JOURNAL GEOLOGICAL SOCIETY OF INDIA
Vol.94, November 2019, pp.515-524

Prioritization of Sub-Watersheds for Soil and Water Conservation in Parts of Narmada River through Morphometric Analysis Using Remote Sensing and GIS

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ABSTRACT

GIS-based prioritization of sub-watersheds of Hoshangabad and Budhni industrial area, Madhya Pradesh, India were carried out to describe the importance of morphometric parameters in the field of water and soil conservation. In the study, four sub-watersheds were prioritized through geomorphologic analysis for soil and water conservation. Topographic maps 55 F/9, 55 F/10 and 55 F/13 on scale 1:50,000 were used to evaluate the drainage characteristics of watershed. SRTM DEM data has been processed for slope analysis and delineation of sub-watersheds. LISS-III, IRS data was processed for land use/ land cover analysis. Soil map has been generated by processing of NBSS & LUP soil map. The various morphometric parameters evaluated in each sub-watershed includes drainage network, drainage geometry and texture analysis and relief parameters in ArcGIS. Each sub-watershed has been prioritized by assigning ranks using compound parameter. After prioritization, land use, soil type and slope classes of each sub-watershed were integrated to propose suitable soil and water conservation structures at appropriate places. It has been suggested that the proposed soil and water conservation structures must be executed on priority basis to reduce the adverse effect on the land and environment. The study shows that classification and prioritization of sub-watersheds are very relevant, supportive and useful in the watershed, where there is high diversity in agricultural practices, soil texture and land cover. Thus, priority wise execution of the proposed soil and water conservation structures will not only reduce the soil erosion but also increase the surface and groundwater availability in the area. Therefore, prioritization of these sub-watersheds is found very helpful for soil conservation and management of groundwater in the watershed.

INTRODUCTION

Morphometric analysis is the measurements and mathematical analysis of land surface configuration, shape and dimensions of landforms (Adinarayana et al., 1995). The efficiency of the drainage network is very important for understanding the processes of landform formation, soil physical properties and erosion characteristics (Malik et al., 2011; Okumura and Araujo, 2014, Rodrigo-Comino et al., 2016) as it determines the runoff discharge such as land management (Tavares et al, 2016; Keesstra et al., 2016; Masselink et al., 2017). The drainage network pattern, density and geometry of the flow systems are primarily controlled by three attributes including topography, climate and geology (Mesa, 2006). The characteristics of the drainage network reflect the effect of changing these determinants from one location to another (Pike, 2000; Aher et al., 2014; Aparna et al., 2015; Sindhu et al., 2015; Fenta et al., 2017;). In the last decade morphometric analysis of drainage networks has been widely used in various fields such as assessment of natural resources and environmental hazards, such as quick flooding (Arnous et al., 2011) assessment of groundwater potential, study of hydrologic behavior of watersheds (Esper Angillieri, 2008; Malik and Shukla, 2018) and prioritizing watersheds in order to protect water and soil resources (Singh et al., 2008; Yadav et al., 2014, 2018; Choudhari, et al., 2018).

Rapid growth in industrialization and wide expansion of urbanization has created a great pressure on land and water resources in India. About 53 % of the geographical area of the India is subjected to soil erosion and other forms of land degradation due to deforestation and other natural and anthropogenic activities (Biswas et al. 1999; Kumar et al. 2011). Therefore, there is great need for sustainable land and water management especially in the arid and semi-arid regions where there is inequity in demand and supply of water. In arid and semi-arid environment, watershed management is one of the best approaches for management of natural resources. The real challenge in planning and management of available natural resources at a small scale is due to requirement of high precision in data. Therefore, micro-level hydrological units i.e. sub-watersheds are chosen for improved planning and management approach by solving the key issues such as soil degradation, soil erosion, droughts and floods. Natural drainage system characteristics in the forms of morphology, topography, soil properties, etc. have direct impact on the site selection and execution of land and water conservation measures (Kumar et al., 2008). Thus, prioritization of micro-level watersheds is essential for development of land and water conservation measures. Prioritization of watershed is also very important for preparing a comprehensive plan for watershed conservation and management. Adaptation of soil conservation measures on priority wise will not only reduces the soil erosion but also increases the water availability at the surface and groundwater and will further reduces the possibility of droughts as well as floods. A number of studies were carried out on prioritization of watersheds based on morphometric analysis, geomorphology and sediment yield index (Khan et al. 2001; Nookaratnam et al. 2005; Thakkar and Dhiman 2007; Srinivasa Vittala et al. 2008; Javed et al. 2009; Kumar et al. 2011), thus, prioritization of sub-watersheds will help in efficient adoption and allocation of the resources on the priority basis.

The prioritization concept is helpful to understand the geomorphology of individual sub-watersheds (Haing et al. 2008; Javed et al. 2011; Brooks et al. 2006; Strahler 1957), whereas GIS technique integrated with other spatial data is useful in positioning the ideal sites for soil conservation measures and water harvesting structures (Gupta et al. 1997; Kumar et al. 2008; Chowdary et al. 2009; Makwana and Tiwari, 2016). Hence, it is mandatory to prioritize the sub-

0016-7622/2019-94-5-515/$ 1.00 © GEOL. SOC. INDIA | DOI: 10.1007/s12594-019-1349-8

watersheds lying in the main watershed for the better understanding of the watershed characteristics (Patel et al., 2013).

The present study is focused on prioritization of sub-watersheds based on the evaluated morphometric parameters for conversation of soil and water in delineated sub-watersheds in the basin. Furthermore, prioritization of watershed using geospatial data and GIS techniques and geomorphological analysis such as land use/ land cover, soil type and slope analysis were also utilized to propose the suitable soil and water conservation measures in the basin.

STUDY AREA

The study area covers parts of Hoshangabad and Budhni industrial area of Narmada river basin. The area is located between Latitude: 22°42'00"- 22°53'00" N Longitude 77°31'00"- 77°47' 00" E. The area is falling in survey of India topographic sheet Nos. 55 F/9, 55 F/10 and 55 F/13. The average elevation of the basin is 278 meters. The climate of the area is generally moderate to dry hot. The highest temperature is 42ºC reaching in May and lowest 5°C in January and the rainfall is between 1300 to 1450 mm mostly receiving during monsoon season. The average rainfall of the district is 1343.6mm. The area is very good for agriculture because of presence of thick black cotton soil cover. Soybean, wheat, pulses, rice, sugarcane are the major crops (Mandloi, 2014). Location map of the area is presented in Fig.1.

MATERIALS AND METHODS

The study of morphometric analysis and their mathematical calculation has been carried out to study the hydrological behavior of watershed and the sub-watersheds (SW). Morphometric analysis provides information regarding the soil permeability, erosion potential, and surface runoff of the basin. In the present study, an integrated approach of digital elevation model (DEM) and Survey of India topographic sheets were utilized for extraction of various drainage parameters. The analysis was performed in GIS platform using a digital elevation map in order to illustrate the characteristics of the drainage basin and topography.

The following process has been followed during the course of study.

A. Survey of India (SOI) topographic sheet No's 55-F-9, 55-F-10, 55-F-13 and 55-F-14 were first Geo-referenced and geometrically rectified by taking ground control points using UTM projection and WGS 84 datum. Furthermore, all Geocoded topographic sheets were mosaic in ERDAS Image processing software.

B. The catchment area of each sub-watershed has been delineated from Survey of India topographic sheets by using data preparation option of ERDAS Image software by making AOI (Area of Interest) of the basin.

C. Arc GIS Software used for digitization of the contour and drainages of all orders from topographic sheets by numerical calculation using the formulas given by Horton, Schumm and Strahler.

DIGITAL ELEVATION MODEL (DEM)

Shuttle radar topographic mission (SRTM) DEM with resolution of 90 m acquired through shuttle radar topographic mission of the area has been downloaded from USGS Earth explorer web was used to study the drainage characteristics and topography of the basin. SOI topographic sheets have been used for extraction of drainage network and delineation of the sub-watersheds. SRTM Digital Elevation Model along with sub-watersheds delineated in the area is presented in Fig. 2. An elevation map of the area has been prepared by digitization of

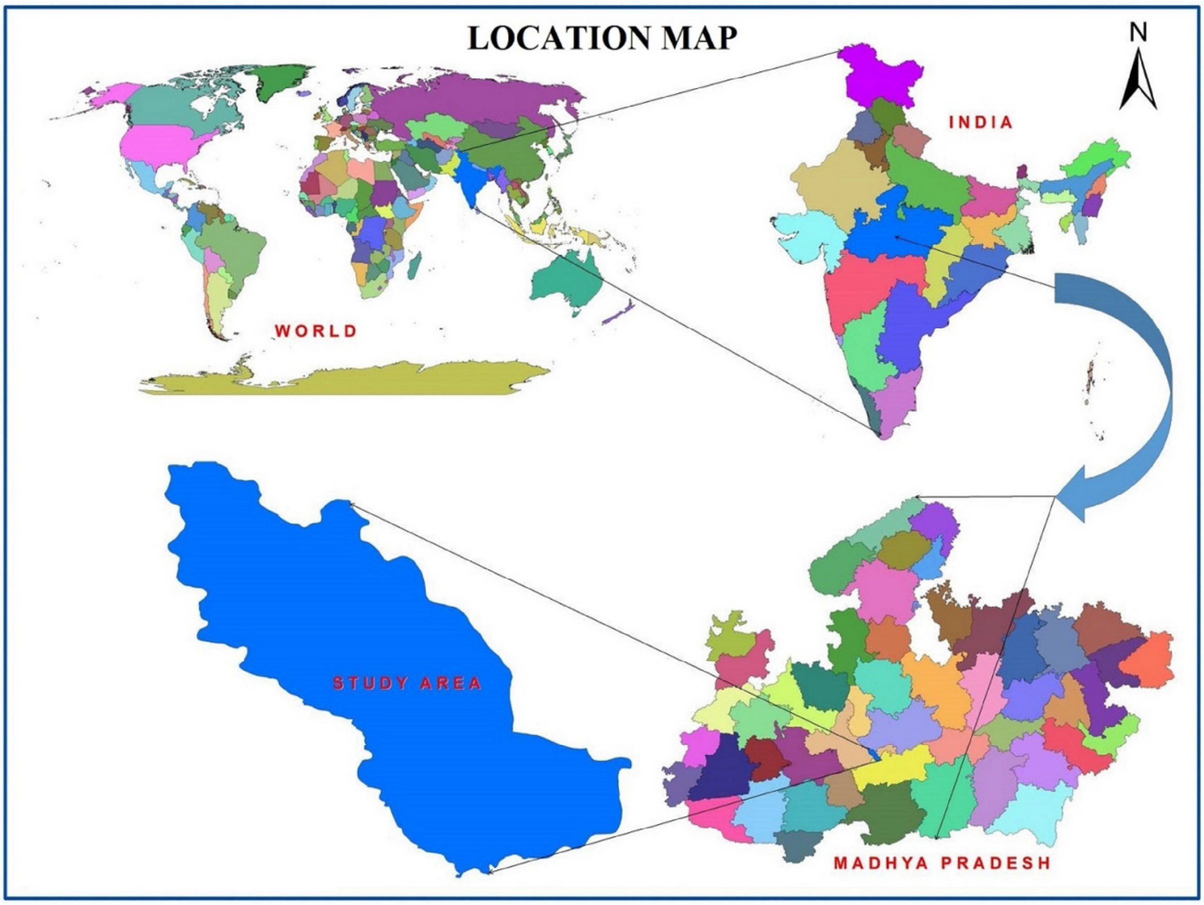

Fig.1. Location map.

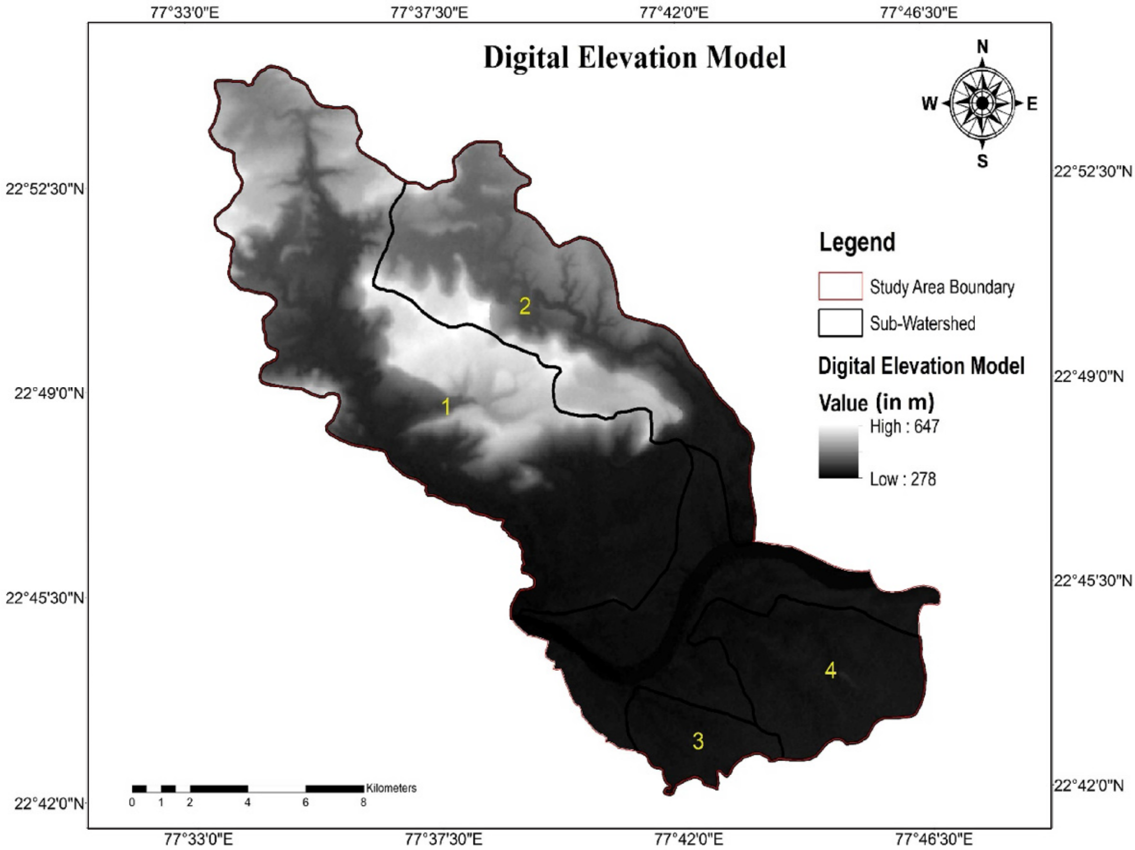

Fig.2. SRTM Digital Elevation Model.

contours from topographic sheets in ArcGIS. The highest contour is 660 m and lowest is 260 m with contour interval of 20 m in the area. The close spacing of contours represents the elevated parts of the area. The area forms a low elevated basin. Contour map of the area is presented in Fig. 3.

Land use/land cover Analysis

LISS-III remote sensing imagery with spatial resolution 23.5 m has been downloaded from www.nrscbhuwan a data source web of National Remote Sensing Centre (NRSC). The imagery was processed for land use/land cover analysis using ArcGIS software. The major land use classes derived from the imagery includes (1) Agriculture land, (2) Built-up (3) Forest, (4) Barren and (5) water body. Major part of the area is occupied of forest cover followed by agricultural (Fig.4).

Soil Map

Soil map of the area has been derived from National Bureau of Soil Survey & Land Use Planning (NBSS & LUP, ICAR 1998) Nagpur. The processing of the map was done using GIS and two main soil classes has been extracted from it viz; fine loamy and loamy skeletal. The soil texture obtained for the area is clayey loam and fine loamy soil (Fig.5).

Slope Map

The slope is generally mapped in three ways slope angle, slope

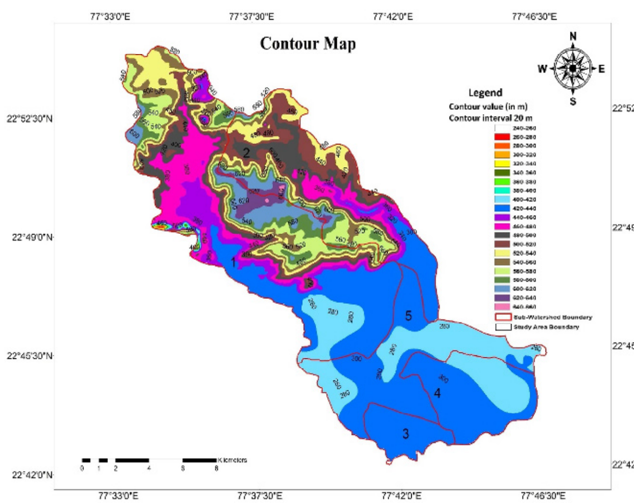

Fig.3. Contour Map

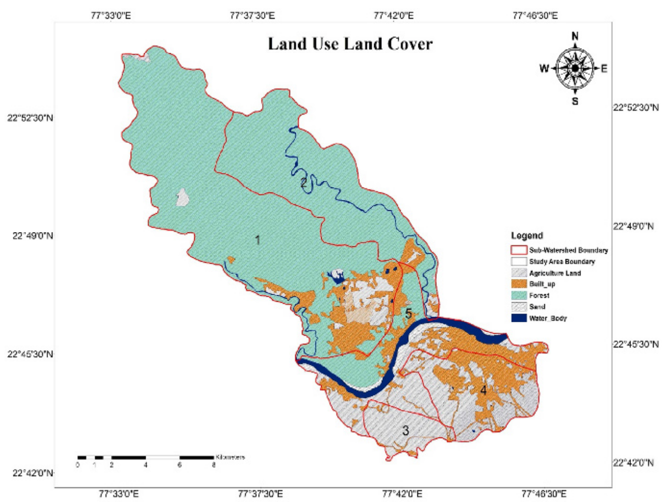

Fig.4. Land Use/Land Cover Map

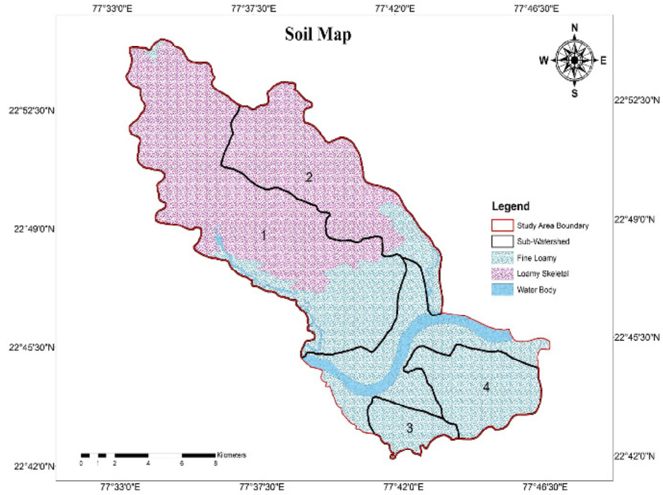

Fig.5. Soil Map

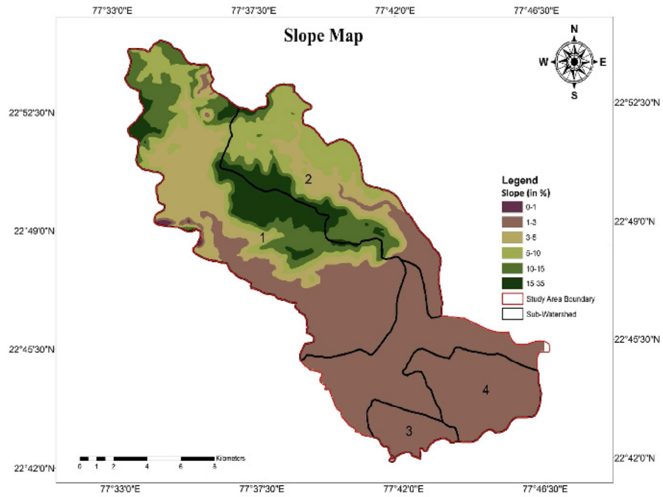

Fig.6. Slope map.

form and slope morphology. In the study, slope of the area has been extracted from SRTM DEM data using the spatial analysis tool in ArcGIS. Slope map of the area has been prepared and presented in Fig.6. Slope varies from 0–35 % which was further divided into six sub-classes. Slope in each class varies from 0–1%, 1–3%, 3–5%, 5–10%, 10–15% and 15–35 %.

RESULT AND DISCUSSION

Morphometric Analysis

Survey of India topographic sheets No's 55-F-9, 55-F-10, 55-F-13 and 55-F-14 were processed to extract the drainage network and other morphologic parameters within GIS environment. The basic parameters which were computed during the study include stream length, area, perimeter, number of streams and basin length derived from the drainage layer using GIS environment. The morphometric parameters of all sub-watersheds have been calculated based on the formula suggested by Horton (1945), Schumm (1956) and Miller (1953). In the study, total 19 morphometric parameters viz; stream number (U), stream length (Lu), mean stream length (Lsm), ltream length ratio (RL), bifurcation ratio (Rb), basin area, perimeter, circulatory ratio (Rc), elongation ratio (Re), compactness constant (Cc), form factor (Ff), basin length, drainage density (Dd), dtream frequency (Fs), constant of channel maintenance (C), texture ratio (T), basin relief (Bh), relief ratio (Rr) and ruggedness number (Rn) were considered for watershed prioritization. The linear parameters such as drainage density, length of overland flow have direct relationship with erosion, i.e. higher is the ratio of linear parameters; more is the erosion (Nookaratnam et al. 2005; Patel et al. 2013). Shape parameters such as elongation ratio, compactness coefficient and circularity ratio and form factor have an inverse relationship with erosion (Javed et al. 2009), i.e. lower values of these shape parameters result in higher erosion and vice versa. Ranking has been assigned based on every single parameter, the ranking values for all linear and shape parameters of each sub-watershed were added for each of the sub-watersheds to the compound parameter. Based on average value of these parameters, the sub-watersheds having the least rating value was assigned highest priority, next higher value was assigned second priority and so on. Standard formulas given by Horton, et al. 1945 were followed for calculation of various morphometric parameters of each sub-watershed. The details of areal, linear and shape parameters and their role in watershed prioritization are discussed below.

Drainage Network

Drainage network is formed by a number of streams of different orders. A first order stream combines with other stream of first order and forms second order stream. Similarly, a second order stream merges with other second order and forms 3rd order and so on. Drainage network helps in delineation of sub-watersheds. It also provides information about relief, runoff and permeability of material. Drainage map of the area has been prepared by digitization of drainages from Survey of India (SOI) topographic sheet Nos. 55F/9, 55F/10, 55F/13 and 55F/14 using ArcGIS software. The watershed forms a 5th order drainage basin and exhibits dendritic type of drainage pattern. Drainage map with stream orders is shown in Fig. 7. The watershed has been divided into four sub-watersheds (SWs) namely as SW1, SW2, SW3 and SW4 and an unclassified watershed has been delineated because of non development of drainages in it (Fig. 8).

Stream Number (Nu)

It is the number of stream segment of various orders and is inversely proportional to the stream order. The number of the stream segments is decreasing with increasing stream order. Stream order *vs* stream number relationship is shown in Fig.9. The dense streams are signature of impermeable medium and poor infiltration. In each sub-watershed the maximum frequency was found in 1st order streams (Table 1). In each sub-watershed there is a decrease in stream frequency as stream order increases. Stream order *vs* stream length relationship is shown in Fig.10.

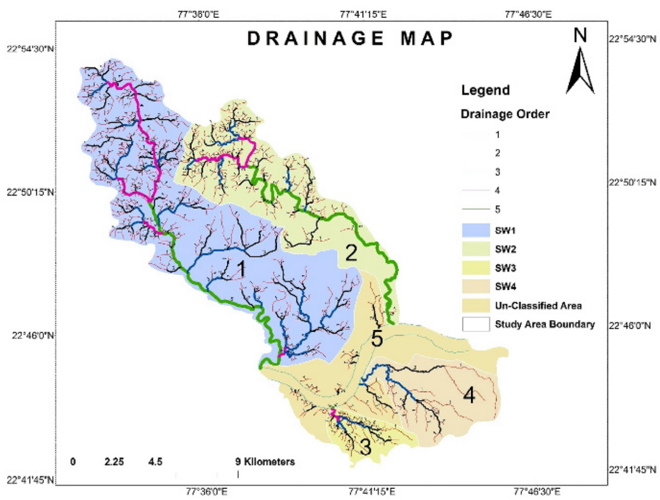

Fig.7. Drainage Map

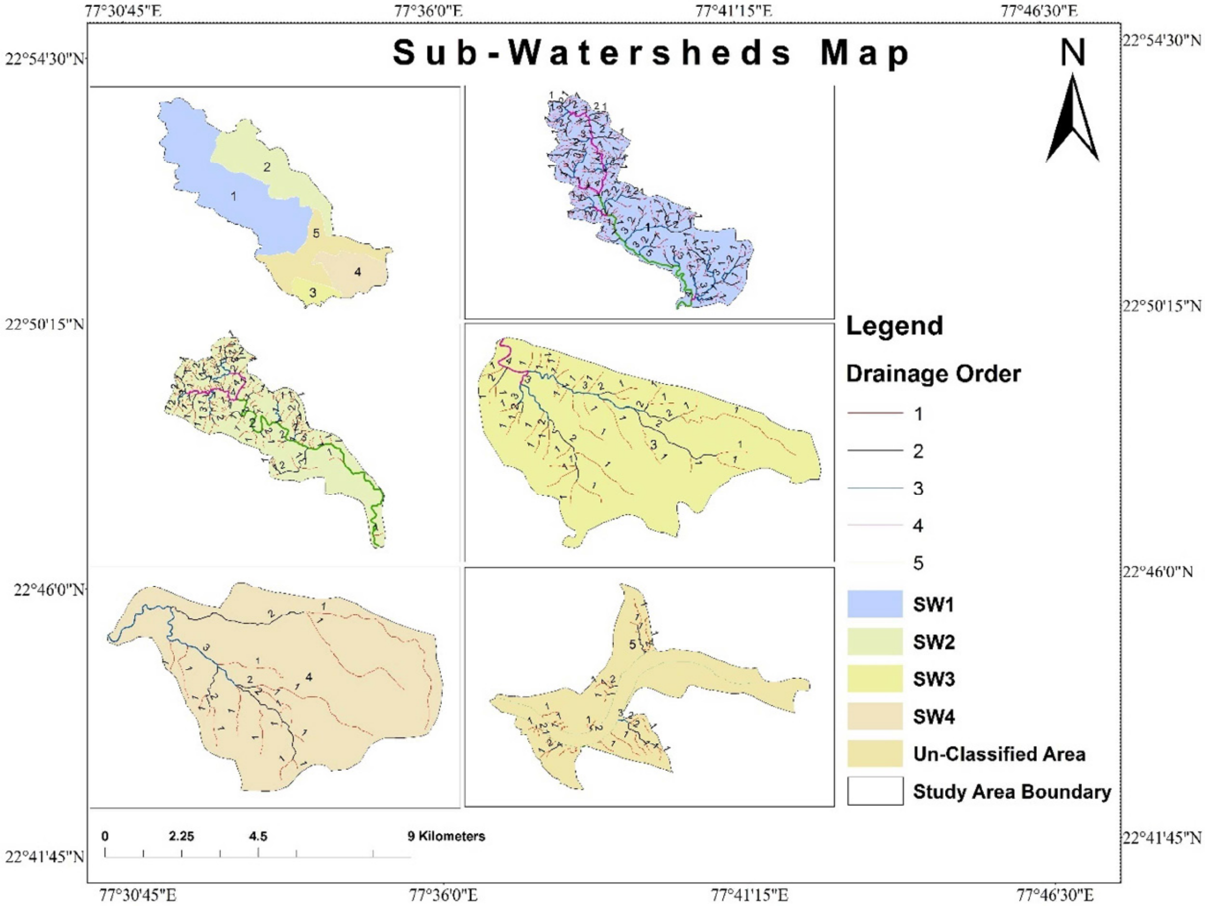

Fig.8. Sub-Watersheds Drainage Map

Stream Order (u)

The geomorphological analysis of a drainage basin is the position of stream order used for the watershed study. A stream that engenders at a source is defined as the first order stream. When two streams of the first order join at a point a 2nd order stream is formed. In the present study, ranking of streams has been carried out based on the method proposed by Strahler (1964). The watershed has been divided into four sub-watersheds namely as SW1, SW2, SW3 and SW4. Stream orders in the watershed are classified up to 5th orders. SW1 and SW2 exhibits Vth order drainage pattern; SW3 exhibits IVth order, while SW4 represents IIIrd order drainage pattern. Stream order and stream number computed is given in Table 1 and 2.

Table 1. Basic Parameters of Sub-Watershed

Sub-Watershed (SW)	Stream Order					Total stream length (km)
	I	II	III	IV	V	
SW1 No. of Stream Stream Length (km)	 262 140.64	 67 53.53	 17 28.99	 4 14.30	 1 16.16	253.62
SW2 No. of Stream Stream Length (km)	 145 66.46	 30 19.60	 8 7.92	 2 6.49	 1 19.71	120.18
SW3 No. of Stream Stream Length (km)	 38 17.90	 9 4.61	 3 3.29	 1 1.34	 0 0	27.14
SW4 No. of Stream Stream Length (km)	 17 23.04	 4 7.81	 1 5.34	 0 0	 0 0	36.19

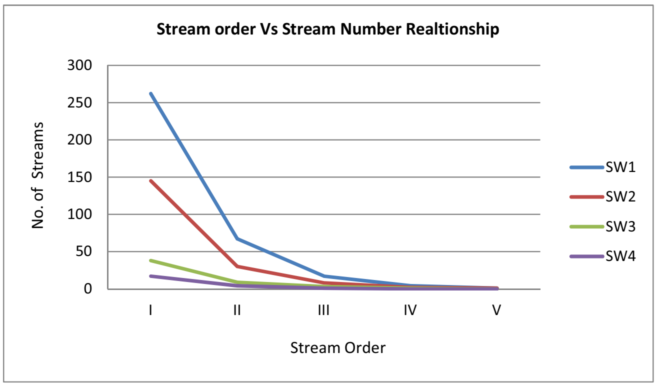

Fig.9. Stream order Vs Stream No. Relationship

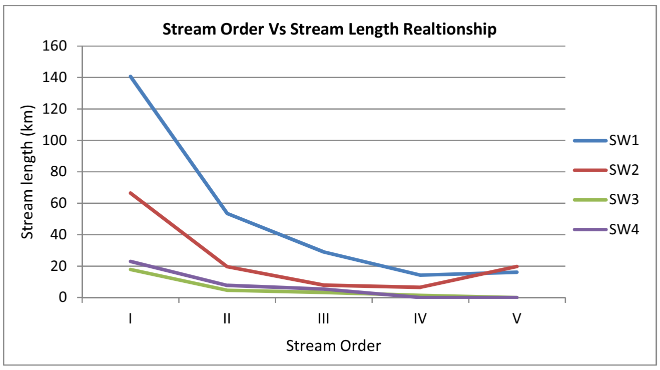

Fig.10. Stream order vs. Stream length Relationship

Stream Length (Lu)

Stream lengths delineate the total lengths of stream segment of each of the successive orders in a basin tend to approximate a direct geometric series in which the first term is the average length of the stream of the first order (Horton, 1945). In the study, stream lengths of the various segments were measured with the help of Arc GIS software. In each sub-watershed total length of stream segments is higher in first-order and decreases as the stream order increases. The total length of streams calculated in SW1 is 253.62 km, 120.18 km in SW2, 27.14 km in SW3 and 36.19 km in SW4. The result of order-wise stream length in each sub-watershed is given in (Table 2).

Mean Stream Length (Lsm)

The mean stream length is a characteristics property related to the drainage network and its associated surface. Mean stream length (Lsm) has been calculated by dividing the total stream length (Lu) of order 'u' by the total number of streams (Nu) of order 'u'. The mean stream length (Lsm) calculated is 0.72 for SW1, 0.64 for SW2, 0.53 for SW3 and 1.6 for SW4. This implies variations in slope and topography (Horton, 1945).

Formula: Lsm = Lu/Nu

Stream Length Ratio (R_L)

Stream length ratio (R_L) is characterized as the ratio of the mean stream length of the one order to the next lower order of stream segment. Stream length segments of each of the successive orders of a basin has tendency to be a direct geometric series with streams length increasing towards higher streams (Horton, 1945). The stream length ratio between the streams of different orders in each sub-watershed shows a minor change. This change might be attributed to variation in slope and topography. The stream length ratio calculated in each sub-watershed is given in Table 2.

Formula: R_L = Lu/ (Lu/-1)

Bifurcation Ratio (Rb)

It is the ratio of the number of streams of given order 'u' to the number of streams of higher order 'u+1'. Rb is indicative of shape of the basin. An elongated basin is likely to have high Rb, whereas a circular basin is likely to have a low Rb (Schumm, 1956). Thus, from the obtained values of Rb, SW1 exhibits elongated shape, whereas SW2 is nearly elongated, SW3 and SW4 are nearly circular in shape. In the study bifurcation ratio of each sub-watershed were calculated which varies from 3.22 in SW1, 2.92 in SW2, 2.56 in SW3 and 2.75 in SW4. The mean bifurcation ratio (Rbm) is defined as the average of bifurcation ratios of all orders. The mean bifurcation ratio calculated for the watershed is 2.86 (Table 2). The higher values of Rb are signature of strong structural control in the drainage pattern, whereas the lower values indicate that the sub-basins are less affected by structural disturbances.

Formula: Rb = Nu/Nu+1

Drainage Geometry

Basin length (Lb)

The stream length is a significant morphometric parameter of the drainage basin as it helps in the calculation of drainage density (Schumm 1956). The basin length is maximum in SW1 and minimum in SW 3. Basin length varies from 27.54 km in SW1, 24.78 km in SW2, 6.02 km in SW3 and 8.59 km inSW4 (Table 3).

Basin Perimeter (P)

The basin perimeter is correlated with basin area, i.e., increase in the perimeter results in an increase in the basin area (Schumm, 1956). In the study, this hypothesis is tested and has been confirmed by the obtained results given in Table 3. The basin perimeter calculated varies from 62.06 km in SW1, 42.87 km in SW2, 21.88 km in SW3 and 14.90 in SW4.

Basin Area (A)

The area of the watershed is another important parameter like the stream length. The relationship between the total watershed area and the total stream length is supported by the contributing areas (Schumm 1956). Basin area of each sub-watershed were calculated which varies from 100.05 km^2 in SW1, 48.39 km^2 in SW2, 8.95 km^2 in SW3 and 23.80 km^2 in SW4 given in (Table 3).

Compactness Coefficient (C_c)

Compactness coefficient has been calculated as the ratio between basin perimeters to the perimeter of a circle to the same area of the watershed (Horton 1945). It denotes the relationship between actual hydrologic basins to the exact circular basin having the same area as that of the hydrologic basin. The *Cc* calculated for the study area varies from 0.36 in SW1, 0.94 in SW2, 0.18 in SW3 and 0.36in SW4 (Table 3). It is directly proportional to the erosion risk assessment factor. Lower values of *Cc* signify less vulnerability risk factors, while higher values indicate great vulnerability and represents the need for implementation of conservation measures.

Formula: $C_c = 0.2821\times P/ A^{0.5}$

Form Factor (F_f)

It is the ratio of basin area (A) to the square of the maximum length of the basin L_b. It is dimensionless property and is used as a

Table 2. Drainage Characteristics of Sub-Watersheds

Sub-Watershed (SW)	Total No. of Streams (Nu)	Total Stream Length (Lu)	Mean Stream Length (Lsm)	Stream Length Ratio (RL)	Bifurcation ratio (Rb)	Mean Bifurcation ratio (Rbm)
SW-1	351	253.62	0.72	1.007	3.22	2.86
SW-2	186	120.18	0.64	1.008	2.92	
SW-3	51	27.14	0.53	1.038	2.56	
SW-4	22	36.19	1.6	1.028	2.75	

Table 3. Drainage Geometry

S. No.	SW	Basin Area (km^2)	Perimeter (km^2)	Circulatory Ratio (Rc)	Elongation Ratio (Re)	Compactness Constant (Cc)	Form Factor (Ff)	Basin Length (km)
1.	SW1	100.05	62.06	0.33	0.39	0.36	0.13	27.54
2.	SW2	48.39	42.87	0.33	0.31	0.94	0.08	24.78
3.	WS3	8.95	21.88	0.23	0.56	0.18	0.25	6.02
4.	SW4	23.80	14.90	0.35	0.63	0.36	0.32	8.59

quantitative expression of the shape of basin (Horton 1945). High form factor normally forms circular shape of the basin and has high peak flow in short duration, while elongated basin with low form factor has low peak flow in long duration. Low form factor values have been obtained in all sub-watersheds. Form factor value calculated varies from 0.08 to 0.32 which indicates the elongated circular shape and suggesting flatter peak flow with longer duration. Form factor values of each sub-watershed calculated are given in Table 3.

Formula: $F_f = A/L^2$

Elongation Ratio (R_e)

It is defined as the ratio between the diameters of a circle with the same area as that of the basin to the maximum length of the basin (Schumm 1956). The elongation ratio calculated varies from 0.39 in SW1, 0.31 in SW2, 0.56 in SW3 and 0.63 in SW4. Elongation ratio close to 1.0 is typically region of very low relief whereas that of 0.6–0.8 is associated with high relief and steep ground slope (Strahler 1964). Elongation values can be grouped into three categories >0.9 circular, 0.9–0.8 oval and <0.7 elongated. The obtained elongation ratios of each sub-watershed are <0.7 thus represents the elongated shape of the basin.

Formula: $R_e = 2(A/p)^2/Lb$

Circulatory Ratio (R_c)

It is the ratio of the SW area and the area of a circle of the SW perimeter (Pr) (Miller 1953). Circulatory ratio of each SW has been calculated and varies from 0.33 in SW1 and SW2, 0.23in SW3 and 0.35 in SW4 (Table 3). The maximum circulatory ratio 0.35 was observed in SW4 and represents the nearly circular shape of the sub-watershed.

Formula: $R_c = 4pA/P_2$

Drainage Texture Analysis

Drainage density (D_d)

Drainage density is one of the most important indicators of the linear scale of landform in stream eroded topography and is defined as the ratio of total length of the streams of all order of watershed to the total area of the watershed (Horton 1945). Drainage density also gives an idea of the physical properties of the underlying rocks of the area. Drainage density in the area various varies from 2.53 km/ km^2 in (SW1) 2.48 km/ km^2, in (SW2) 3.04 km/ km^2 in (SW3) and 1.52 km/ km^2 in (SW4) representing medium to high drainage density (Table 4). Low drainage density generally results in areas of permeable sub-soil material, dense vegetation, low relief and coarse drainage texture (Nag, 1998). High drainage density is resultant of impermeable subsurface medium, sparse vegetation, mountainous relief and fine drainage texture.

Formula: $D_d = Lu/A$

Stream Frequency (F_s)

Stream frequency is the number of streams per unit area of the basin. It mainly depends upon the lithology of the basin and reflects the texture of the drainage network (Horton 1945). Low values of stream frequency indicate presence of a permeable sub-surface material and low relief. In the study, each sub-watershed is showing a different stream frequency value. Higher stream frequency was observed in SW1, SW2 and SW3 which represents impervious sub-surface media with high relief, whereas low stream frequency was resulted in SW4 and represents the porous sub-surface media with low relief. The stream frequency values computed are given in (Table 4).

Table 4. Drainage Texture Analysis

Sub-Watershed	Drainage Density (Dd) km/ km^2	Stream Frequency (F_s) Number/km^2	Constant of Channel Maintenance (C)	Texture Ratio (T)
SW1	2.53	3.51	0.40	5.66
SW2	2.48	3.84	0.40	4.33
SW3	3.04.	5.70	0.33	2.33
SW4	1.52	0.92	0.66	1.48

Formula: $F_s = Nu/A$

Relief Characteristics

Relief Ratio (Rr)

Relief ratio is the ratio of maximum relief to the horizontal distance along the longest dimension of the basin parallel to the principal drainage line is termed as relief (Schumm 1956). Difference in the elevation between the highest point of a basin and the lowest point on the valley floor is termed as the total relief of that river basin. Relief ratio of each sub-watershed was computed which varies from 0.02, in SW1 0.02, in SW2, 0.17 in SW3 and 0.12 in SW4 (Table 5). Low value of relief ratios is mainly due to the resistant basement rocks of the sub-watershed and low degree of slope.

Formula: $Rr = R/L$

Ruggedness Number (Rn)

It is the product of maximum basin relief (B_h) and drainage density (D_d), where both parameters are in the same unit. An extremely high value of ruggedness number occurs when both variables are large and the slope is not only steep but long as well (Strahler 1964). In the study, ruggedness number of each sub-watershed were computed which varies from 0.17 in SW1, 0.19 in SW2 0.33 in SW3 and 0.33 in SW4 (Table 5). The low values of ruggedness number resulted reveals that the area is moderately rugged.

Formula: $Rn = R*D_d$

Table 5. Relief Characteristics

Sub Watershed	Basin Relief (B_h)	Relief Ratio (R_r)	Ruggedness (R_n)
SW1	0.44	0.02	0.17
SW2	0.47	0.02	0.19
SW3	1.0	0.17	0.33
SW4	1.0	0.12	0.33

Prioritization of Sub-watersheds Based on the Calculated Morphometric Parameters

Prioritization of sub-watersheds has been done based on the calculated morphometric parameters of the watershed. The compound parameter value of each sub-watershed has been calculated and their prioritization ratings were assigned which is given in Table 6. Sub-watershed 1 with compound parameter value of 5.92 and sub-watershed 2 with a compound parameter value of 6.72 has been given the highest priorities. High priority rank indicates the high degree of erosion and surface runoff potential associated in the particular sub-watershed and has been considered as potential area for adaptation of soil and water conservation structures. Therefore, in the watershed sub-watershed 1 and 2 has assigned first and second priority rank. Thus, the proposed suitable soil and water conservation structures must be executed in these sub-watersheds based on their priority rank. This prioritization study of the watershed will help in enhancement of the groundwater recharge and protection of top fertile soil cover in the basin.

Table 6. Priorities of sub-watersheds and their Ranks

Parameters	Parameter Name	SW-1	SW-2	SW3	SW-4
Drainage Network	Stream No. (U)	351	186	51	22
	Stream Length (Lu)	253.62	120.18	27.14	36.19
	Mean Stream Length (Lsm)	1.38	1.54	1.88	1.028
	Stream Length Ratio (RL)	1.007	1.008	1.038	1.028
	Bifurcation ratio (Rb)	3.22	2.92	2.56	2.75
Drainage Geometry	Basin Area (km^2)	100.05	48.39	8.95	23.80
	Perimeter (km^2)	62.06	42.87	21.88	14.90
	Circulatory Ratio (Rc)	0.33	0.33	0.23	0.35
	Elongation Ratio (Re)	0.39	0.31	0.56	0.63
	Compactness Constant (Cc)	0.36	0.94	0.18	0.36
	Form Factor (Ff)	0.13	0.08	0.25	0.32
	Basin Length	27.54	24.78	6.02	8.59
Drainage Texture	Drainage Density (Dd) km/ km^2	2.53	2.48	3.04	1.52
	Stream Frequency (F_s)	3.51	3.84	5.70	0.92
	Constant of Channel Maintenance (C)	0.40	0.40	0.33	0.66
	Texture Ratio (T)	5.66	4.33	2.33	1.48
Relief Charac-teristics	Basin Relief (B_h)	0.44	0.47	1	1
	Relief Ratio (R_r)	0.02	0.02	0.17	0.12
	Ruggedness (R_n)	0.17	0.19	0.33	0.33
	Compound Parameter value	812.57	22.05	6.72	5.92
	Final Priority	4	3	2	1

Land Use and Soil Analysis

In the study besides prioritizing the sub-watershed using geomorphological analysis, effect of land use and soil type were also considered to propose appropriate locations for the conservation of soil and water in the area. Different type of land use and soil texture analysis in each sub-watershed of the area is presented in Table 7. It can be observed that all these sub-watersheds not only vary significantly in terms of size but also contain high variability in terms of different land use and soil classes.

Table 7. Land use and soil classes of sub-watersheds

	Land use class				Soil class			
SW No.	Water Bodies (km^2)	Agri. Land (km^2)	Forest (km^2)	Built-up (km^2)	Sand (km^2)	Fine Loamy (km^2)	Loamy Skeletal (km^2)	Water Body (km^2)
SW-1	0.91	6.13	82.80	11.61	0.0	25.83	72.94	1.08
SW-2	1.28	0.72	44.84	1.43	0.0	7.10	40.76	0.41
SW-3	0.0	8.21	0.0	0.71	0.0	8.92	0.0	0.0
SW-4	2.46	13.73	0.0	10.02	0.0	23.74	0.0	0.0

Proposed Soil and Water Conservation Structures

Priority of the sub-watersheds has been assigned as per the calculated various morphometric parameters. Further, soil type, land use/land cover, topography and drainage network has been utilized to propose suitable soil and water conservation structures in the basin. It has been seen that sub-watersheds 1and 2 are highly vulnerable for soil erosion because of high relief, high drainage density, surface runoff and sparse vegetation, thus was given high priority for soil and water conservation measures. As per soil and slope analysis sub-watershed 1 and 2 are characterized with loamy to loamy skeletal soils and have steep slope varies from 5–35 % occupied the north western parts of the basin. Further, it has been observed that sub-watershed 3 and 4 are dominant of fine loamy soils with gentle to plain topography occupied the south east part of the basin. The slope of SW3 and SW4 varies from 0-3%. Thus, followed the geological and topographical conditions and criteria of CGWB suitable water and soil conservation structures were proposed to be executed at necessary places of the watershed. Furthermore, interpretation of satellite data was done for recognition of the already existing artificial recharge structures in the area. The existing water conservation structures verified in the area includes, check dam, stop dam and gully plug found. Thus, based on the above given criteria development of suitable water and soil conservation structures has been proposed at the appropriate sites of the watershed. In sub-watershed 1 and 2 Nala bunds are proposed which should be constructed across bigger Nala of second order streams at gentle slopes. A Nala bund acts like a mini percolation tank. Gully Plugs are small runoff conservation structures built across small guiles and streams to conserve runoff and enhance recharge locally during the rainy season. Gully plug structures have also been proposed to construct at convergence point of 1st and 2nd order streams. Percolation tanks are most prevalent structures to recharge the groundwater reservoir both in alluvial as well as hard rock formations. The efficacy and feasibility of these structures are more in hard rock formation where the rocks are highly fractured and weathered. Percolation tanks and contour bund has been proposed as suitable soil and water conservation measures at some places in the basin. Sub-watersheds 3 and 4 possessing gentle to plain topography, covered with think Narmada river fluvial deposits where percolation tank structures have been proposed to be constructed to enhance the infiltration water. At these plain topographical and fertile areas agriculture practices are dominant, crop pattern should be adopted for maintaining the soil fertility as well as soil conservation measures. The details of locations of the proposed structures of the area are given in Fig.11. Thus, due to the execution of these proposed structures at their proposed sites groundwater resources of the area will be enhanced.

CONCLUSION

Geomorphometric analysis for Hoshangabad, Budhni and its surrounding industrial area has been carried out using topographic maps and satellite data for the assessment of hydro-geological condition, water and soil conservation measures, water resource management and geographic characteristics of the drainage basin. The drainage basin has been classified into 4 sub-watersheds. Various morphometric parameters of each sub-watershed were evaluated using the formula suggested by Horton, Schumm, and Miller. Compound parameter value of each sub-watershed was calculated on the basis of morphometric parameters and their prioritization ratings were assigned for soil and water conservation measures. As we know the erosion of fertile soils is one of the major problems faced by the agricultural land, thus, prioritization of watersheds is important way to take appropriate agricultural and mechanical measures to prevent soil erosion. Therefore, in the study, a combined approach of remote sensing, GIS and topographical mapping were adopted to prioritize all the sub-watersheds and then to propose appropriate soil and water conservation measures. Each sub-watershed is assigned a rank on the basis of priority for adopting soil and water conservation measures. Furthermore, land use and soil type, slope and drainage network has been taken into consideration for proposing suitable soil and water conservation structures in the highly vulnerable sub-watersheds. The suitable soil conservation measures are proposed as per the adoptability in different type of land uses, soil types and slope which varies from 0 to 35 %. In the study, it is proposed that soil conservation measures should be adopted as per their priority assigned to reduce the adverse effect on the land and environment. Thus, analysis was carried out by coupling the land use, soil type, drainage network and slope to propose appropriate soil and water conservation measures. It

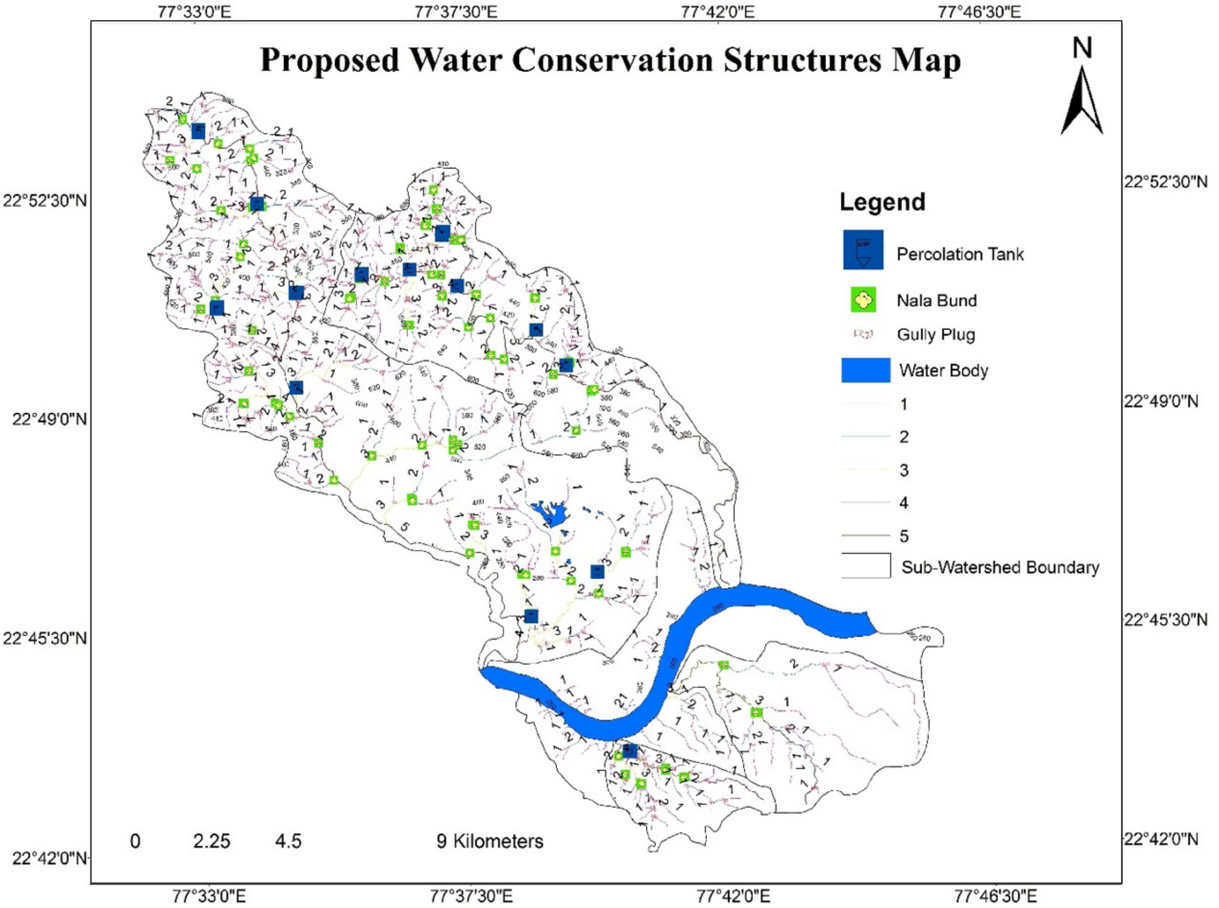

Fig.11. Proposed Soil and Water conservation Structures map.

is concluded that delineation of watersheds into sub-watersheds and prioritization of these sub-watersheds is very relevant and important because there is high diversity in agricultural practices and size of land holdings. It has been found that SRTM DEM, LISS-III remote sensing image, soil, land use mapping and GIS technique employed are very efficient tools for watershed hydrology and morphometric analysis and is providing promising results in the watershed prioritization. Besides, it also emphasized during the study that consideration of land use, soil type and slope and drainage networking in the sub-watersheds have helped to select appropriate soil and water conservation measures. In the area a major part of irrigation is satisfied by extraction of groundwater through open wells/bore wells; that provides a huge scope for execution of proposed suitable soil and water conservation structures in the area.

Acknowledgement: Authors are thankful to Coordinator of AcSIR, CSIR-AMPRI Bhopal and Director CSIR-AMPRI, Bhopal for giving permission to publish this manuscript. Authors are grateful to the reviewers for their helpful suggestions and recommendations that helped in the improvement and presentation of the manuscript.

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(Received: 15 March 2019; Revised form accepted: 29 July 2019)