Site suitability analysis for establishing soil and water conservation structures using Geoinformatics - A case study of Chinnar watershed, Tamil Nadu, India

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Abstract: Watershed is an ideal unit for management of soil and water resources. Water harvesting structure is one of the important components of watershed management to conserve these resources. Determination of potential sites for water harvesting structures is essential for proper conservation which requires thorough understanding of rainfall-runoff characteristics and detailed evaluation of surface topography, soil characteristics, geomorphology and land use/land cover. To demarcate suitable zones for soil and water conservation structures, these characteristics need to be integrated in a weighted manner. In the present study, an attempt has been made to identify potential sites for construction of soil and water conservation structures in Chinnar watershed - located in Dharmapuri and Krishnagiri districts of Tamil Nadu. The study uses thematic layers such as runoff, slope, land cover/ land use, lineament, drainage density, soil texture and geomorphology. All these layers were prepared with the help of remote sensing images and toposheets and integrated using weighted overlay techniques in GIS environment to derive suitable sites for soil and water conservation structures. The lower value of one was assigned to the factor that is not favorable for the conservation structures and the higher value of nine was assigned to the factor that is highly suitable for conservation structures. All the factor values were summed up and overall site suitability score was computed. The computed score was classified finally into four suitability classes. The results show that only less than one percent area is highly suitable for implementing soil and water conservation structures. About 34 percent of the study area is moderately suitable and about 65 percent area is less suitable for soil and water conservation structures. Based on site suitability results and topographic characteristics, locations for conservation structures including check dams, stop dams, percolation tanks and farm ponds were identified. These locations are ecologically sound and economically viable and this will sustain the productivity of the watershed.

Keywords: Watershed, Runoff, Weighted Overlay Analysis, SCS-CN Method, GIS, Remote Sensing

1. Introduction

Site suitability evaluation in the watershed is a subset of watershed management wherein the objective is to conserve water for watershed use, sediment reduction, and improved productivity for all land uses (Rao and Raghavendra, 2009).

Soil and water conservation are activities that maintain or enhance the productive capacity of land in areas affected by or prone to soil erosion. There are many methods offered for soil and water conservation and rainfall runoff modeling. Soil Conservation Services and Curve Number (SCS–CN) technique is one of the primogenital and simplest method to measure the runoff. The curve number is a function of land use and Hydrologic Soil Group (HSG). It is a method that can incorporate land use for the computation of runoff from rainfall. The SCS-CN method provides a rapid way to estimate runoff change due to land use change (Zhan and Huang 2004).

Integrated analysis of all thematic maps and their respective weightage in GIS platform could be utilised to prepare a map showing potential zones for water conservation structures and their appropriate measures (Varade et al., 2017; Anbazhagan et al., 2005). Different water conservation structures and measures are recommended for an effective site- specific soil and water conservation plan of the study area (Varade et al., 2017).

The present study of Chinnar watershed of Cauvery river basin covers the western part of Krishnagiri and upper part Dharmapuri district in Tamil Nadu. This watershed comes under Hosur, Denkanikottai (Krishnagiri), Pennagram and Palacode taluks (Dharmapuri). Chinnar watershed is covered by 2/4 part of the hilly area. Therefore, topography act as a barrier for agriculture activities but nearly 70% of the workforce is dependent on agriculture and allied activities. The important crops of the watershed which are cultivated especially in monsoon season are paddy, maize, ragi, banana, sugarcane, cotton, tamarind, coconut, mango and groundnut. The district is one among most backward and drought prone area in the state. As the area is drought prone, it has become essential to conserve soil and water resources of the watershed in a proper manner.

1.1 Study area

The area of Chinnar watershed is 1564.36 sq. km., it extends between 12º4'41" N to 12º40'31'' N latitude and 77º36'14'' E to 78º04'41'' E longitudes. The Karnataka State is located in the north and northwest side, Krishnagiri in west and Dharmapuri is located in south of the watershed. The river originates on the northwest slope of Vattalaimalai (1195m AMSL) in Krishnagiri district and meets river Cauvery at Hogenikkal waterfalls in Dharmapuri district (Venkateswaran, 2013) (Figure 1).

The study area is affected by drought due to scanty rainfall. The annual average rainfall over the study area is about 700 mm to1100 mm. The soil texture of the study area is clay, sand, sandy clay loam, sandy loam and loamy sand. The soil texture is governed by physiography of the study area.

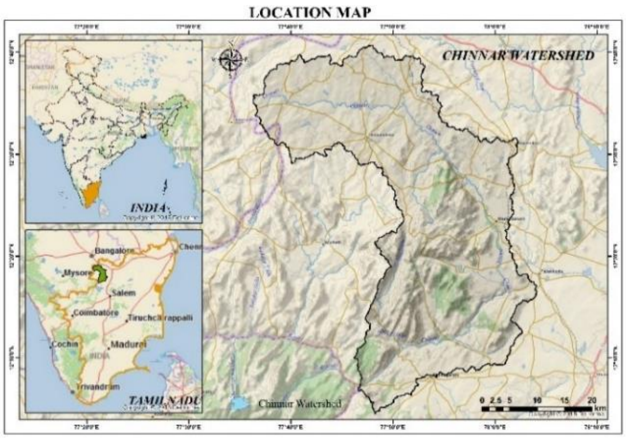

Figure 1: Location map of study area

1.2 Aim and objectives

The aim of the study is to find out suitable sites for establishing soil and water conservation structures in Chinnar Watershed using GIS and Remote Sensing techniques. Specific objectives are:

- To study physical parameters of the watershed.
- To analyze rainfall-runoff depth during northwest monsoon season (2005-2013).
- To perform site suitability analysis using weighted overlay techniques.
- To locate suitable sites for different structures for conservation of soil and water.

1.3 Methodology

The Chinnar watershed area is generated using ArcSWAT tool and is 1,564 sq.km. in its extent. The stream network is generated from the SOI topographic maps on 1:50,000 scale. The generated stream network has been used for stream ordering based on Strahler method. The satellite data for the study are downloaded from Bhuvan Data Archive including Digital Elevation Model (DEM) from Cartosat-1 satellite (Figure 2). The DEM data is used for generating slope map of the study area. The LISS-III of Resourcesat –I have been used for the preparation of landuse/land cover map.

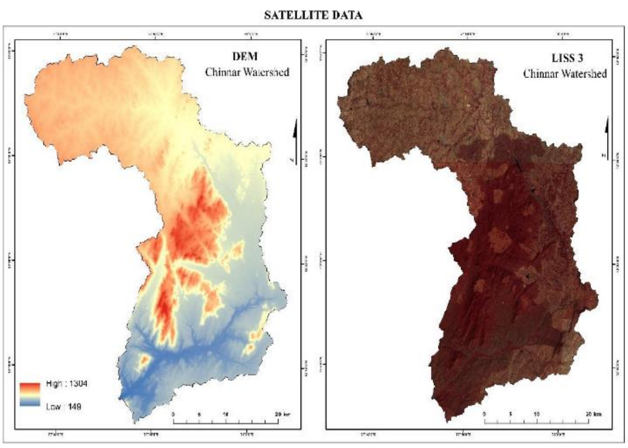

Figure 2: Cartosat DEM and LISS-III FCC of the Chinnar watershed

Figure 3 shows the flow chart of methodology adopted for identifying suitable sites for soil and water conservation structures. Geomorphology and lineaments features are extracted from Bhuvan thematic services by adding the WMS server in ArcGIS software. Lineaments features are used to applying the multi-ring buffer with a distance of 100, 200, and 500 and more than 500 m for assigning weightage for site suitability analysis. Geology map is created using the data collected from Geological Survey of India (GSI). Soil map is created from the data published by National Bureau of Soil Survey (NBSS).

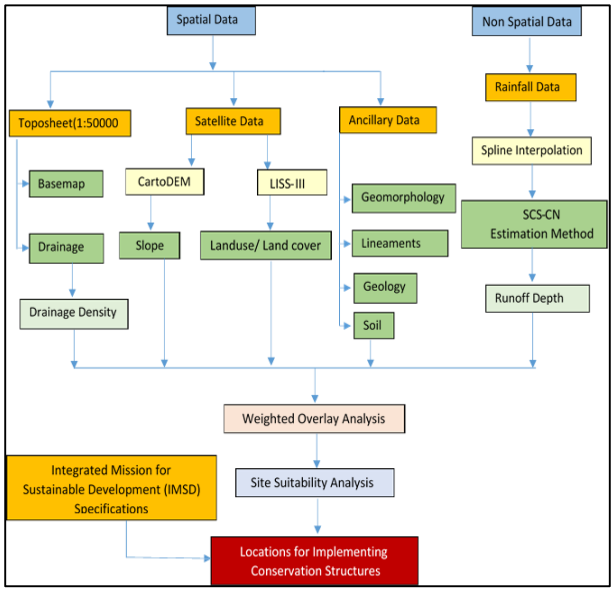

Figure 3: Flow chart showing the methodology adopted for identifying suitable sites for soil and water conservation structures

2. Physical environment

2.1 Climate

The climate of the study area is sub-humid to semi-arid. The mean temperature varies from 24°C to 40°C. The hottest period of the year is generally from March to May and the highest temperature rises to 40°C in April. The climate becomes cool in December and continuous up to February. The annual average rainfall over the study area is about 700 mm to1100 mm.

The highest rainfall occurs in upper part of the study area. Thally and Denkanikottai stations situated in the upper part of the watershed receive more rainfall. The middle part of the study area is affected by drought due to scanty rainfall. Hoganikkal, Pennagaram, Palacode, Panchppalli and Marandhalli stations receive very less to moderate rainfall (Figure 4).

2.2 Drainage

The drainage pattern of the watershed is dendritic. Drainage density is high in the hilly area and it is decreasing from central part to northern side. Lowest drainage density is found in upper part of the study area. Based on Strahler's system of stream ordering the watershed is 7th order (Figure 5 & 6).

2.3 Geology

Figure 7 shows the geology of Chinnar watershed. In various rock types, depth of weathering ranges from 2.2 to 50 m, while the fractures in rocks extend up to 50 m depth. The thickness of weathering in the rocks varies from 5 to 15 m near hills and 3 to 30 m in the plain area.

Groundwater occurs in the weathered residuum under unconfined conditions as well as in the fractured rocks under semi-confined condition (Venkateswaran, 2013). Groundwater fluctuation ranges from 3.52 m to 11.38 m below ground level (BGL). It reaches the lowest level during summer (March-June) and subsequently rise until the end of monsoon season (August–January) (Figure 7).

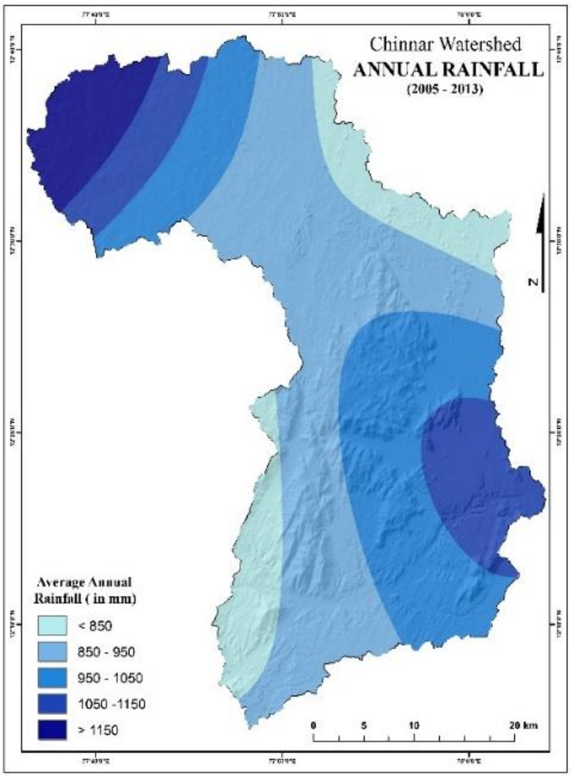

Figure 4: Rainfall distribution (2005-2013)

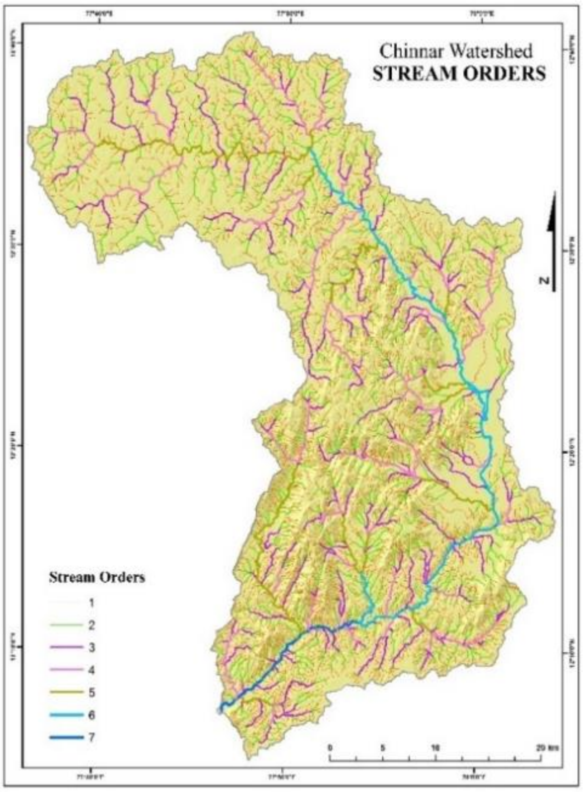

Figure 5: Stream ordering using Strahler's system

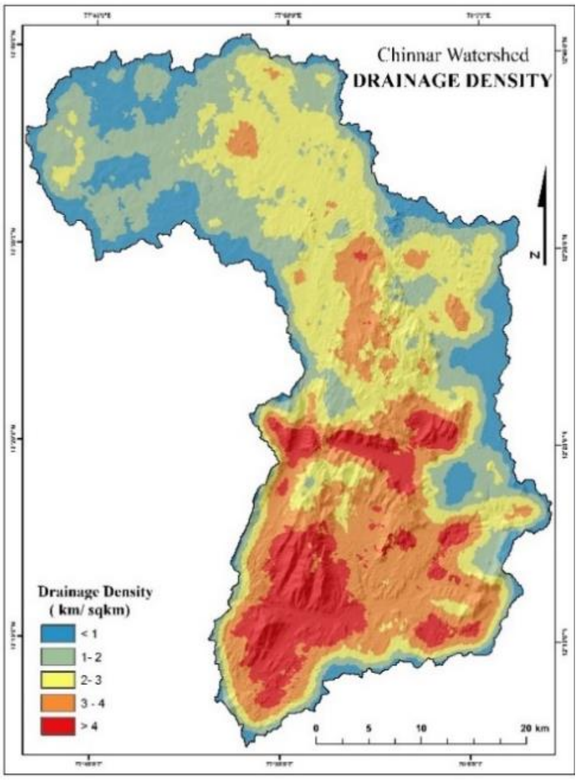

Figure 6: Drainage density of the watershed

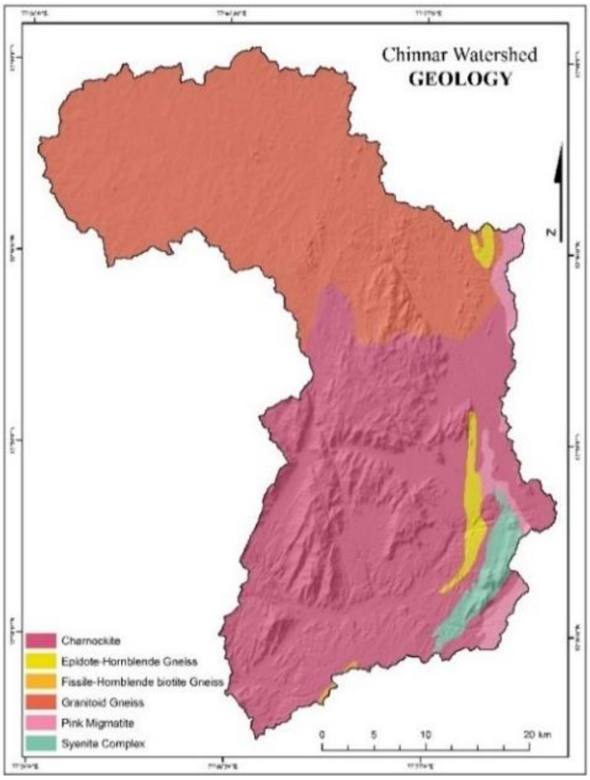

Figure 7: Geology of the watershed

2.4 Geomorphology

The study area is dominated by landforms of structural origin and denudational origin. The study area has been divided into two units each depending upon the degree of dissections namely, 1) Low dissected hills and valleys and 2) Moderately dissected hills and valleys. The pediment-pediplain complex is along the Chinnar River. The upper plateau adjoins hilly topography (Figure 8).

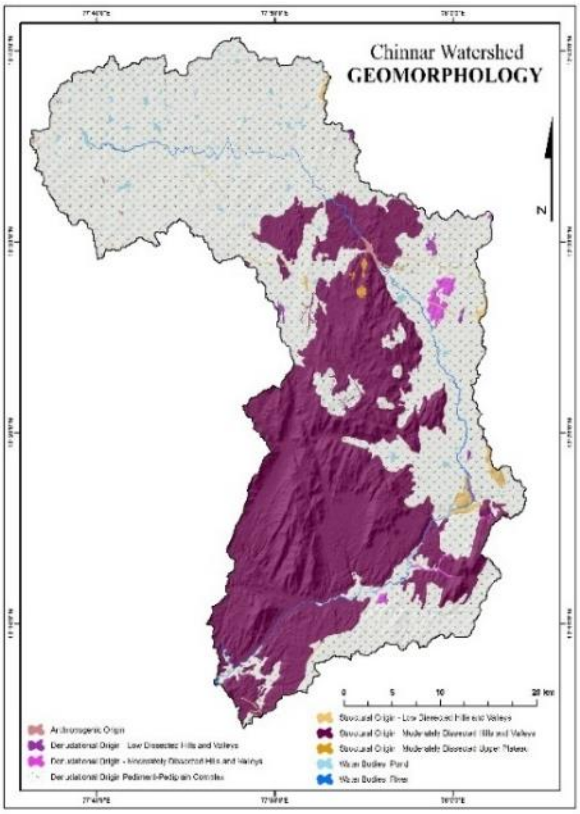

Figure 8: Geomorphology of the watershed

2.5 Lineaments

The lineament of the study area is of two major types viz., geomorphic lineaments and structural lineaments. Drainage parallel and scrap parallel are considered as geomorphic lineaments, observed in the western part of the study area and joint/Fracture are considered as structural features observed in entire study area (Figure 9).

2.6 Soil

The soil of the study area can be classified into clay, sand, sandy clay loam, sandy loam and loamy sand. The classification depends on the climate, rainfall, drainage, characteristics and geology of the area. Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. Most of the upper part of the study area is covered by sand because of the erosion. Sandy clay loam is observed along the banks of the river and along the channel. The sandy loam is observed over the hilly area in the central part of the watershed, and loamy sand is observed in the upper western part of the study area (Figure 10).

2.7 Slope

The slope is a measure of the steepness of a line. The slope of the study area varies from 0 to 60 degrees. The slope map is generated from CartoDEM (30m) which was collected from Bhuvan. The slope values are classified in five classes such as <4, 4-8, 8-16, 16-24, and more than 24 degree (Figure 11).

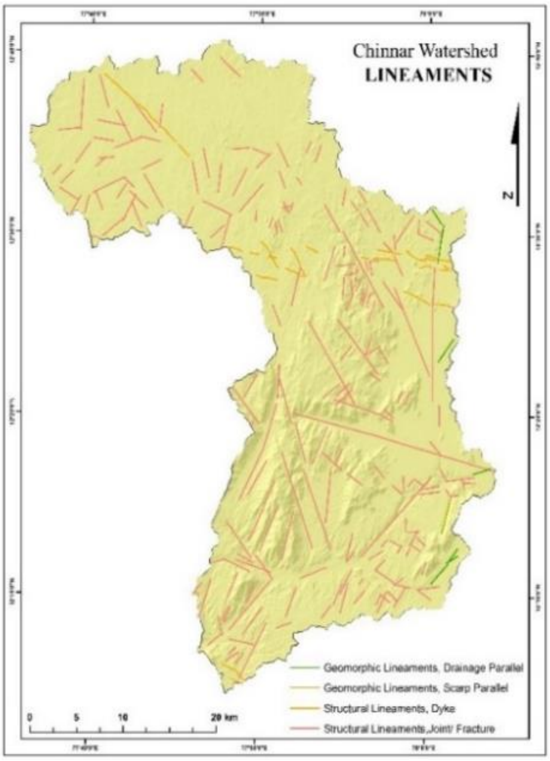

Figure 9: Lineaments in the watershed

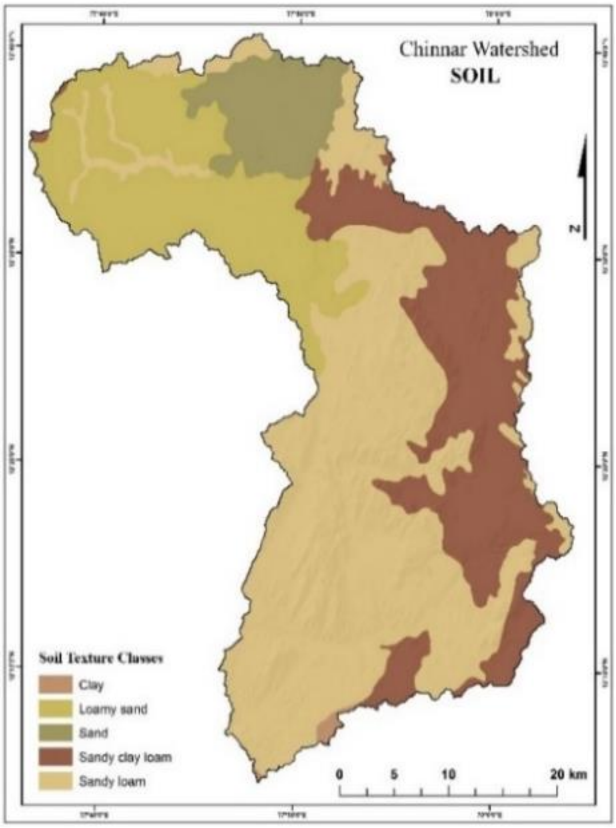

Figure 10: Soil texture of the watershed

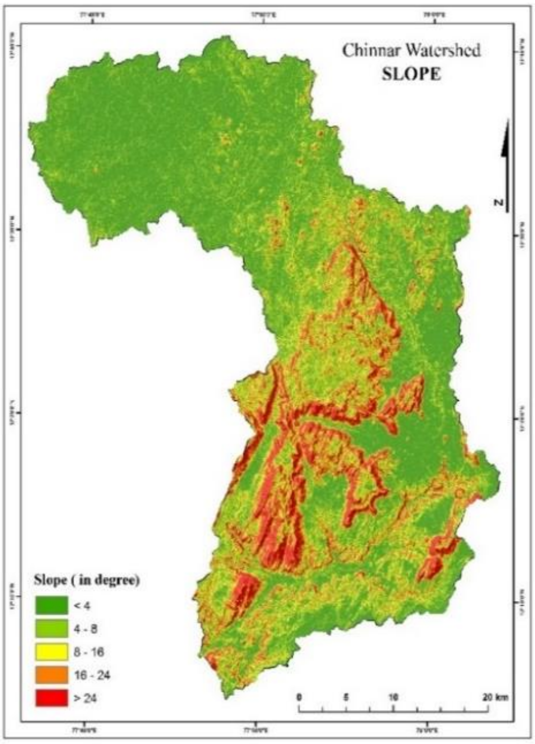

Figure 11: Slope of the study area

3. Social environment

3.1 Landuse/Land Cover

Agriculture and forest covers more area than other landuse classes. These classes cover approximately 573 sq km of study area. Hilly area is covered by forest in form of deciduous, evergreen, and scrub forests. Scrublands are observed in the eastern part of watershed (Figure 12). Table 1 shows distribution of landuse /land cover of the study area.

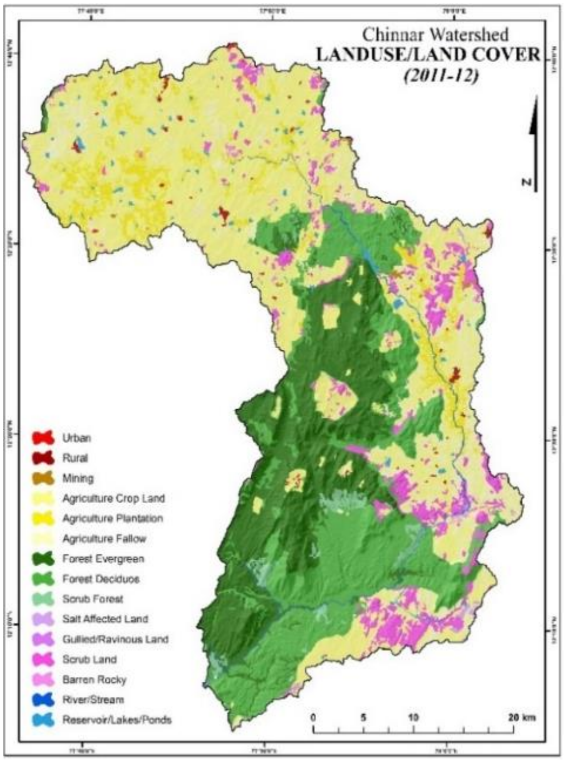

Figure 12: Landuse/land cover

Table 1: Area under landuse land cover

LULC features	Area in sqkm
Built-up	7.33
Agriculture	573.74
Plantation	81.54
Fallow	132.24
Forest (Deciduous)	323.67
Forest (Evergreen)	298.16
Scrub Forest	21.95
Wasteland	105.28
Waterbody	20.46

4. Rainfall-Runoff estimation

Runoff is a loose term that covers the movement of water to a channelized stream, after it has reached the ground as precipitation. The run-off of a stream is influenced by many complex conditions as, for instance, the amount of rainfall, its intensity, nature of soil, slope of the surface, area and configuration of catchment basin (Jain and Singh, 2003). It is also influenced by geologic structures, forests, wind, force of vapor pressure and few other elements.

When, intensity of the rainfall exceeds the infiltration rate, the excess rainfall begins to pond on the soil surface. When the rainfall ceases, the water held in surface storage either infiltrates into the soil or evaporate (Assefa and Wendy 2004). The volume of water that exceeds the volume of surface storage becomes surface runoff. Rainfall-runoff modeling may be used for a variety of purposes. The use of relatively simple rainfall-runoff models has become common over the years for designing detention storage or for design projects in medium to large watersheds where channel and floodplain storage are important factors in evaluating the flood hydrograph (Rao et al., 2001). Rainfall-runoff modeling may also be used as a management tool, for example, in the management of storm water runoff for water quality and urban development.

4.1 Rainfall

Rainfall is measured using rainguages. During a given storm, it is likely that depth measured by two or more rainguage will not be the same, therefore it is often necessary to determine the spatial average of the rainfall depth over the watershed area (Rafter, 1903). The study area has 10 rainfall gauging stations viz., Hosur, Thally, Denikanikottai, Rayakottai, Panchapalli, Marandahalli, Anchetty, Palacode, Pennagaram and Hoganikkal. The daily rainfall data from 2005 to 2013 was collected from Department of Economics and Statistics, Tamilnadu. The average rainfall was calculated from August to November, and it has been interpolated. Table 2 shows the distribution of rainfall during this period.

4.2 Rainfall-Runoff modelling

Rainfall-runoff estimation is very much required for identifying a suitable location for impounding harvesting structures. The report on the quantitative measurement in hydrology published by Perrault (1974) compared the measured annual rainfall (Pa) and the estimated annual streamflow (Qa) of the seine river in Paris. In order to estimate, amount of direct runoff that will be produced from a given precipitation from a watershed, various hydrologic models can be used (Jonathan, 2003).

Table 2: Average rainfall distribution during northeast monsoon season (2005-2013)

RF Station.	Aug	Sep	Oct	Nov	Seasonal
Pennagaram	122.70	86.39	152.79	114.4	476.25
Heganikkal	108.07	79.97	168.26	116.9	472.48
Palacode	115.99	144.72	194.37	148.2	603.28
Thally	218.46	153.67	207.10	124.2	703.40
Marandahalli	120.96	95.65	206.00	151.6	574.23
Anchetty	114.10	98.63	148.12	90.43	451.29
Panchapalli	100.28	102.12	216.80	122.9	542.17
Rayakotta	95.67	100.23	147.76	106.1	449.79
Denikanikotti	113.02	116.74	189.26	110	529.93
Hosur	104.26	133.24	175.02	95.27	507.79

These models range from complex to simple, having different structures and input data requirements. Amongst these models, soil conservation service (SCS) model is most widely used for the estimation of direct run-off.

4.2.1 SCS-CN Rainfall estimation method

The Soil Conservation Service - Curve Number (SCS-CN) method is one of the most popular methods for computing the runoff volume from a rainstorm. The SCS-CN method was originally developed for its use on small agricultural watersheds and has since been extended and applied to rural, forest and urban watershed. In this study for calculating CN values and runoff, average rainfall data for the year 2005-2013 was used. Instead of using the annual rainfall, only the rainfall occurs between August and November has been used in this study because these month’s receives comparatively more amount of rainfall and soil is almost wet in condition. Runoff curve number equation estimates total runoff from rainfall events and this relationship excludes time as a variable and rainfall intensity. Its stability is ensured by the fact that runoff depth (Q) is bounded between the maximum rainfall depth (P). This implies that as rainfall amount increase the actual retention (P-Q), approaches a constant value; the maximum potential retention (USDA, 2007). The runoff estimation related runoff (Q) to precipitation (P) and the curve number (CN) which is in turn related to storage (S). CN is based on the following parameters; hydrologic soil group, land use and treatment classes and hydrologic surface conditions. Following equation gives the relationship (Prasad et al., 2014):

$$Q = \frac{(P - Ia)^2}{(P - Ia) + S}$$

where; Q = runoff depth (mm); P = rainfall (mm); Ia = initial abstraction (mm); S = potential maximum retention after runoff start.

Initial abstraction consists mainly of interception and infiltration during early parts of the storm and surface depression storage. Its determination is not easy due to the variability of infiltration during the early part of the storm. Since it depends on conditions of the watershed at the start of a storm such as the land cover, surface conditions and rainfall intensity; thus, it is assumed as a function of the maximum potential retention as mentioned below (USDA, 2007)

$$Ia = 0.2S$$

The Curve Number can be calculated using potential maximum retention (S).

$$S = \frac{25400}{CN} - 254$$

The model is mainly depending on the runoff Curve Number. Curve number is estimated via the effect of soil and land cover on the rainfall runoff processes. The range of the Curve Number is between 1 (100 % rainfall infiltration) and 100, lower values of the Curve Number indicate lower runoff, while higher values of Curve Number refers to higher values of runoff (Mishra and Singh, 2003).

4.3 Hydrological soil group

Soils are assigned to hydrologic soil groups based on measured rainfall, runoff, and infiltrometer data. Since the initial work was done to establish these groupings, assignment of soils to hydrologic soil groups has been based on the judgment of soil scientists. Assignments are made based on comparison of the characteristics of unclassified soil profiles with profiles of soils already placed into hydrologic soil groups. Most of the groupings are based on the premise that soils found within a climatic region that are similar in depth to a restrictive layer or water table, transmission rate of water, texture, structure, and degree of swelling when saturated, will have similar runoff responses. The classes are based on the following factors (USDA, 2007):

- Intake and transmission of water under the conditions of maximum yearly wetness (thoroughly wet)
- Soil not frozen
- Bare soil surface, and
- Maximum swelling of expansive clays the slope of the soil surface is not considered when assigning hydrologic soil groups.

The four hydrologic soil groups (HSGs) are described by USDA (2007) as follows:

- ***Group A***: Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam or silt loam textures may be placed in this group if they are well aggregated, are of low bulk density, or contain greater than 35 percent rock fragments.
- ***Group B***: Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures.

Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, are of low bulk density, or contain greater than 35 percent rock fragments.

- ***Group C***: Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, are of low bulk density, or contain greater than 35 percent rock fragments.
- ***Group D***: Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential. All soils with a depth to a water impermeable layer less than 50 centimeter's [20 inches] and all soils with a water table within 60 centimeter's [24 inches] of the surface are in this group, although some may have a dual classification, as described in the next section, if they can be adequately drained.

Table 3 was used to find the hydrologic soil group of the study area depending upon the soil texture. Curve number is used to characterize the runoff properties for a certain soil and land cover/ land use. The soil conservation service runoff equation uses the curve number value as input parameter. Curve Numbers were evaluated for the study area on pixel basis using the land cover/land use and soil map that are reclassified to hydrologic conditions and hydrologic soil group. Curve numbers were thus generated using land cover and Hydrological Soil Group (HSG) classification system. A high value of the curve number (such as 100) refers to an area that has a high runoff potential and low infiltration.

Infiltration depends on the soil property, which effects the relation between rainfall and runoff (Arun, 2003). The soil conservation service model divides all soils into four Hydrologic Soil groups according to the United States Department of Agriculture (USDA) and the classification of soil to hydrologic soil group depends on infiltration rates and the soil texture composition. Only classes A, C and D are observed in the study area (Figure 13). Table 4 shows runoff curve number for combinations of different land cover and hydrological soil groups based on the USDA classification system.

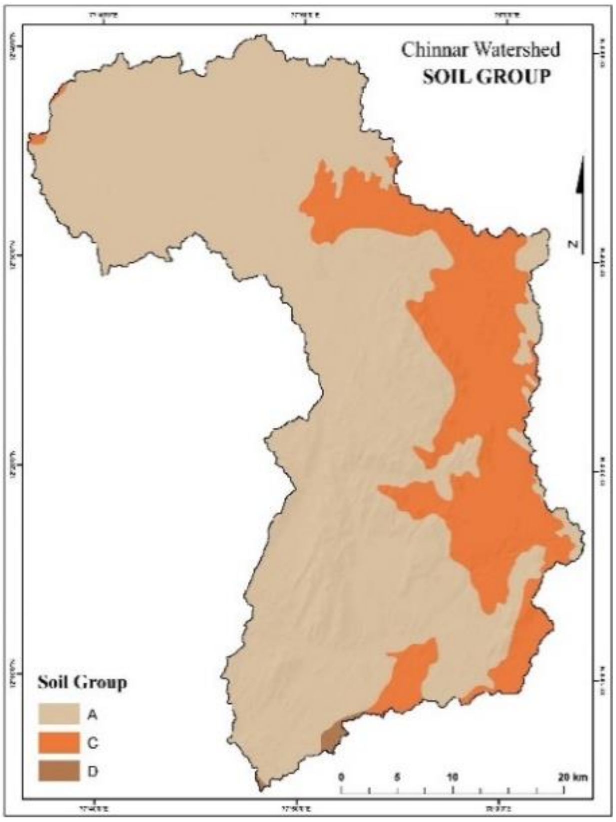

Figure 13: Hydrological soil group

Table 4: Runoff curve numbers

Landuse/ Land cover Classes	Hydrological Soil Group			
	A	**B**	**C**	**D**
Built-up	48	66	78	83
Agriculture Land	67	78	85	89
Plantation	65	73	79	81
Fallow Land	76	85	90	93
Forest (Deciduous)	68	79	86	89
Forest (Evergreen)	48	67	77	83
Scrub Forest	48	67	77	83
Wastelands	64	75	83	85
Waterbody	90	94	98	100

Table 3: Soil group and corresponding soil texture (Source: USDA, 1986; Rao et al., 2010)

Soil Group	Runoff Description	Soil Texture
A	Low runoff potential because of high infiltration rates	Sand, Loamy sand and Sandy loam
B	Moderately infiltration rates leading to moderately runoff potential	Silty loam and Loam
C	High/moderately runoff potential because of slow infiltration rates	Sandy clay loam
D	High runoff potential with very low infiltration	Clay loam, silty clay loam, sandy clay, silty clay and Clay

A low value to the curve number (such as 48) indicates an area that has a low runoff potential and high infiltration. (USDA, 1986).

4.4 Rainfall-Runoff depth

The rainfall runoff depth was calculated using SCS-CN method. Land use/land cover and hydrological soil groups curve numbers with average annual rainfall were estimated using raster calculator in ArcGIS 10.1. The high runoff potential is observed in the northern part of the study area (fallow land). The soil texture is loamy sand and sandy loam. A moderate runoff potential occurs in the eastern part of the study area (undulating hills and moderately sloppy terrain (Figure 14).

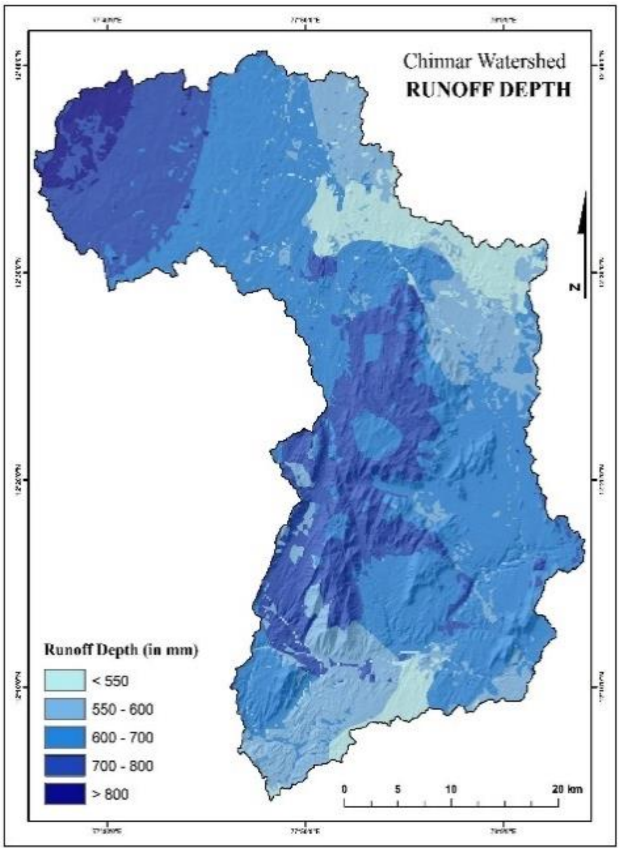

Fig 14: Runoff depth of the study area

5. Results and Discussion

Site suitability analysis is a type of analysis used in GIS to determine the best place or site for something (Patel et al., 2012). Potential sites used in suitability analysis can include the location of check dams and rainwater harvesting structures. Site selection analysis can be performed with vector or raster data but one of the most widely used types of site selections is weighted overlay site selection using raster data. Weighted overlay site selection analysis allows users to rank raster cells and assign a relative importance value to each layer. The result is a suitability surface which ranks potential sites from 1 to 9. Sites with a value of 1 are least suitable and those with a value of 9 are most suitable (Table 5).

Table 5: Weight determination of different Layers

Raster Layers	% influence	Feature Classes	Weightage
Slope	25	< 4 (Gentle Sloping)	5
(in degree)		4 - 8 (Moderately Sloping)	9
		8 - 16 (Strongly Sloping)	7
		16 - 24 (Moderately Steep Sloping)	3
		> 24 (Very Steep Sloping)	1
Runoff	15	< 550	1
(in mm)		550 - 600	3
		600 - 700	5
		700 - 800	7
		> 800	9
Soil Texture	10	Clay	1
		Loamy Sand	9
		Sand	5
		Sandy clay loam	7
		Sandy Loam	9
Geomorphology	15	Anthropogenic Origin	1
		Denudational Origin – Low Dissected Hills and Valleys	5
		Denudational Origin – Moderately Dissected Hills and Valleys	7
		Denudational Origin Pediment-Pediplain Complex	3
		Structural Origin - Low Dissected Hills and Valleys	5
		Structural Origin - Moderately Dissected Hills and Valleys	9
		Structural Origin - Moderately Dissected Upper Plateau	2
		Water Bodies- Pond	1
		Water Bodies- River	1
Drainage Density	10	< 1	1
(in sqkm)		1 - 2.	3
		2 - 3.	5
		3 - 4.	7
		> 4	9
Landuse/Land cover	10	Built up	1
		Agriculture	2
		Plantation	3
		Fallow	3
		Forest (Deciduous)	5
		Forest (Evergreen)	3
		Scrub Forest	9
		Wasteland	7
		Waterbody	1
Lineaments	15	Lineament buffer < 500 m	9
		Lineament buffer 500 - 1000 m	5
		Lineament buffer 1000 - 2000 m	3
		Lineament buffer > 2000 m	1

5.1.1 Weighted Index Model

Weighted Index Model represent weighting the multiple parameters. In this study, weighted index model was used for data integration. All thematic layers prepared for Chinnar watershed are classified with reference to the site suitability for water harvesting structures. In this study, most important aspect is to assess the area of high potential zones of water as it would help to prepare a plan for sustainable development of soil and water resources. This is carried out keeping in view that all the parameters are dependent on each other with respect to the study (Prasad et al., 2014).

5.2 Site suitability analysis

Identification of suitable sites for soil and water conservation structures are based on slope, runoff, geomorphology, soil, drainage density, landuse/land cover and lineaments (Prasad et al., 2014).

All the layers were generated in the ArcGIS- 10.1 software were in the vector format. In weighted overlay analysis, the rasterization of each physiographic unit was performed by using the conversion tools in the ArcToolbox Window. So, the first step of data conversion is rasterization for converting different lines and polygon into raster data format. After this, reclassification of all the raster files was performed using scale values of each unit. All the layers were ranked based on their influence following Lynn, (2009). For the site selection of soil water conservation structures in Chinnar Watershed, the weightage overlay analysis was used. Depending upon the influencing factors, weightages were assigned from rank 1 to 9. The lower value 1 represents the low or not suitable sites whereas the high values 9 represents highly suitable site over the Chinnar watershed. Further, using the Spatial Analyst Tool, weighted overlay function has been processed and suitability zones are identified (Figure 15). The resulted values range from 2 to 9. These are classified into highly suitable (7 - 9), moderately suitable (5 - 7), less suitable (3 -5) and not suitable (2 - 3) classes.

5.2.1 Highly suitable areas

The site having favorable location for construction of soil and water conservation structures is considered as highly suitable. These locations will not significantly effect on benefits and will not raise inputs above an acceptable level. The southwest part of the study area especially foots of hills are highly suitable for soil and water conservation. About 0.80% of the study area is highly suitable for implementing soil and water conservation structures.

.5.2.2 Moderately suitable areas

The site having moderately favorable location for construction of soil and water conservation structures is considered as moderately suitable. These locations will reduce some benefits and increase the required inputs to the extent that the overall advantage gained from use. The most part of the study area is moderately suitable for soil and water conservation. About 31 % of the study area is moderately suitable for implementing soil and water conservation structures.

5.2.3 Less suitable areas

The site having less favorable location for construction of soil and water conservation structures is considered as less suitable. Structures constructed in such area shall not be beneficial. The upper part of the study area is less suitable for soil and water conservation due to plain topography. About 65 % of the study area is less suitable for implementing soil and water conservation structures.

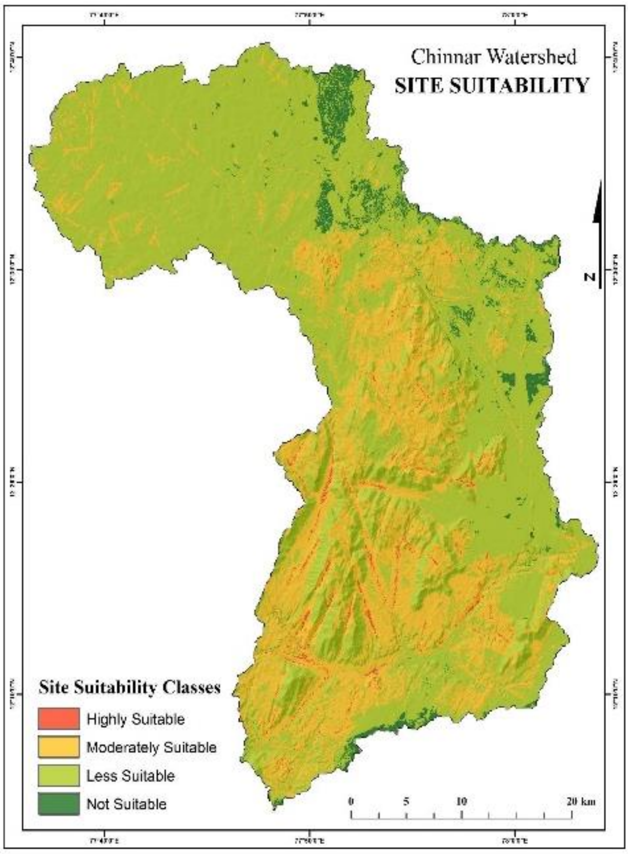

Figure 15: Site suitability for implementing soil and water conservation structures in the watershed

5.2.4 Not suitable areas

The site having severe limitations for the construction of soil and water conservation structures is considered as not suitable. Construction of any water conservation structure in these regions are not cost and time effective (Chopra et al, 2005). The areas that are not suitable are observed in the eastern part of the study area. About 3 % of the study area is not suitable for implementing any soil and water conservation structure.

5.3 Water conservation structures

The multi-layer integration through land use/cover, slope, flow direction, drainage density and rainfall depth gave the suitability units for identifying water-conservation sites for check dams, stop dams, percolation tank and farm ponds (Khare et al., 2013). Factor layers were incorporated in ArcMap, using weighted overlay function in the ArcGIS analyst and provided final suitability map. This map was used to identify potential sites (Figure 16) for different water harvesting structures in study area. Technical guidelines suggested by IMSD (1995) and INCOH (1995) were used for selecting suitable sites for conservation structures. Availability of water depends on many variables like slope, landuse, soils, drainage, runoff potential, proximity to utility points, etc. These guidelines are used as a knowledge base for identifying sites (Perumal et al., 2003). The decision rules used in the present study for identifying suitable zones for water conservation structures are shown in Table 6.

Table 6: Soil and water conservation structures

Type of Structure	Slope	Runoff	Lineament Buffer (m)	Stream Order
Check Dams	Medium or Gentle Slope	High to Low	100 - 200	3rd,4th
Stop Dams	Very Gentle Slope	Moderate to low	200 - 500	3rd ,4th & 5th
Percolation Tanks	Gentle Slope	High to Low	< 100	4th & 5th
Farm Ponds	Flat or Gentle Slope	Moderate	> 500	3rd 4th & 5th

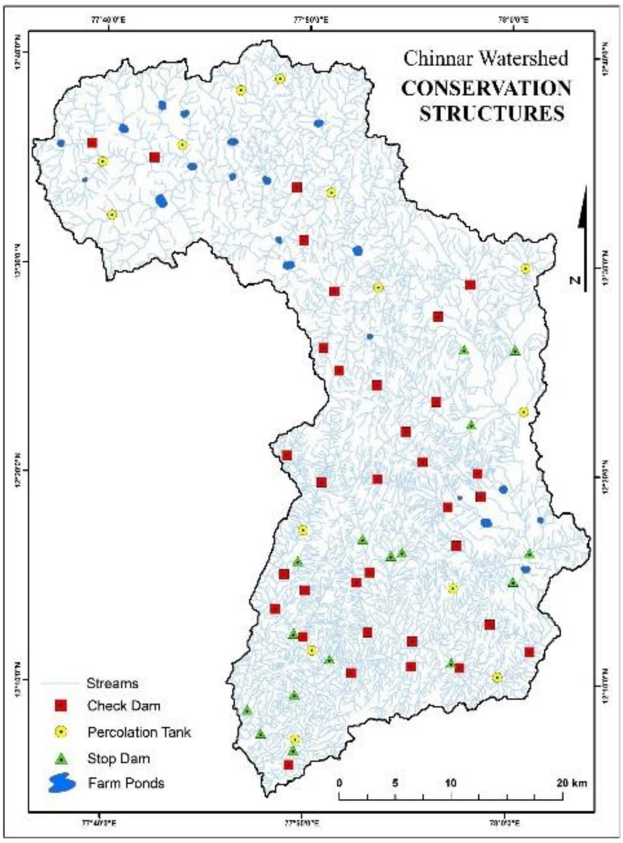

Figure 16: Optimal locations for soil and water conservation structures

5.3.1 Check dams

Check dams are very popular type of water harvesting structures and have greater importance since it has got a complimentary benefit of controlling soil erosion (IMSD, 1995). Check dams are structures constructed of rock, sediment retention fibre rolls, gravel bags, sandbags, or other proprietary product placed across a natural or manmade channel or drainage ditch. In Chinnar watershed, medium or gentle slope and 3rd and 4th orders streams are considered suitable sites for constructing check dams. There are 41 suitable sites identified for construction of check dam in the Chinnar watershed. These sites are fulfilling all the necessary conditions needed for construction of check dams.

5.3.2 Stop dams

Stop Dam is constructed across the direction of water flow on shallow rivers and streams for the purpose of water harvesting for irrigation as well as for domestic and animal use. In the study area deciduous forest, high to low runoff gentle slope and 3rd, 4th or 5th stream order is considered for selecting suitable sites for constructing stop dams. Thirteen sites have been identified suitable for the construction of stop dams in Chinnar watershed.

5.3.3 Percolation tanks

Percolation tanks are the structures for recharging ground water. These are generally constructed across streams and bigger gullies in order to impound a part of the run-off water (IMSD, 1995). In Chinnar watershed, moderate slope and proximity to lineaments (<100) are considered as suitable for percolation tank. There are 14 sites identified as suitable for construction of percolation tanks in Chinnar watershed.

5.3.4 Farm ponds

Farm ponds are made by either constructing an embankment across a water source or by excavating pits or the combination of both. These are the low-cost structures constructed in agricultural land located on higher reaches (IMSD, 1995). The farm ponds are used for protective irrigation in a prolonged dry spell in monsoon season.

Most part of the study area is highly suitable for construction of farm ponds. Sixteen favourable sites were identified for the construction of farm ponds based on rainfall pattern, heavy texture soil and agriculture lands,

6. Conclusions

Watershed is an ideal unit for management and sustainable development of its natural resources. The appropriate use of land and water resources of a watershed requires suitable engineering measures for conservation. Potential sites for water harvesting structures are identified normally based on the rainfall characteristics and rainfall runoff processes. Rainfall- runoff modeling of the watershed could be estimated using the soil conservation service-curve number (SCS-CN) method. Remote sensing and GIS provides an appropriate platform for estimating runoff using SCS-CN method. These methods play a significant role in generation of input parameters and spatial analysis. The SCS-CN method was applied in this study using average annual rainfall for the period 2005 to 2013 to estimate the runoff depth. The result indicates that significant amounts of annual runoff can be harvested through potential soil and water conservation structures.

As Chinnar watershed is drought-prone region and mainly depends on agriculture, it has become essential to conserve soil and water resources in a proper manner. Hence, site suitability analysis was carried out based on runoff, drainage density, slope, soil, land use/land cover, geomorphology and lineaments features. The weightage overlay analysis was used to delineate potential zones for establishing conservation structures because the approach gives relative importance to the influencing parameters. Based on the suitable zones, locations for constructing check dams, stop dams, percolation tanks and farm pond were identified. These locations are ecologically sound and economically viable and this will sustain the agriculture productivity of the watershed.

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