Development of Land and Water Resources Plan for a Small Watershed in Chhattisgarh

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ABSRACT

A study on planning of land and water resources for a small agricultural watershed of Mungeli district in Chhattisgarh was conducted in the Department of Soil and Water Engineering, SVCAET & RS, Faculty of Agricultural Engineering, IGKV, Raipur during the year 2015-16. This study deals with the use of modern tools and technology for micro level land and water resource planning. *Tesua* watershed of Mungeli district was selected in this study. The *Tesua* watershed covers an area of 279.7 km^2 and is bounded by North latitudes $21^0 56' 30''$ to $22^0 09' 30''$ and East longitudes $81^0 28' 30''$ to $81^0 45' 30''$ with intended boundary falling in Survey of India topographic map no. 64G09, 64G13, 64F12 and 64F16 on 1:50,000 scale. Average annual rainfall of study area is reported to be 973 mm. The minimum temperature during in November-January was about 28^0C to 30^0C. The maximum temperature ranges between the 40^0C to 48^0C during April-May. The predominant soil of watershed is sandy clay loam; sandy loam, loam and clay loam are also found in the watershed. Based on analysis of agro meteorological, hydrological and geomorphological data, it was found that, the *Tesua* watershed consists of 4th order stream network. Water resource plan was developed based on the surface and ground water availability. On the basis of estimate it was found that 41.02 Mm^3 of water can be stored and recharged by the Water Harvesting Structure (WHS) and can support 2716.75 ha of additional crop area. Based on superimposing technique (overlaying) of various thematic maps different water harvesting and recharge structures such as percolation tank (59 nos.), check dam (126 nos.) for storage, check dam (21 nos.) for ground water recharge and farm ponds (341 nos.) are proposed at appropriate locations in the *Tesua* watershed of Mungeli district of Chhattisgarh state. On the basis of this study it can be concluded that the modern tools and technology can successfully be adopted for micro level land and water resources planning of a small agricultural watershed.

Introduction

Water resources is a specialized discipline which deals with the planning and management of natural and artificial systems that are typically contained within watersheds. Basically it includes hydrologic, biological, economic, and political systems. Water resources planning requires integrating a wide range of disciplines to ensure success, including hydrology, hydraulics, water quality evaluation, resource economics, microeconomics, epidemiology, environmental impact assessment, finance, and public policy, and public participation. Recently remote sensing and Geographic Information System (GIS) technique is proved to be a cost effective and time saving tool to produce valuable data on geomorphology, geology, land use/cover, slope, lineament density, drainage density, etc. which helps to decipher groundwater recharge potential zones. In recent times, many researchers such as Patil and Mohite (2014), Waikar and Nilawar (2014), Lalbaikmawia (2015) have used the approach of remote sensing and GIS for identification of groundwater potential zones and exploration of groundwater with locating the artificial recharge sites. Muthukrishnan and Manjunatha (2008), Balachandar et al (2010), Mungiah and Venkatraman (2013), Rais and Javed (2014) have used GIS for identification of sites suitable for artificial recharging.

Ahmad and Verma (2015) determined the suitable site for water storage in Sheonath river basin using remote sensing data and GIS techniques. Based on the various physical characteristics of the basin, they applied the Multi Criteria Evaluation (MSE) technique to determine the most suitable water storage sites. Haji et al. (2015) identified the suitable sites for water conservation structures in a watershed using remote sensing and GIS. Prasad et al. (2014) identified suitable zones for water harvesting structures in Pisangan watershed of Ajmer district, Rajasthan by using GIS and MSE. They reported that the application of multi criteria evaluation technique using geographic information system help the decision makers in determining suitable zones for water harvesting structures based on the physical characteristics of the watershed. Singh et al. (2009) identified suitable sites for water harvesting structures in Soankhad watershed, Punjab using information technologies such as remote sensing and geographical information system. Sinha et al. (2015) demarcated suitable sites to develop a water resources development plan in Bilrai watershed of Shivpuri district Madhya Pradesh using geospatial techniques. They overplayed various thematic maps and prepared a map showing suitable sites for the water harvesting structures based on the Integrated Mission for Sustainable Development (IMSD) criteria.

Integrated approach of remote sensing and GIS can provide the appropriate platform for convergent analysis of divergent datasets for decision making in not only mapping and planning of surface and groundwater resources but also management of these water resources for their efficient and cost effective utilization for a region or state. This study is aimed to develop and apply integrated method for combining the information obtained by analyzing multi-source remotely sensed data in a GIS environment for better understanding the surface and groundwater resource and identifying suitable sites for artificial recharge structures for a watershed in Mungeli district, Chhattisgarh, India.

Methods and Materials

The Tesua watershed was selected for the study, which is a part of Mungeli Block of Mungeli District in Chhattishgarh. The study watershed covers 279.7 Km^2 area and bounded by North latitudes $21^{0}56'30''$ to $22^{0}09'30''$ and East longitudes $81^{0}28'30''$ to $81^{0}45'30''$. Average annual rainfall is 973 mm. The minimum temperature during November to January ranges from $28^{0}C$ to $30^{0}C$. The maximum temperature ranges between $40^{0}C$ to $48^{0}C$ during April to May. Location of Tesus watershed is shown in Fig. 1.

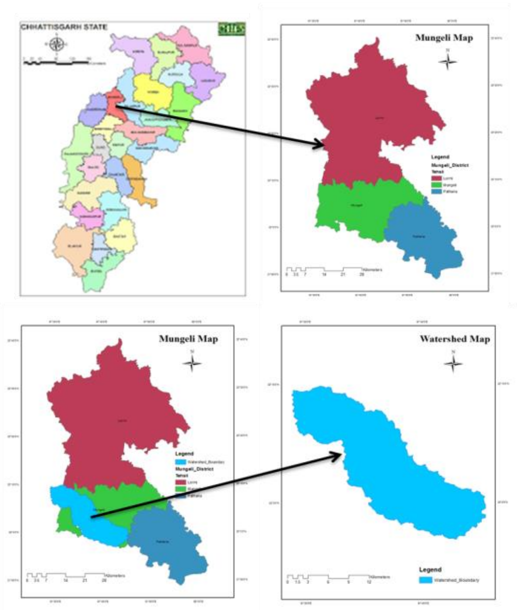

Fig. 1: Location of the study watershed

The Survey of India (SOI) topographic maps No. 64G09, 64G13, 64F12, 64F16 on 1:50,000 scales were scanned then imported to Arc GIS 10 for the preparation of base map of the study area. The scanned topographic map was georeferenced (Projection and Coordinate System) using Universal Transverse Mercator (UTM) Projected Coordinate System and World Geology System 1984. False Colour Composite (FCC) of Indian Remote Sensing Satellite P6 (IRS P6) LISS IV of 10^{th} October, 2014 having spatial resolution of 5.8 m was utilized for thematic maps preparation. In the present study multi criteria based analysis has been adopted for the identification of water harvesting structures. Equal Weightage Overlay (EWO) method of ArcGIS has been applied to generate rankings. In this method inputs are the raster layers, where each layer was given equal weightage. The process of identification of suitable location of water storage structure has been shown with the help of flowchart in Fig. 2.

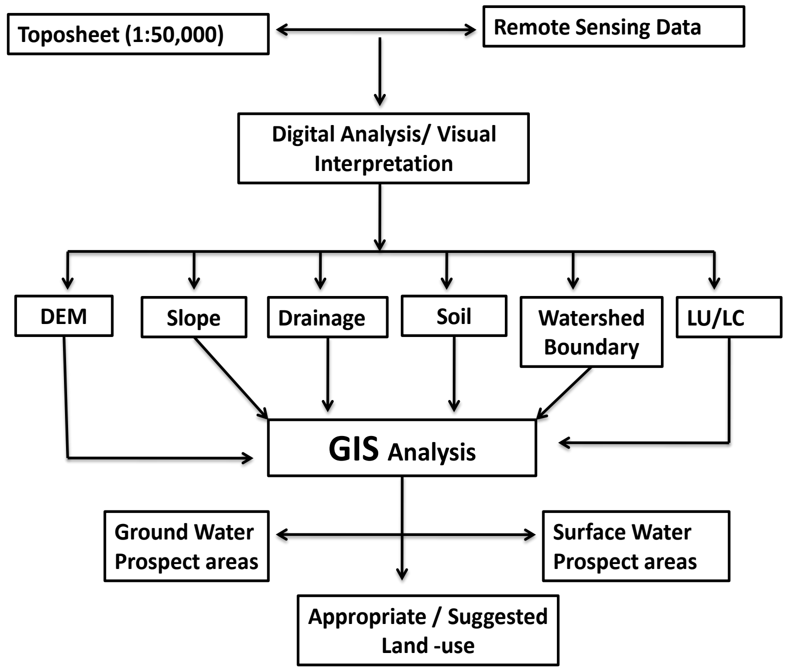

Fig. 2: Layout of methodology adopted in this study

The suitability of water storage structure is described with the help of Suitability Level Index (SLI). In this study suitability scale value in the range 1 to 5 was used. All the layers were given ranking based on their influence on the study applying equal weightage to all the parameters. Further, in the Spatial Analyst Tool, Weighted Overlay Function (WOF) has been used for identification of the suitable area. Based on the WOF, suitability map showing locations for water harvesting and groundwater research structures was prepared for the Tesua watershed.

Preparation of Thematic Maps

Land use land cover: Land use/cover features control the occurrence of groundwater and also causes for infiltration for recharge, with variety of classes among itself. Remote sensing data and GIS technique provide reliable, accurate baseline information for land use land cover mapping, which plays vital role in determining land use pattern. As per NRSC (ISRO) the study area has been classified as settlement (10.43%), deep water (0.81%), shallow water (0.68%), low land paddy (11.66%), mid land paddy (43.32%), soybean (8.97%), current fallow (12.72%) and barren land (2.87%) . The land use/cover map of the Tesua watershed is shown in Fig. 3.

Slope Map: The slope map was prepared from the contour map of the study watershed. The contour map was first converted to Digital Elevation Model (DEM) and then slope map was prepared using the standard procedure. The slope map, designated in value domain was prepared using filtering technique. Slope map as shown in Fig. 4 indicated the ranges of slope percent from 0.05-0.8%. The average slope of the watershed was found to be gentle (0.3%).

The slope map was further classified for exploring potential suitable sites for several groundwater recharging structures.

Soil Map: Soil sample data was acquired from Soil Testing Laboratory, Department of Agriculture, Bilaspur and Department of Soil Science and Agricultural Chemistry, College of Agriculture, IGKV, Raipur (C.G.). The Excel data that contains geographic locations in the form of x, y coordinates. The x, y coordinates describe discrete locations on the earth's surface such as the location of the points where soil samples were collected. The soil data exported from Excel to ArcGIS environment. Once added the data to ArcGIS environment, it becomes an XY event layer and behaves like other point feature layers. After that, the interpolation of data through Geostatistical Analyst Tool converts the point feature layers to raster layer. The predominant soils of the watershed are clay and sandy clay loam which have moderate to high water holding capacity. These soils can support the second crop if grown during rabi season. Soil map of the Tesua watershed is shown in Fig. 5.

Drainage Map: The drainage map was prepared by digitizing drainage lines using Survey of India topographic maps having 1:50,000 scale. Drainage line delineation tool and Shuttle Radar Topography Mission (SRTM) was used for delineation of drainage lines of the study area and there after corrected by making comparison with drainage lines given in the SOI topographical sheets in GIS environment. Fig. 1.6 shows that there are 79 streams out of which 58 streams are of 1^{st} order, 16 streams are of 2^{nd}, 3 streams are of 3^{rd} order and 1 stream in 4^{th} order in the watershed. The total length of streams was found to be 179.25 km.

Lineament Map: Lineament involves fractures in the strata present in the study area. Lineament map was collected from Central Ground Water Board, Raipur (C.G.). Buffer of 100 m around the lineaments were created in the environment of GIS. Lineament map of the watershed is shown in Fig 7. The total length of lineament in the study watershed was found to be 63 km.

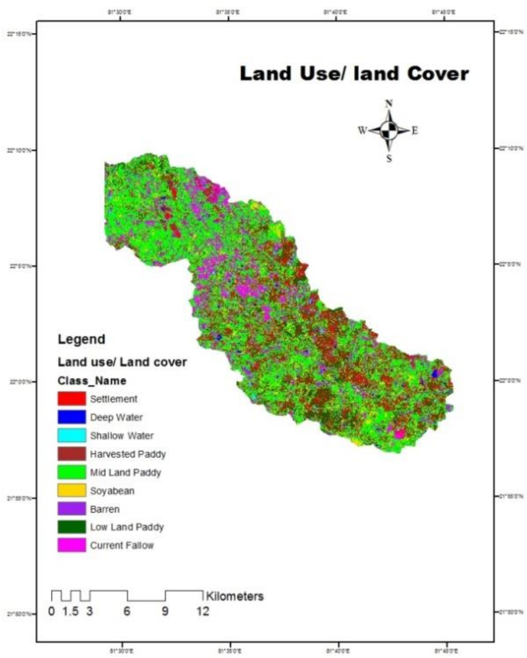

Fig. 3: Land use/cover map of the Tesua watershed

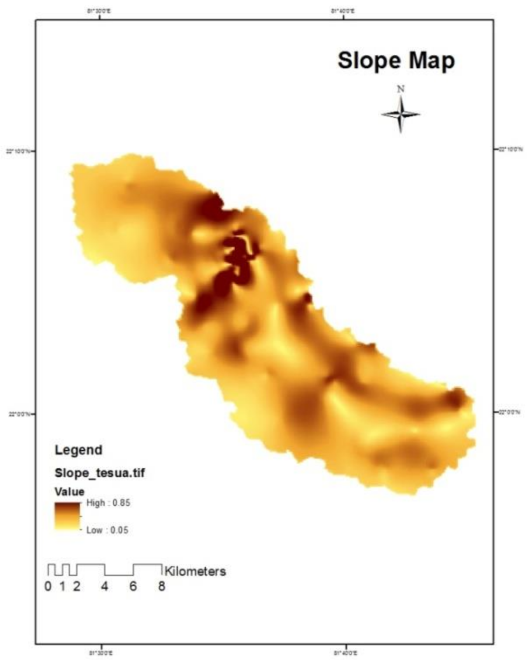

Fig 4: Slope map of the Tesua watershed

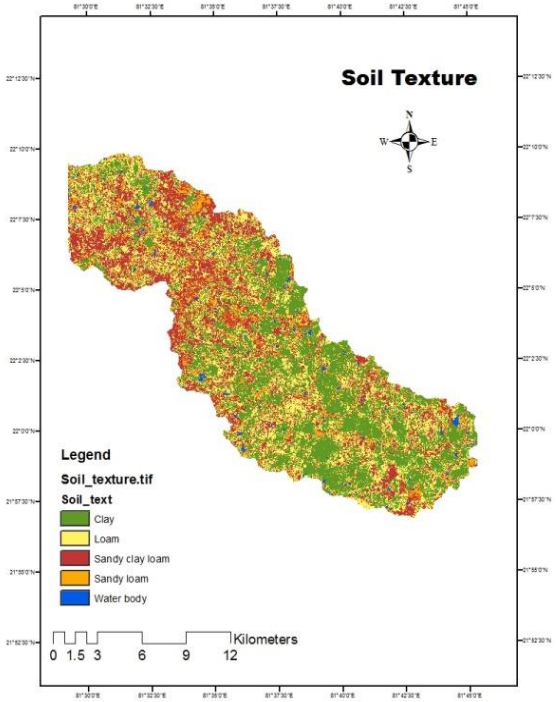

Fig. 5: Soil texture map of the Tesua watershed

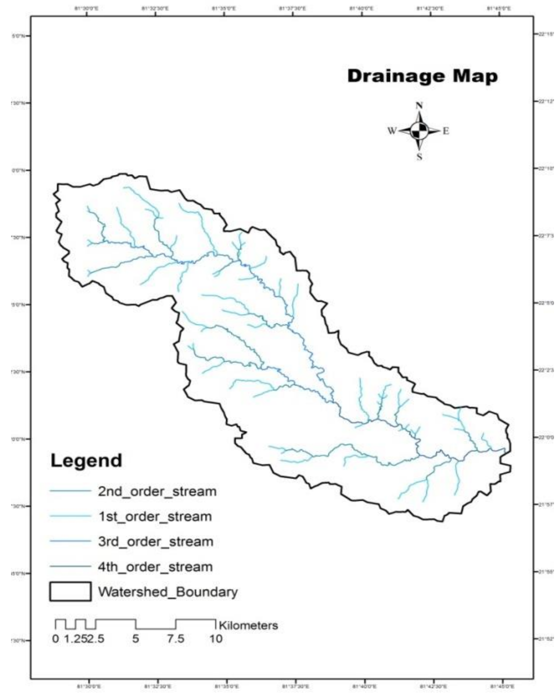

Fig. 6: Drainage map of the Tesua watershed

Weighted Overlay Analysis

Geographic Information system (Arc GIS 10.0) was used for the preparation of various thematic maps. The weightages of individual themes and feature score were fixed and added to each layers depending on their suitability of water harvesting structures. This process involves raster overlay analysis and is known as Multi Criteria Evaluation (MCE) techniques. Multi criteria based analysis has been adopted for the identification of water harvesting structures. The generated layers are in vector format, for Weighted Overlay Analysis (WOA) these format is to convert into raster format, which is known as "Rasterization". The rasterization of each layer is performed for converting different lines and polygon coverage into raster data format. After this, reclassification of all the raster files is processed along with providing the scale value of each unit. A scale value in the range of 1 to 5 (5 was the highest weightage order and 1 was the lowest weightage order) was used. All the layers are given ranking based on their influence on the study applying equal weightage to all the parameters which means all parameters are of equal importance (Table 1 and Table 2). In the Spatial Analyst Tool, Weighted Overlay Function has been applied to process for identification of suitable place for both surface water storage and

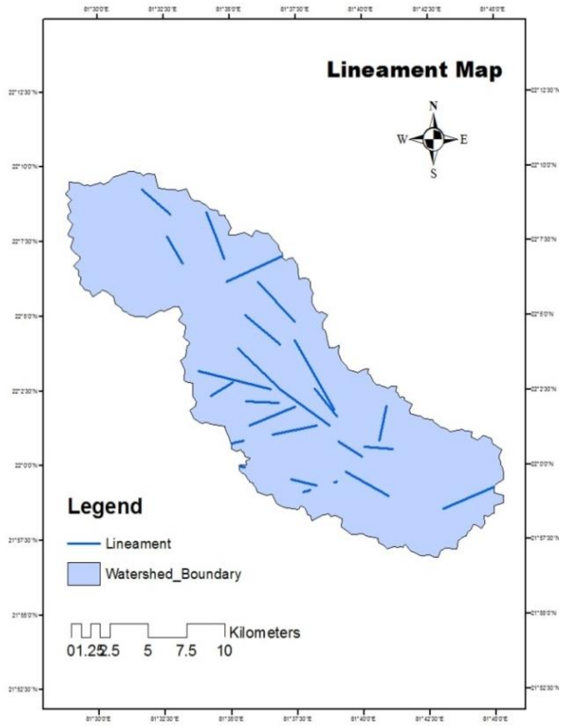

Fig. 7: Lineament map of the Tesua watershed

groundwater recharge structures. Based on the Weighted Overlay Function (WOF) a suitability map was developed, which is showing appropriate sites/locations for all the structures.

Table 1: Weightage criteria for groundwater recharge structures

Raster Feature	% Influence (Weightage Assigned)	Feature Classes	Feature Weighted Scale Value
LULC	15	Settlement	1
		Low land paddy	2
		Mid land paddy	4
		Soyabean	5
		Harvested paddy	2
		Deep water	4
		Shallow water	4
		Current fallow	5
		Barren land	3
Slope	20	0.05-0.2	1
		0.2-0.3	4
		0.3-0.8	5
Soil Texture	15	Sandy loam	5
		Sandy clay loam	4
		Loam	2
		Clay	1
Stream Order	20	1^{st} order	2
		2^{nd} order	4
		3^{rd} order	5
		4^{th} order	5
Lithology	15	Unclassified shale and Limestone	5
Lineament	15	Fracture	5

Table 2: Weightage criteria for water storage structures

Raster Feature	% Influence (Weightage Assigned)	Feature Classes	Feature Weighted Scale Value
LULC	15	Settlement	1
		Low land paddy	5
		Mid land paddy	5
		Soyabean	5
		Harvested paddy	5
		Deep water	3
		Shallow water	3
		Current fallow	2
		Barren land	1
Slope	15	0.05-0.2	5

		0.2-0.3	4
		0.3-0.8	3
Soil Texture	25	Sandy loam	1
		Sandy clay loam	3
		Loam	4
		Clay	5
Stream Order	25	1^{st} order	2
		2^{nd} order	4
		3^{rd} order	5
		4^{th} order	5
Lithology	20	Unclassified shale and Limestone	5

Results and Discussion

The multi-layer integration through land use/cover (LULC), slope, hydrologic soil group (HSG), stream order lineament and settlement gave the suitable sites for identifying the water harvesting structures. These layers were combined in ArcGIS using Weighted Overlay Tool. A final map was generated which provide the suitable location for recharge sites, as per the criteria laid by Integrated Mission for Sustainable Development (IMSD). Fig. 8 and Fig. 9 shows the suitability map for location of farm ponds and check dams (both water storage structures), respectively and Fig. 10 and Fig. 11 shows the suitability map for location of percolation tanks and check dams (both recharge structures), respectively. Both water storage and recharge structures are proposed for the Tesua watershed at appropriate locations. Structures such as farm ponds (341 nos.) check dam (126 nos.) for water storage, check dam (21 nos.) and percolation tank (59 nos.) for groundwater recharge are proposed for the study watershed.

These structures for enhancing the water resources can help to increase the production and productivity of the moderately fertile farming situations. The productivity of crops could be increased due to the interventions along with the increased area for cultivation due to recharged water.

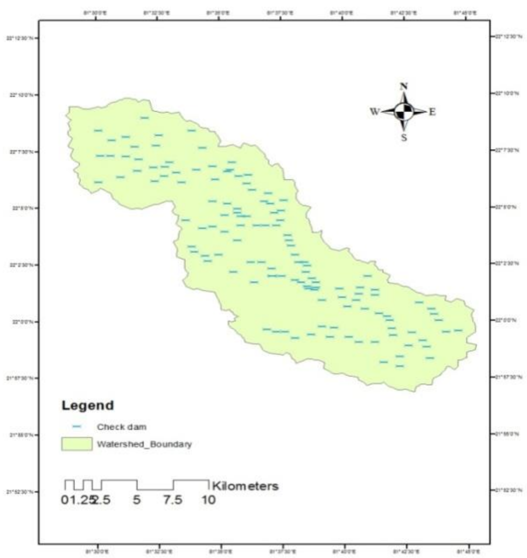

Fig. 8: Proposed sites for farm pond as water storage structure in the watershed

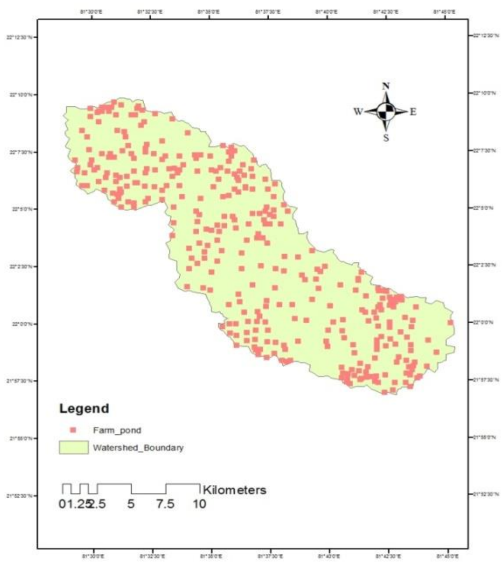

Fig. 9: Proposed sites for check dam as water storage structure in the watershed

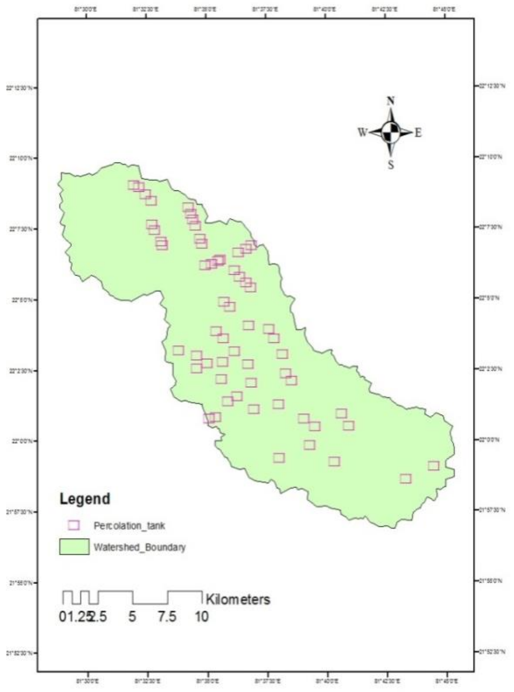

Fig.10: Proposed sites for percolation tank as groundwater recharge structure in the watershed

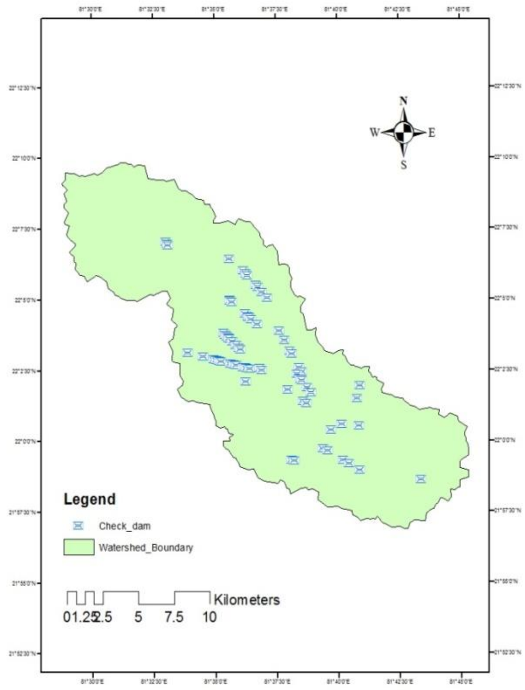

Fig.11: Proposed sites for check dam as groundwater recharge structure in the watershed recharge

Conclusions

Geographical Information System (GIS) and remote sensing has proved to be powerful and cost effective method for developing the site suitability maps for the surface water storage and groundwater recharge structures in a part of Mungeli District of Chhattisgarh. By using multi criteria evaluation techniques, the suitable sites for water storage and recharge structures are suggested by considering the physical and cultural parameters of water for irrigation and other purposes. The different water storage and groundwater recharge structures viz. check dams (126 nos), farm ponds (341 nos), percolation tanks (59 nos) and check dams for recharge (21 nos) and their suitable locations has been suggested/proposed in different farming situations to utilize their maximum potential for enhancing the productivity.

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