission for Sustainable Development (IMSD) gives technical guidelines for site selection of ground water harvesting structures. These guidelines prepared by National Remote Sensing Agency (NRSA), India and by the guidelines given Indian National Committee on Hydrology (INCOH). The guidelines for the selection of various water conservation structures are discussed in this paper.

In the present study, two types of structures namely check dam and percolation tank are taken into consideration. To carry out this study, various thematic layers have been generated namely drainage map, slope map, land use/ land cover map, geohydrology map and buffer map of village and agriculture using Arc GIS software and multi criteria analysis was done in the same software. Using the guidelines given by various references, a decision rule was applied for identification of suitable sites for various water conservation structures.

Check dams, and percolation tank provide a good measure of rainwater harvesting structures by arresting runoff and increasing the surface area of infiltration. Suitability of these structures depends on various factors, which can be integrated by GIS techniques [10]. To assess the groundwater recharge zones in the study area, all the different polygons in the thematic maps were labeled separately. Knowledge based weightages are assigned to each thematic features after considering their importance with respect to groundwater. All the thematic maps were integrated in GIS environment and the polygons have been regrouped into different classes.

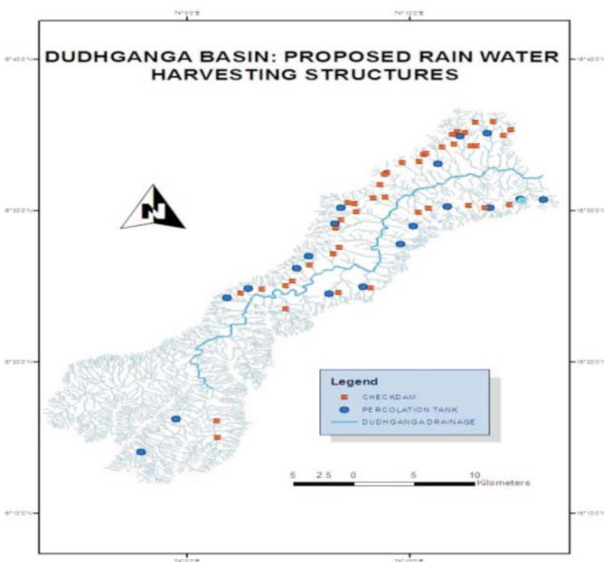

Fig. 5. Proposed RWH Structures

Thematic layers viz., geohydrology, land use/ land cover, buffer zone, slope and drainage map have been considered for site suitability analysis. Based on the available knowledge on the role of each of these parameters in controlling the occurrence, storage and distribution of groundwater, weightages were assigned for geohydrology, buffer zone, land use/ land cover, slope and drainage respectively. Again each of these layers has further been classified into different classes. Each of the classes, based on its ability to facilitate water infiltration has been given ranks from 1 to 4. Finally, scores have been calculated as the product of the weightage and rank.

In the first step, geohydrology and land use/ land cover layers were integrated by the union option. The integrated output layer (OL1) comprises polygons of the geohydrology layer and polygons of the land use/ land cover layer and after union it resulted in new polygons having attributes of both the layers. Adding these two layers derived the weight of each polygon in the integrated layer. In the next step, the first layer (OL1) was intersected with the drainage order. In this step, the integrated layer OL2 was generated by adding geohydrology, drainage and land use/land cover layers. The OL2 layer was integrated with polygons of slope and OL3 layer has been created. This OL3 layer was again integrated with buffer zone for the creation of final OL4 layer. The polygons in the integrated layer (OL4) contain the composite detail of all the thematic layers together. The final score has been calculated by the multiplication of the rank and weightage of the class. The thematic layers were integrated with one another through GIS using the weighted aggregation method.

The site suitability analysis has helped in locating the suitable sites for the water harvesting structures. Based on the above classification as well as terrain conditions, a map suggesting the type of structures to be built at various locations has been prepared (Fig. 5). The hilly part of the study area with rocky outcrops and steep slopes acts as a high runoff zone. The runoff washes away precious top soil from the hill slopes. Hence there is a need for proper soil moisture conservation measures and rain water harvesting and ground water recharge.

VI. CONCLUSION

Integration of remote sensing techniques, field survey data and GIS provides convergent analysis of diverse data sets to administrators and decision makers for better ground water management. In the study region forty two sites for check dams and eighteen sites for percolation tanks are found suitable.

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