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SITE SUITABILITY ANALYSIS OF WATER STORAGE STRUCTURES USING REMOTE SENSING & GIS FOR A SMALL WATERSHED OF LORMI BLOCK IN MUNGELI DISTRICT, CHHATTISGARH STATE

Love Kumar*, Khalkho, D., Pandey, V. K., Nigam, G.K. and Yatnesh Bisen
Department of Soil Water Engineering, S.V. College of Agricultural Engineering and Technology & Research Station I.G.K.V., Raipur
*Corresponding author email: loverajfae@gmail.com

ABSTRACT
Water plays a vital role not only in fulfilling basic human need for life and health but in socio-economic development also. As the primary source of water is rainfall, so it becomes necessary for us to harvest it effectively we can maximize the storage and minimize the wastage of rain water. Water storage is like an insurance mechanism and acts as a barrier against the variability of the rainfall regimes and therefore increases the resilience of the stakeholder against dry spell during the rainy season. Water storage structures are one of the important Water storage structures are one of the important components of watershed development which not only collects and stores water but also utilized for infiltration purpose to recharge the ground water. The construction of water storage structure requires a considerable investment. Decision making and planning about the required number and type of water storages structures to be constructed using remote sensing and GIS is extremely important to avoid huge investment. Maniari watershed is is situated in Lormi block of Mungeli district and located between 21^0 11’0”and 21^0 34’0” N latitudes and $81^0$28’30” and $81^0$57’30” E longitudes (Fig 1). It falls in SOI topographical map no. 64 F/12 (1: 50,000). The Maniari watershed covers geographical area of 1085.65 km^2. The general elevation of the area ranges from 262 to 980 m above mean sea level (MSL). In the present study an attempt is made to determine the suitable site for water storage in Maniari watershed using remote data and geographic information system (GIS) technique. Based on the various physical characteristics of the basin, Multi-Criteria Evaluation technique is being applied to determine the most suitable water storage sites. For this purpose hydrologic soil group, land use, lineament, slope, stream order and Geology data is required. Different layers were formed based on the mentioned data and given equal weightage to all the layers. A scale value in the range 1 to 3 is used in which„ 1‟ is for least suitable, „2‟ is for moderate suitable and „3‟ is for highly suitable. These layers are overlay in GIS to produce the site suitability map of the study area. As per the multi-criteria evaluation technique, there are about 93 locations coming under the category of highly suitable sites. This mapping helps in selecting potential site for water storage structures.

KEYWORDS: Water, life**,** socio-economic, Maniari watershed, mapping, potential site.

INTRODUCTION
Water plays a vital role not only in fulfilling basic human need for life and health but in socio-economic development also. As the primary source of water is rainfall, so it becomes necessary for us to harvest it effectively we can maximize the storage and minimize the wastage of rain water. Water storage is like an insurance mechanism and acts as a barrier against the variability of the rainfall regimes and therefore increases the resilience of the stakeholder against dry spell during the rainy season (Payen, *et al*., 2012). Water storage structures are one of the important Water storage structures are one of the important components of watershed development which not only collects and stores water but also utilized for infiltration purpose to recharge the ground water. The construction of water storage structure requires a considerable investment. Decision making and planning about the required number and type of water storages structures to be constructed using remote sensing and GIS is extremely important to avoid huge investment (Singh, *et al*., 2009). Harvested water can

be used for variety of purposes when the common sources such as; streams, springs or wells fall. In addition to supplying drinking water for people, live stock and wild life; water-harvesting systems can provide supplemental water for growing food and fibre crops (Verma, *et al*., 1995). Therefore, it becomes important to Identification of suitable sites for water storage structures needs a large volume of multidisplinary data from various source for which the applications of modern remote sensing and geographic information system techniques it becomes easier to perform the watershed analysis in shorter time and cost effective manner. In the recent years it has been observed that locations of storage structures is not properly planned and influenced mainly by social conditions. The objective of this paper is to identify suitable location for water storage sites under the guidelines of Integrated Mission for Sustainable Development (IMSD) using remote sensing and GIS techniques.

Study Area
Sub watershed is is situated in Lormi block of Mungeli district and located between 21^0 11’0”and 21^0 34’0” N latitudes and $81^0$28’30” and $81^0$57’30” E longitudes (Figure 1). It falls in SOI topographical map no. 64 F/12 (1: 50,000). The Maniari watershed covers geographical

area of 1085.65 km^2. The general elevation of the area ranges from 262 to 980 m above mean sea level (MSL).

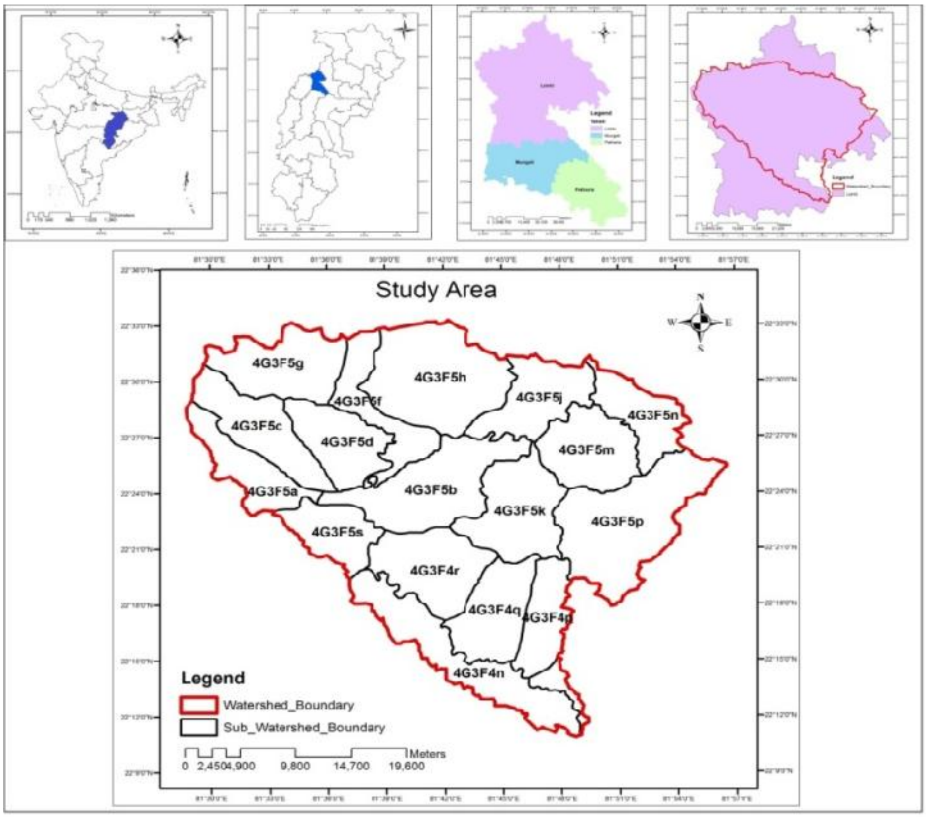

FIGURE 1: Location Map of the Maniari watershed

Data used

To achieve the objectives of the study both spatial and non-spatial data are required which includes

1. LULC from National Remote Sensing Agency, Hyderabad.
2. The Spatial resolution of the DEM obtained from Shuttle Radar Topography Mission (SRTM) is 30 m.
3. Topographic Sheets from Survey of India (SOI).
4. Soil Data from NBSS & LUP, Nagpur.
5. Rainfall Data from collected from the office of the Assistant Soil Conservation Officer (ASCO), Department of Agriculture, Mungeli (C.G).

The data obtained were digitized and converted into digital format using ArcGIS 10 for creating various criteria based layers. In the present study Multi-Criteria Evaluation technique is used to determine the suitability of various grids for the suitable water storage structure. The multi-criteria evaluation is used to investigate alternative choices (Voogd, *et al*., 1983). and to generate overall ranking of these choices (Janssen, *et al*., 1990). Equal Weightage Overlay method of GIS has been applied to generate rankings. In the 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 Figure 2.

As per the IMSD guidelines following criteria have been followed for selecting the suitable sites for water storage structures (Singh, *et al*., 2009 & Padmavathy, *et al*., 1993):

1. The slope should be less than 15%
2. The land use may be barren, shrub land and river bed.
3. The infiltration rate of the soil should be less.
4. The type of soil should be sandy clay loam.

The suitability of water storage structure is described with the help of Suitability Level Index. Gosschalk (2002). has described the suitability levels for regional dams scaled from 1 to 9. In this study suitability levels were in the range from 1 to 3. „1‟ for least suitable, „2‟ for moderate suitable and „3‟ for highly suitable. The Suitability Level Index adopted in the study is shown in Table 1. Suitability level factors includes Landuse/Landcover, Slope, Soil type, Stream order, lineament The spatial data were used to prepare various thematic maps viz. drainage map, stream order map, land use map, slope map, soil map and lineament maps.

TABLE 1: Suitability Level Index

	Suitability Level		
Factor	**1**	**2**	**3**
LULC	Settlement	Forest, Barren land, Current Fallow	Agriculture, Water bodies
Slope	Very steep sloping, Strongly sloping	Gently sloping, Moderately sloping	Nearly level, Very gently sloping
Soil	HSG Group A & B	HSG Group C	HSG Group D
Stream Order	1st & 2nd Order	3rd & 4th Order	5th, 6th & 7thOrder
Lineament	Fractu (100 m Buffer)	-----	------

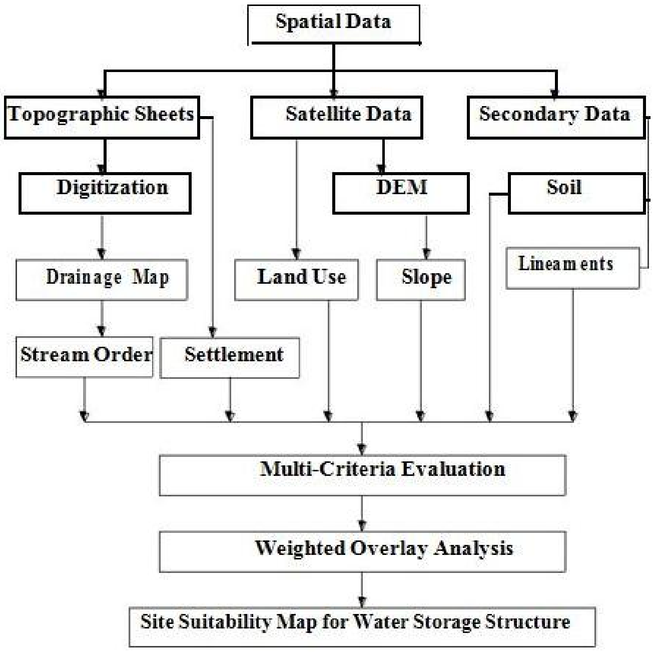

FIGURE 2: Flowchart for Identifying Suitable Location of Water Storage Structure

METHODOLOGY

The proposed methodology of study involved various activities such as base map preparation, LULC map preparation, Digitization and image processing using software and interpretation of the outputs. First stage includes development of spatial data base by using survey of India (SOI) toposheet on a 1: 50000 scale and cloud free geocoded digital data of IRS-R2 (LISS-IV). GIS and remote sensing technology is applied to prepare various thematic maps with reference to surface water like drainage map, hydrologic soil group map, land use land cover, slope, and lineament map. Additionally, the Land Utilization Survey Database and on site investigation are adopted to quantitatively and qualitatively describe the hydro-geo- logical conditions of the area. The second stage involved preparation of digital elevation model (DEM) by Shuttle Radar Topography Mission (SRTM) data were used to derive the Digital elevation model (DEM) and slope of the area. The Spatial resolution of the DEM obtained from SRTM is 30 m. The accuracy evaluation of the SRTM has done by the digitized contour and slope map of the area than SRTM (30m) data was used in this study to extract drainage network and analysis of Morphometric parameters. Hydrology tool under Spatial Analyst Tools in ArcGIS10 software was used to extract drainage channels, and other parameters.

In the third stage, digital image processing of the satellite data is done for geo-referencing & geometric correction. This is followed by creation of different thematic layers using supervised classification technique. All the attributes from the collected data then summed to create the buffer map for agriculture area & settlement area. It is then followed by creation of other important data which is used to determine the ground water potential at the later stage like land use/land cover map, geological/lineament map.

In the fourth stage all above themes are further processed and analysed in overlay and ranking is given to evaluate suitable groundwater potential zone. All the thematic layers will overlay by using GIS to find the final integrated output of suitability map for location of water storage structure sites in the present study, drainage map, hydrologic soil group map, land use land cover, slope, and lineament map are considered for the suitability location of water storage structure sites.

Spatial Database Building

ArcGIS software is used to generate datasets of features, attribute tables, topology / geometric network and other data items in database, which provides various tools. Different thematic maps are created using procedure as below.

1. Digitization of scanned toposheets / maps and editing for elimination of errors

2. Providing map projection system to spatial dataset
3. Extraction of various feature classes for all the layers
4. Assignment of attributes for each layer

Data integration through GIS

Various favourable groundwater thematic maps have been integrated into a single suitability location of water storage structure sites with the application of GIS techniques. Data integration required steps as below.

1. Assignment of ranks to various features in different themes of spatial data
2. Integration by overlay of various thematic maps in ArcGIS environment
3. Assignment of weightage to different themes in overlay analysis in GIS environment
4. Generation of suitability map for location of water storage structure sites

Spatial Analysis

The process of study of locations of geographic phenomena together with their dimensions and attributes, classification, polygon classification, rank and weightage ssignment to individual class and feature class respectively, is significant and important. The various thematic maps, such as drainage map, hydrologic soil group map, land use land cover, slope, and lineament map have been prepared and duly assigned ranks for individual class and weightage to each theme depending upon its influence on surface water and movement and also more importantly infiltration and runoff. For example slope plays prominent role in runoff process; as the slope is steeper more is the runoff. Similar is the case of geomorphology, which causes more holding capacity for surface water than other factors once infiltration takes place. Further identification of suitability sites for location of water storage structure has been carried out with the prior knowledge of ranks and weightages assigned to the various features / themes as explained above. The thematic maps of (i) Slope map, (ii) Land Use and Land Cover, (iii) hydrologic soil group map, (iv) Drainage map and (v) Lineament map, alongwith well locations data obtained through GPS receiver spread over the study area, have been prepared on the scale 1:50000 using remote sensing data, and field investigations data, using ArcGIS software. From STER DEM 30m, a thematic percent slope map has been generated. SOI toposheets and IRS-R2 (LISS-IV) image has been used to prepare various thematic maps in ArcGIS environment.

Each theme provides certain clue regarding surface water occurrence, holding and recharge in study area, which is evident from the initial readings and study. These thematic layers, such as drainage map, soil map, land use land cover, slope, and lineament map etc. are used for multi-criteria or weighted overlay analysis by intersecting polygons. Using weighted overlay analysis a new integrated map indicating suitability sites for location of water storage structure is generated, which is integration of various feature classes from different thematic maps and combining all these features from various thematic maps into one map. Thus final composite map for suitability map for location of water storage structure sites is obtained showing class wise surface water storage for a watershed of the study area. According to their respective influence or prominence on surface water storage, various themes have been considered in assigning the final weightages to the layers in the form of polygons, during weighted overlay analysis, to integrate various thematic maps. Weighted overlay analysis is a GIS technique to be applied for divergent input themes to bring them into the unique convergent output. The suitability map for location of water storage structure sites (figure 9) has been generated through this weighted overlay analysis and has been categorized into three zones viz. ‘Low suitable’, ‘moderately suitable’ and ‘most suitable’, from groundwater recharge potential point of view. Flowchart showing methodology adopted for this study is represented as Figure 2.

TABLE 2: Land Resources use pattern of small watershed

S.NO	Land Use	Area	Percentage area
1	Forest	77302.7	71.2%
2	Barren land	190.2	0.2%
3	Current Fallow	3277.9	3.0%
4	Shallow Water	568.6	0.5%
5	Midland Paddy	3154.5	2.9%
6	Lowland Paddy	16549.7	15.2%
7	Deep Water	2185.9	2.0%
8	Settlement	4782.6	4.4%
9	Soybean	553.1	0.5%
	Total	108565.2	100.0%

Preparation of Thematic Maps

Land use land cover

The cloud free geocoded digital data of IRS-R2 (LISS-IV) in CD ROM was obtained from the NRSC Data Centre, Hyderabad. The imagery, which covers the watershed, was used in the study. Pixel based classification technique was used to classify the land under Nine Class. Area under different land use classes obtained after classification are given in the table 2.The results showed that there were 9 land use classes in the watershed with major part of the study area is dominated by Forest (77302.7 ha) which is 71% of the total area. This is followed by Lowland Paddy (16549.7 ha), which is 15.2% Midland Paddy (3154.5 ha), which is 2.9 % Soybean (553.1 ha), which is 0.5% current fallow (3277.9 ha) which is 3.0% of the total area Barren land (190.2 ha) which is 0.2% of the total area. Deep water body contributes 2.0% of the total area and Shallow Water body by 0.5% of the total area. Watershed is mainly multi cropped and paddy and soybean are the major crop during *kharif* season.

Slope

Slope is the degree of inclination of the surface from horizontal expressed in per cent or degrees. In survey of India toposheet the heights above MSL are shown by contours (lines of equal elevation), which also give an indication of the general topography and relief. Slope is one of the important terrain parameters, which can be explained by horizontal spacing of the contours. Slope can be calculated both in vector and raster forms. Slope is the change in gradient over a certain distance. The slope has been measured by taking a ratio of difference in contour interval to horizontal distance between contours. In general, closely spaced contours represent steeper slope and sparse contours exhibit gentle slope, whereas in the elevation output raster every cell has a slope value. Here, the lower slope values indicate the flatter terrain (gentle slope) and higher slope values correspond to steeper slope of the terrain. The slope values can be measured either in percentage or degrees.The slope map (Figure 4) was prepared using the contour information of survey of India topographical maps on 1:50000 scales with 10-meter contour interval. The different classes of slopes corresponding to their percentages were categorized in Table 3.

TABLE 3: Slope categories

Class	Percentage	Slope Category
1	0-1	Nearly level
2	1-3	Very gently sloping
3	3-5	Gently sloping
4	5-10	Moderately sloping
5	10-15	Strongly sloping
6	15-50	Very steep sloping

Soil

Soil data has been procured from National Bureau of Soil Survey & Land Use Planning, Nagpur. The same is converted to digital format using ArcGIS. For the study purpose it is required to group the various soil. As per USDA Natural Resources Conservation Services (NRCS) [9& 11], depending upon the infiltration and runoff potential, soil is categorized into four groups A, B, C & D known as Hydrologic Soil Group [HSG]. The various characteristics of HSG is shown in Table 4. The spatial extent of these soil groups is shown with the help of figure 5.

TABLE 4: Generic conditions for soil classification (according to the CN method)

Hydrological Soil	Type of soil	Runoff Potential	Final Infiltration Rate (mm/hr)	Remarks
Group A	Deep, well-drained sands and gravels	Low	>7.5	High rate of water transmission
Group B	Moderately deep, well-drained with moderately fine to coarse textures	Moderate	3.8-7.5	Moderate rate of water transmission
Group C	Clay loams, shallow sandy loam soils with moderately fine to fine textures	Moderately high	1.3-3.8	Moderate rate of water transmission
Group D	Clay soils that swell significantly when wet, heavy plastic and soils high water table with a permanent	High	<1.3	Low rate of water transmission

Lineament

Lineament involves fractures, faults and folds in identified in the study area. Lineament data is collected form Chhattisgarh Council of Science & Technology and the analyzed in GIS, creating a buffer of 100m around the lineaments. The lineaments are shown in figure 7.

Stream Order Map

Drainage map was prepared by using Survey of India Topographic maps on 1:50,000. All the streams existing in this Small watershed are marked in Figure 6. The entire area of the Small watershed is drained by river Maniari.The drainage pattern is typically dendritic and is controlled by initial slope. The drainage density is very high in the hilly areas of North and northeast indicating that the infiltration rate is low.The morphometric analysis has been done for this district and is given in Table 5. It can be seen that, there was a total of 3796 streamlets found in the entire Maniari Small watershed out of which 2865 streamlets are of 1st order, 659 are of 2nd order, 187 are of 3rd order, 66 are of 4th order, 15 are of 5th order and 4 are of 6th order . The total length of the streams was found to be 2819.54 km. Bifurcation Ratio of the area was found to be 3.09. Drainage density of the area was found to be 2.59 km/km^2 which was indicating high runoff potential of this watershed.

TABLE 5: Stream analysis of watersheds of Small watershed

SL.No	Sub Watershed	Number of Streams						Stream Length in Km					
		1st	2nd	3rd	4th	5th	6th	1st	2nd	3rd	4th	5th	6th
1	4G3F4n	8	4	1	1	0	0	7.08	22.9	3.52	0	0	50.53
2	4G3F4p	42	11	2	3	1	0	31.48	18.73	9.25	8.44	0	50.53
3	4G3F4q	74	16	6	1	1	0	48.22	21.17	17.12	0.51	0	50.53
4	4G3F4r	112	21	7	3	1	1	75.89	34.02	19.32	10.28	2.86	50.53
5	4G3F5a	91	25	10	3	2	2	66.61	21.16	18.2	10.2	6.5	68.33
6	4G3F5b	174	50	13	5	3	2	115.97	62.12	38.46	13.03	17.23	36.17
7	4G3F5c	173	31	8	6	2	1	98.13	33.05	23.1	20.9	6.53	17.79
8	4G3F5d	146	34	10	7	1	1	85.14	25.36	16.02	16.54	4.26	17.79
9	4G3F5f	120	27	4	1	2	2	78.78	22.31	19.12	3.1	15.87	36.17
10	4G3F5g	228	53	12	3	1	0	120.35	43.8	19.7	17.47	5.28	0
11	4G3F5h	454	92	30	11	2	0	222.89	65.09	54.5	18.06	12.49	0
12	4G3F5j	236	57	10	6	2	1	112.67	44.74	25.54	13.01	7.76	18.38
13	4G3F5k	259	59	14	6	1	1	147.65	51.87	17.32	9.67	9.37	18.38
14	4G3F5m	258	64	21	3	2	2	128.01	42.73	32.81	4.2	13.07	22.68
15	4G3F5n	225	44	13	5	4	0	98.66	37.44	21.42	5.01	11.23	0
16	4G3F5p	415	97	27	8	1	0	215.55	65.34	56.2	22.31	11.89	0
17	4G3F5s	91	20	7	1	1	0	47.12	26.95	9.71	1.39	50.53	0

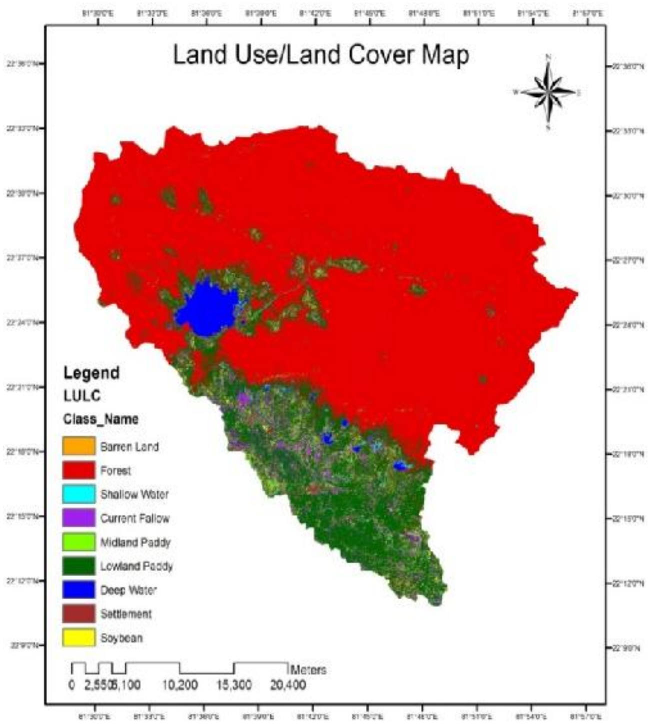

FIGURE 3: Land Use/Cover Map of the Agriculture watershed

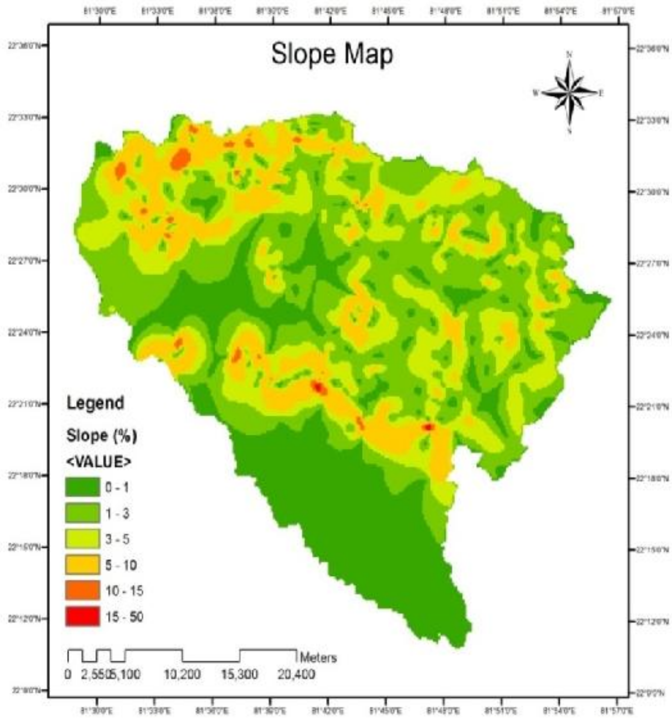

FIGURE 4: Slop map of the Small watershed

Weighted Overlay Analysis

To implement the rules laid by IMSD given in Table 1, number of information layers is prepared by overlaying the landuse, slope, hydrologic soil group stream order and lineament to match the criteria‟s laid. A Multi Criteria based analysis has been adopted for the identification of water storage structures (Prasad, *et al*., 2014 & Weerasinghe, *et al*., 2011). The generated layers are in vector format, for Weighted Overlay Analysis the "Rasterization" of each layer is performed. The first step of data conversion is "Rasterization" 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 1 to 3 is used in which „1‟ is for least suitable, „2‟ is for moderate suitable and „3‟ is for highly suitable. 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, the same is shown in Table 6. Further, in the Spatial Analyst Tool, Weighted Overlay Function has been processed for identification of the suitable area. Based on the Weighted Overlay Function a site suitability map is prepared and is shown in figure 8.

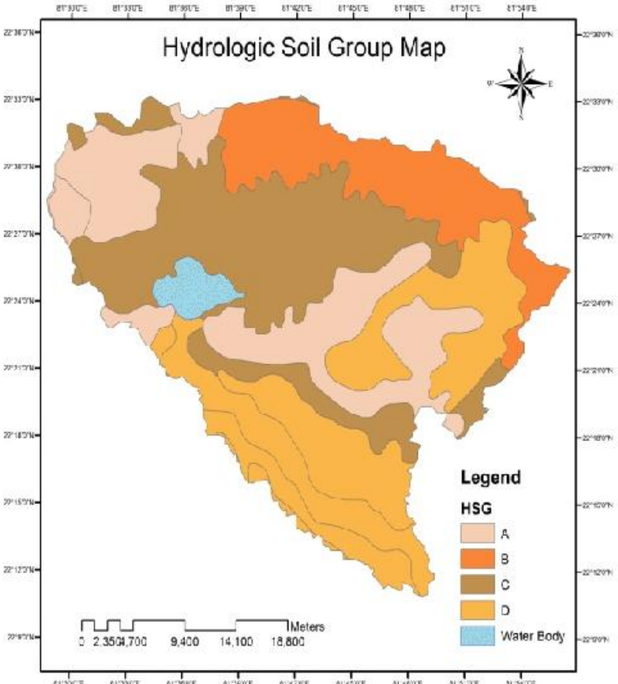

FIGURE 5: Hydrologic Soil Group Map of the Study Area

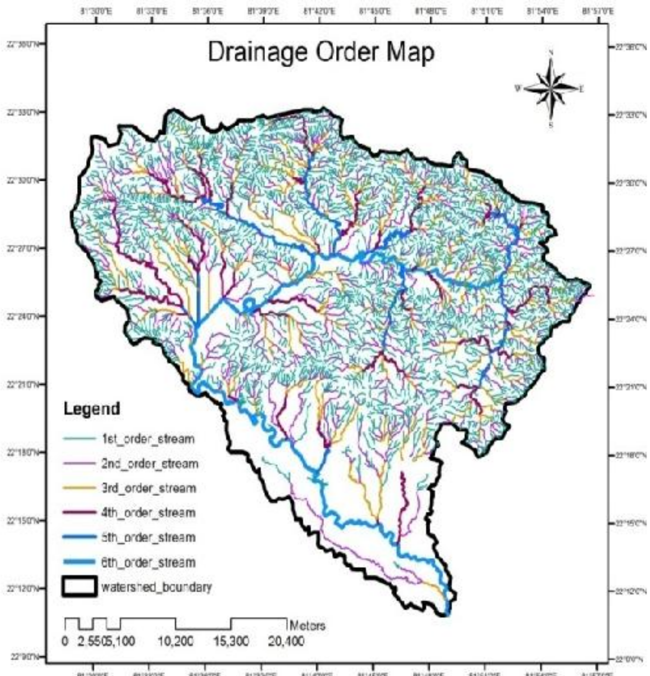

Figure 6: Drainage map of the Small watershed

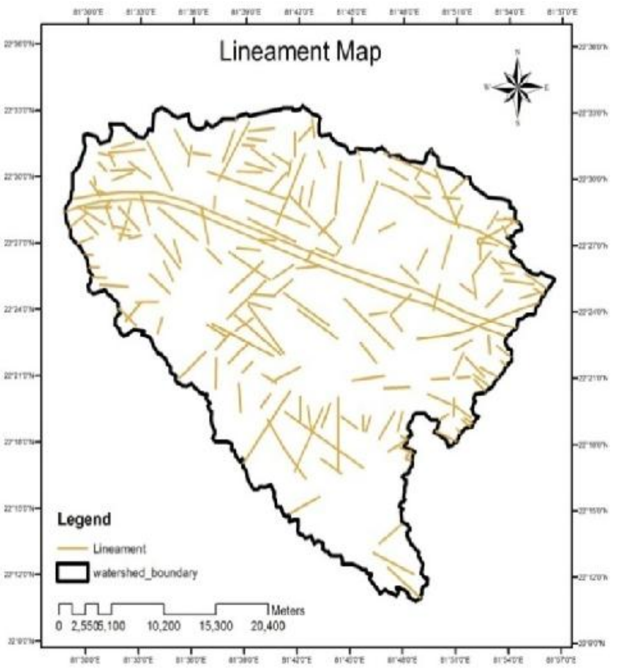

FIGURE 7: Lineament map of the Small watershed

TABLE 6. Weight and Scale Value given to Different layers

Parameter	Influence(%)	Feature Classes	Feature Weight
		Barren land	2
		Current Fallow	2
		Deep Water	2
		Forest	2
LULC	20	Lowland Paddy	3
		Midland Paddy	3
		Settlement	1
		Shallow Water	3
		Soybean	3
		Nearly level	3
Slope	25	Very gently sloping	3
		Gently sloping	2

		Moderately sloping	2
		Strongly sloping	1
		Very steep sloping	1
Soil	20	HSG Group D	3
		HSG Group C	2
		HSG Group B	1
		HSG Group A	1
Stream Order	20	1st Order	1
		2nd Order	1
		3rd Order	2
		4th Order	2
		5th Order	3
		6th Order	3
Lineament	15	Fault (100mBuffer)	1

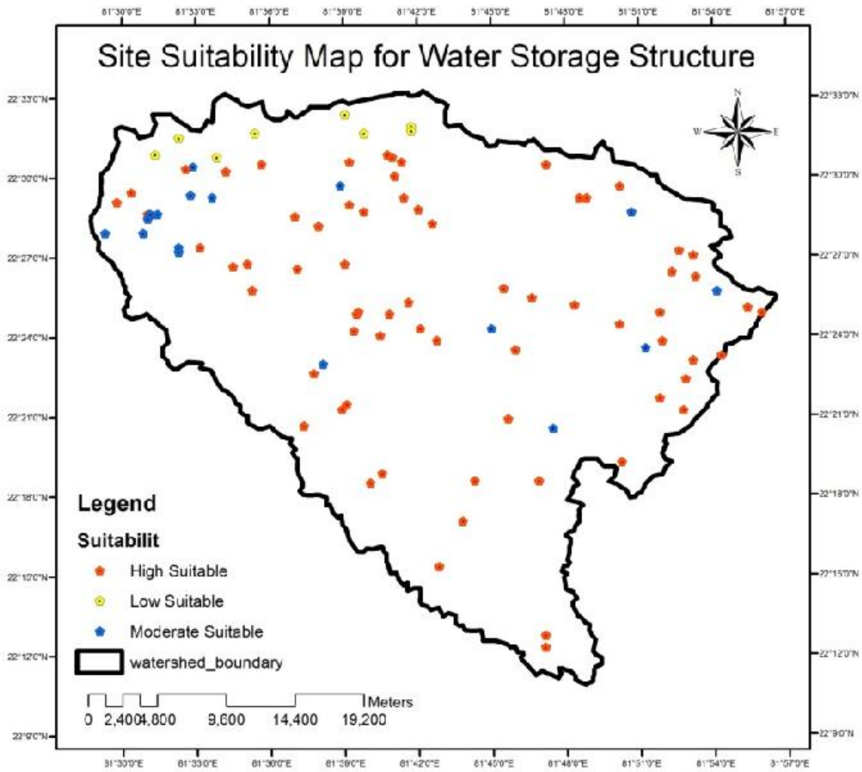

FIGURE 8: Site Suitability Map for Water Storage Structure in Small watershed

RESULT

The multi-layer integration through LULC, slope, soil (HSG), stream order lineament and settlement gave the suitability sites for identifying the water storage structures. These layers were combined in ArcGIS using weighted overlay tool. A final map was generated which provide us the suitable location for water storage sites, as per the criteria laid by IMSD. Figure 8 show the suitability map for location of water storage structure sites. There are about 93 numbers of sites identified, which are highly suitable for creating water storage structures.

CONCLUSION

Due to rapid urbanization in the study area, demand for water Consumption has increased at an unprecedented rate. Statistics on water availability in the study area has already revealed that water table has gone down remarkably in last 2-3 decades. Nevertheless, the area has sufficient potential to feed on the ever increasing demand of water if harvest and conserve properly. In the present study GIS has been extensively used in the determination of suitable locations for water storage structure. GIS can handle a large amount of spatial and non-spatial data (Ramkrishnan, *et al*., 2009).. Remote sensing data is especially used to derive the various physical parameters of the basin. The integration of Remote Sensing and GIS provides an appropriate approach for solving various water resources management problems.

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