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Cadastral Level Soil and Water Conservation Priority Zonation using Geospatial Technology

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ABSTRACT

Water is the most precious commodity that human being wanted, nowadays water is depleting due to several human interventions. In Kerala state, even though high rainfall is received, still water scarcity is faced during summer and soil erosion is higher. This watershed area is prone to water scarcity during the summer season and stream networks become dry during that period. This clearly indicates that human interventions and unscientific agricultural activities may be the result. In this, study GIS and RS technologies are used to find and map the Soil and water conservation priority zones, also several action Plans where proposed. SOI Topo sheet were used to digitize the contours and DEM was created using that with ArcGIS 10.2.2 software. LULC maps were digitized from satellite image and using other parameters and suitable weight values, the weighted overlay was done to find out the Priority Zones. Cadastral Plot boundaries were overlaid for plot-wise priority zones and several conservation methods like gully plugin, check dams, vegetation bund etc. were proposed.

Keywords:
Watershed management; GIS; Priority Zonation; Satellite imagery; Remote Sensing

1. Introduction

Water and soil play a major role in attaining sustainable livelihood throughout the world, therefore it's high time that it should be checked and conserved. Uncontrolled population growth puts pressure on the civic amenities, which are depleting and collapsing (Singh et al., 2013; Jha et al., 2007). In addition, for the management of these natural resources, the most suitable unit is the watershed (Patel et al., 2012; Roy et al., 2017). Water and soil conservation is the method of carrying out scientific methods, which involves the changing and modification in elements of the watershed (Johnson et al., 2002; Nathawat et al., 2010). It also says about the use of soil and water resources of a watershed for required production with minimum pressure to natural resources (Osborne & Wiley 1988; Kessler *et al*., 1992).

Water extends about 71% of the surface of the earth and is essential for the existence and sustainability of living organisms on the surface of the earth. Freshwater is only 2.5% of the water on earth. Approximately 0.3% of fresh water is found in rivers, lakes, and the atmosphere. In general, understanding the quality of water plays a critical role before use for various purposes, including drinking. Water is a fundamental requirement for successful breeding of crops. Cultures should be supplied with water in the quantities required for optimal growth, especially in the critical stages of crop growth (Vinayak & Umesh, 2013). Advances in remote sensing approaches have provided the ability to acquire information on the quality of water to spatial and temporal resolutions beyond the capacity of regular measurements and in situ measurement points. By integrating remote sensing data with geographic information systems, a more comprehensive analysis of water quality has been made possible.

Optical and thermal sensors, when deployed on ships, aircraft or satellites can provide both spatial and temporal information needed to understand changes in the quality characteristics of the water are usually the same essential characteristics for the development of best practices management to test the quality of water (Singh et al., 2013; Jha et al., 2007). Predicting hydrological behavior requires regionally heterogeneous data that are often prohibitively expensive to acquire on the floor. As a result, satellite remote sensing has become a powerful tool for surface hydrology. Groundwater hydrology has yet to realize the benefits of remote sensing, although the superficial expressions of groundwater can be controlled from space.

Remote sensing indicators of groundwater can provide important data where practical alternatives are not available. The potential for remote sensing of groundwater is explored here in the context of active sensors and planned satellite-based. Satellite technology is reviewed concerning its ability to measure potential groundwater storage and fluxes. Here it is argued that the satellite data may be used if the auxiliary analysis is used to infer the behavior of the groundwater from surface expression. Remote sensing data are most useful when combined with numerical modeling, geographic information systems, and ground-based information (Sreedevi et al., 2013). GIS and RS technology provide abilities to manage large databases very easily. Thus, a combination of GIS and RS technologies has proved that it is an efficient tool and several investigators for water and soil conservation projects along with other watershed prioritization projects (Kumar et al., 2001; Kanga & Singh, 2017) use this. Many researchers, using the weighted overlay method, in both India and abroad (Krishnamurthy et al., 1996; Shahid et al., 2000; Solomon & Quiel, 2006; Agarwal et al., 2016), have conducted several studies on groundwater potential zoning using RS and GIS technologies. A lot of time, money, and labor expenses can be saved, if we use GIS and RS for positioning of conservation structures, particularly for remote areas. These structures will control the loss of excessive water from the watershed through runoff and hence lead the water and soil conservation (Patel et al., 2012; Pandey & Singh, 2015). The present study is an attempt using remote sensing and GIS techniques to propose various water harvesting and soil conservation measures to suggest integrated land and water resource development plan for Maniyakupara watershed covering 654 ha in Kottayam district, Kerala.

Natural resources are a major part of the development of a country. Among that, water and soil are the most important. A country that tends to have more natural resources and has a way to refine it has a better and stable economy. Kerala is a state, which normally gets a good amount of rainfall and still facing water scarcity during summer. This is a major concern and suitable methods should be adopted for the conservation of water, soil, and minerals of the area. Our area of study is the Maniyakupara watershed of the Muvattupuzha River. This watershed area suffers water scarcity during the summer season and streams become dry. Human interventions and unscientific agricultural approaches may be the result. Due to this soil and water are manipulated. The present study emphasizes the identification of priority zones for soil and water conservation in the watershed area and to generate a watershed treatment plan for the area.

2. Materials and Methods

Maniyakupara watershed is situated in Kottayam district of Kerala State. Geographically it lies between places, Kuravilangadu and Monipally and it includes some part of Uzhavoor and Marangatupally gram panchayat (Figure 1). The total geographical area of the study area or watershed is about 654 hectares. Maniyakupara watershed area lies at 9˚46′6.572″ North latitude and 76˚33'45.625" East longitude. The main water source and higher-order stream available is Kurianadu valiyathodu. Valiyathodu is a part of Muvattupuzha watershed and the study area covers the micro watersheds 13m64d and 16m64e in the Kerala Watershed Atlas (KSLUB. 1996). The watershed area is moderately sloping (5 – 15%) in majority areas. The Maniyakupara watershed area consists of 2 Grama panchayaths - Marangattupally with wards 2 fully and 1, 12, 14 (Partially), and Uzhavoor with 11th ward fully which together forms a total of 654 ha as treatable area. The study area is moderately sloping, elevation ranging from 13 to 145 m above Mean Sea Level (Table 1).

2.1. Database Preparation

In this study, data were obtained from the Survey of India (SOI) toposheet, Toposheet code was 58 C/9, and scale was 1:50000. It was scanned at 400 dpi. Then it was georeferenced using ERDAS Imagine 2013. Image to Image georeferencing was conducted with the Google image downloaded. Google earth's image was already georeferenced and subsetted along the watershed boundary. CNES/Astrium (Google earth) image of the year 2018 was downloaded using Google Earth software with the help of a software named "GIS_tool_2010". GIS_tool_2010 is a software which is capable of generating KML grid of SOI toposheets, which can be used to overlay in google earth. Corresponding.kml file of "58C/9 toposheet" is created and used to overlay in the Google earth. These grids are used as a reference for downloading the image and for georeferencing. Precipitation data was acquired from a district agricultural farm, Kozha. Average rainfall was calculated by analyzing the 10-year.

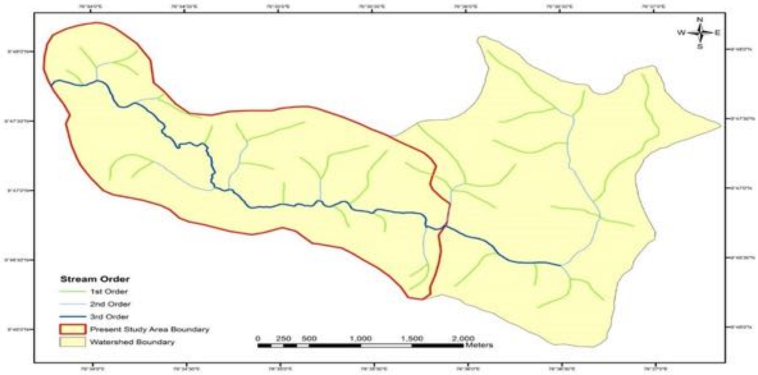

Figure 1. Entire watershed area with stream network and present study area

Table 1. Watershed area at a glance - General Information

1	Name of the Block	Uzhavoor Block Panchayath
2	Name of the District	Kottayam
3	Geographical Area of the Watershed	654 ha
4	Latitude	9°46'6.572"N 9°48'12.105"N
5	Longitude	76°33'45.625"E 76°35'55.856"E
6	Name of the Watershed	Maniyakupara
7	Major Water Source	Kurianad valiyathodu
8	River flowing nearby the watershed area	Muvattupuzha
9	Livelihood Options	Agriculture, Animal Husbandry Business Wages Govt. Job
		Demography
10	Population	4949
11	Number of Males	2331
12	Number of Females	2618
13	Number of SC families	60
14	Number of ST families	0
		Agriculture
15	Major Crops	Rubber, Areca nut, Coconut, Nutmeg, Banana
16	Marketing	Local
		Land Characteristics
17	Slope	Moderately Sloping
18	Erosion	Severe
		Soil Characteristics
19	Soil Type	Gravelly clay loam

Interpolation technique was used to create the Rainfall raster, "IDW" tool in ArcGIS software was used for that purpose (Figure 3). Several thematic layers were created using that. The coordinate system used was UTM zone 43N. The database was created to store the features in the watershed, which was digitized in ArcGIS 10.2.2. Cadastral boundary shapefiles and study area boundaries were already digitized by CSRD and that was also acquired. Feature classes like Stream network, Road, powerline, contour, and spot heights were created from SOI toposheet. LULC was created from satellite images and direct field visits (Table 2).

2.2. Drainage line survey

The survey on the drainage line was conducted in the study area. All major streams and drains were visited by team members. The survey helped a lot to suggest the various methods to conserve and protect the water bodies. This process was with the help of native people who knows their water bodies. The drainage line was classified into two namely upstream and downstream for deep observation. The upstream section was surveyed on the first day. Due to the presence of bedrock along the line in some parts, it was quite accessible. For the side protection Rubble masonry was seen. The information's about the dam locations which is to be checked was obtained from the Panchayat Representatives. GIS tools were aided for the analysis of submerged areas. Through field observations bedrock was found in the examined area and location preferred for check dams were existing three check dams were also examined.

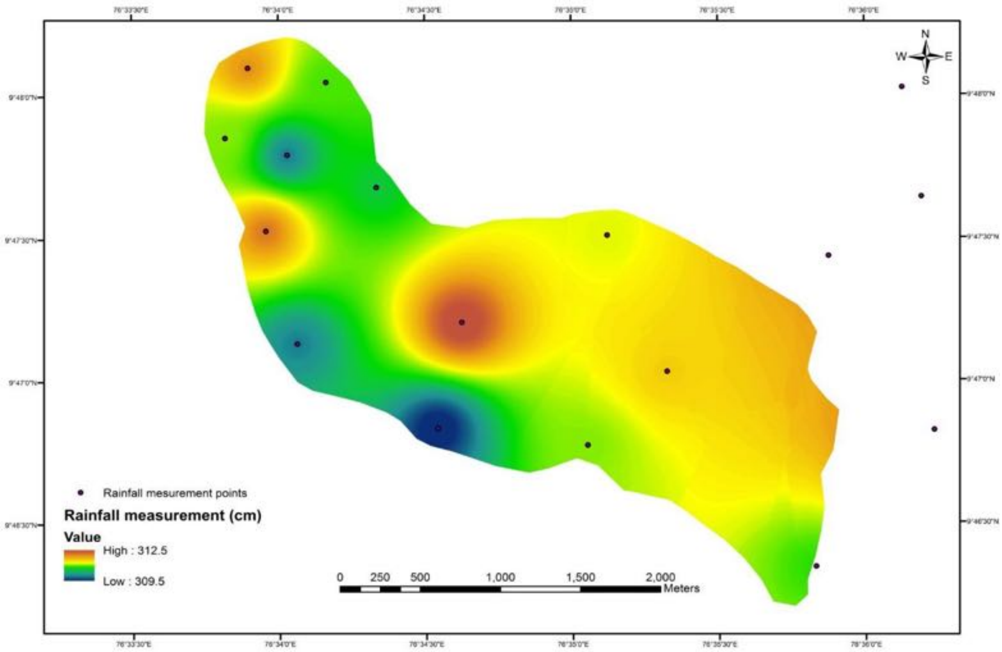

Figure 2. Rainfall distribution raster and measurement points of an entire watershed

The instrument used to carry out a detailed land topographic survey was the Digital Total Station. A detailed land topographic survey was done to point out the limitations while conducting hydrological analysis in the study area using the Digital Elevation Model (DEM) from SOI toposheet. Therefore, a watershed boundary of a small supporting stream was chosen to conduct a total station based detailed topographic survey. The watershed area was of 9.305277 ha, the boundary was delineated by field observation and spot heights were taken along the ridgeline and inside the watershed very frequently. The feature inside the watershed boundary was digitized and several feature classes are created in ArcGIS 9.3. Cadastral details were already digitized by CSRD and we obtained that data. From the cadastral map and SOI toposheet, we created feature classes like roads, power lines, stream networks, survey boundary, and panchayat boundary, block boundary, etc. Land use land cover was created using high-resolution Google earth images and direct field observations. Contour lines of the area were digitized from SOI toposheet (Table 2).

Table 2. Thematic layers with their geometry type and source

No	Thematic Layers	Geometry Type	Source
1	Roads	Line	Cadastral maps, toposheet, CNES/Astrium image
2	Survey field boundary	Polygon	Cadastral map
3	Stream network	Line	Toposheet
4	Watershed boundary	Polygon	Drawn from toposheet

5	Study area	Polygon	Obtained from CSRD
6	Spot heights	Point	Toposheet
7	LULC	Polygon	Drawn from CNES/Astrium image
8	Power line	Line	Toposheet, CNES/Astrium image
9	Contour	Line	Toposheet
10	DEM	Raster	Using Toposheet contours and spot heights as inputs in "topo to raster tool" in ArcGIS

2.3. Conservation priority analysis

Using the weighted overlay technique in ArcGIS 10.2.2 the priority zones for the conservation of soil and water were observed. The factors which contribute to soil and water conservation are, Land use/ Landcover, Slope, Elevation, Stream density, Road density, Distance from the settlement. The weighted overlay was done and the resultant raster shows the priority zone for the conservation and the techniques were taken in the highly problematic area. A multi-criteria evaluation approach was used and criteria source was given according to the importance (Table 3). The priority raster was changed to a polygon in ArcGIS using the "raster to polygon" conversion tool. The "union tool" is used in ArcGIS to unite the output polygon feature and also the survey plot boundary polygon. The attribute of this resultant polygon was examined and plot-level priority was analyzed and concluded.

Along with the present condition of stream and land, treatment plans were selected. According to the survey, the major area was rubber plantation and there was a contour bund so avoided contour bund from conservation methods. While other conservation methods like increase s of vegetation in rubber plantation were adopted to decrease water runoff and to help in water storage. At last, from discussions, we concluded to following conservation methods. They are, Check dam, Gully plugs and Boulder check bund.

Table 3. The influencing factors with their criteria scores and relative influence weightages

Sl. No.	Influencing Factors	Classes	Score	Weightage
1	Land use/ Land cover	Rubber Plantation	3	30%
		Settlements	NoDat a	
		Barren Lands	10	
		Pineapple Cultivation	6	
		Tapioca Cultivation	8	
		Mixed Trees	2	
		Areca Nut	2	
		Water body	NoDat a	
2	Slope (%)	Flat to nearly level (0 – 1)	1	35%
		Very gentle sloping (1 – 3)	2	
		Gently sloping (3 – 5)	3	
		Moderately sloping(5 – 15)	4	
		Moderately steep to steep(15 – 25)	6	
		Steep (25 – 33)	7	
		Very steep (33 – 50)	8	
		Very very steep (>50)	10	
3	Elevation (m) above MSL	High (101.2676 – 145.3019)	10	5 %
		Medium	5	

		(57.2333 -101.2676)		
		Low (13.1990 – 57.2333)	3	
4	Stream density(m/km²)	0.00 – 894.94	1	10%
		894.94 – 1789.88	2	
		1789.88 – 2684.82	3	
		2684.82 – 3579.76	4	
		3579.76 – 4474.71	5	
		4474.71 – 5369.65	6	
		5369.65 -- 6264.59	7	
		6264.59 – 7159.53	8	
		7159.53 – 8054.47	9	
		8054.47 – 8949.42	10	
5	Road density(m/km²)	0.00 – 2555.66	1	10%
		2555.66 – 5111.32	2	
		5111.32 – 7666.97	3	

Coir netting was suggested to the regions with high slopes near to the roads The regions which needed more conserved was found out by analysis land use/land cover (LULC). Vegetation bund (vetiver and agave) were suggested to the areas like barren lands and water bodies. By GIS the location was analyzed and methods of conservation were decided. Roads, LULC, stream network are the thematic layout which was overlaid with priority, slope raster and location were suggested (Table 4).

Table 4. Conservation methods adopted

Sl. No.	Conservation Methods
1	Check dam
2	Gully plug
3	Boulder check bund
4	Vegetation bund (Vettiver and Agave)
5	Coir netting
6	Ground vegetation cover improvement (Pea plant and other common grasses)

The area volume of check dams was obtained by GIS tools. Using create contour tools submergence area of each check dams were found elevation contours were made by adding the height of check dams and the base height of each check dams. Then it is converted to feature by using a tool graphics to feature tool. Since the result obtained was a line feature, it is corrected in the editor which gives check dam width at the outlet. Using feature to polygon tool this line feature is converted to polygon feature. The DEM of the study was put together with the polygon and also check dam elevation raster was made. The volume was calculated using the surface-volume tool in ArcGIS using check dam DEM. The input given was the clipped raster, and the reference plane selected as 'below' and a plane height is given as check dam height. The output was a table depicting the volume and surface area of the check dams.

3. Results and Discussion

Land cover data documents how an area is covered by forests, wetlands, impervious surfaces, agriculture, and other types of land and water. Water types include wetlands or free water. Land use shows how people use the landscape - whether for the development, conservation, or mixed uses. The different types of land cover can be managed or used differently. Land cover can be determined by analysis of satellite and aerial images. Land use cannot be determined from satellite images. The land cover maps provide information to help managers better understand the current landscape (Figure 4, Table 5). To see the changes over time, the land cover maps for several different years are needed. With this information, managers can assess past management decisions, as well as gain insight into the possible effects of their current decisions before they are implemented. The results of the distribution of various influencing themes are following.

3.1. Land use/ Land cover

The slope is a measure of elevation change. It is a crucial parameter in several well-known predictive models used for environmental management, including soil loss equation and universal agricultural pollution models of non-point sources. One way to express the slope is expressed as a percentage (Figure 5).

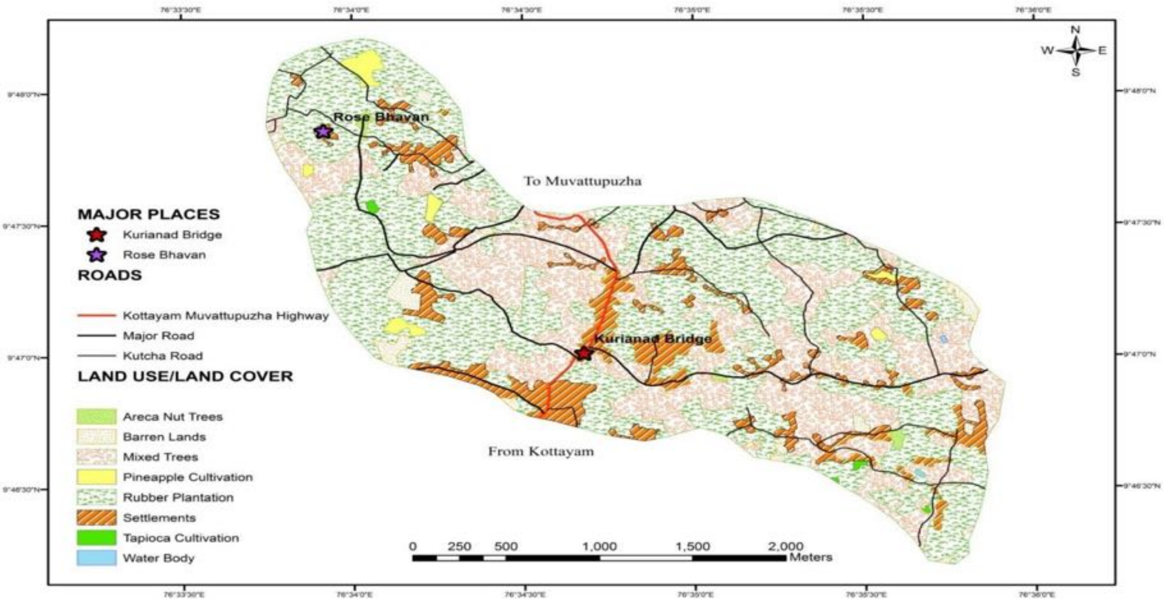

Figure 4. Land use/Land cover of the study area along with roads and major locations.

Table 5. Extent of various Land use/ Land cover types in the study area

Code	Description	Area (ha)	Percentage (%)
1	Rubber Plantation	334.1	51.24
2	Settlements	74.14	11.37
3	Barren Lands	12.47	1.91
4	Pineapple Cultivation	7.79	1.19
5	Tapioca Cultivation	1.08	0.17
6	Mixed Trees	222.08	34.06
7	Water Body	0.31	0.04

To calculate the percent of the slope, split the difference between the heights of the two points by the distance between them and multiply by 100. The height difference between the points is called up. The distance between points is called the race. Thus, equal percent slope (rise / run) x 100. Stream density is the length of all channels in the basin divided by the area of the basin. Gravity flow is one of the most important features for the evaluation of the flow potential.

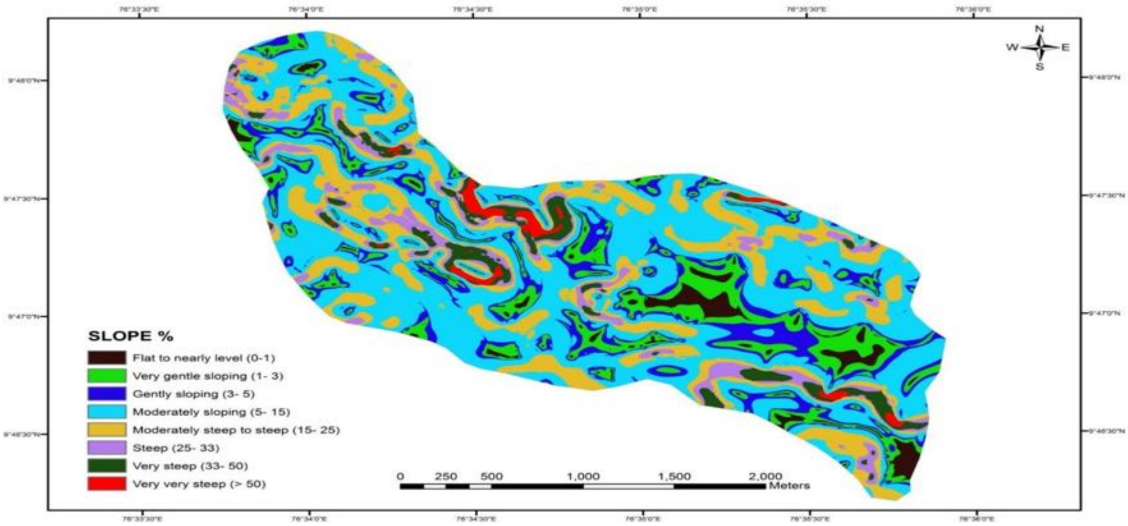

Figure 5. Distribution of slope (%)

A drainage basin with many tributaries has a current density above a basin with very few tributary streams. A higher flux density allows the landscape to drain more efficiently following a storm. More effective means of drainage water that moves in the streams and creeks faster, causing the storm peak flows.

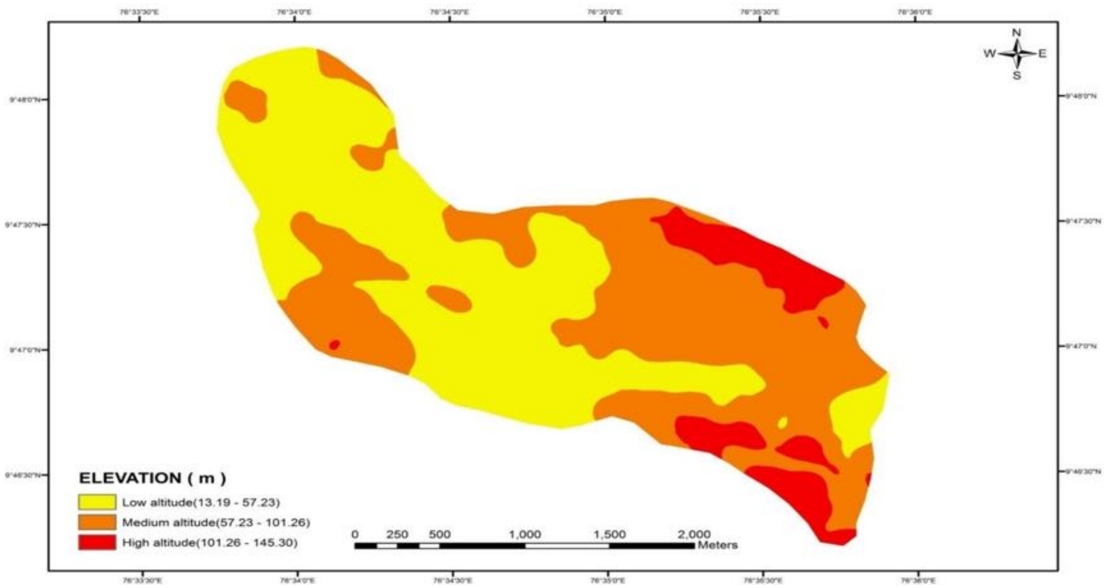

Figure 6. Distribution of elevation (m above MSL)

A pond with a lower current density usually indicates a deep, well developed (Figure 6). In this case, water is more likely to soak into the ground rather than become surface runoff and enter the canal system. Urbanization typically leads to changes on the ground and course surfaces of natural pool water (Figure 7). The permeability of the surface, the size of the basin, the current density, surface roughness, and the channel length and slope can all be affected in a manner that leads to greater amplitude and speed of flow. In urban areas, the greater coverage of the road, buildings and compacted soil prevents the infiltration of precipitation and snowmelt over the natural soil surface (Figure 8). This can dramatically increase the magnitude of runoff. Urban features such as dikes and road berms can act to break the natural pools in smaller sub-basins. Small drainage reacts much more quickly to localized rainfall as large ponds. The roads, ditches, and storm sewer systems act as a network of tributaries and effectively increase the density streams (Figure 9). The rise in flux density results in the flow faster in the flow channels.

Compared to a bed during natural water, road surfaces, culverts, and storm drains have smooth surfaces. This reduction in surface roughness allows the flow to move much more quickly to the main channel flows it would be in a more natural setting. Streams in urban areas often have vegetation removed and are sometimes lined with concrete in a process called "channelization". This also decreases the roughness and causes the water velocity to increase. Sometimes in the course of urban streams recovered in channels having removed meanders. This reduces the distance that the water from the top to bottom of the drain pan. It also effectively increases the slope because the flow is now experiencing the same drop in elevation, but in a shorter distance.

3.2. Raster Reclassification

The reduction of the distance and increasing the slope will result in a faster response to the flood runoff. Overall, the urban environment will result in a faster runoff with more runoff reaching streams than in a rural environment. Current density, also known as drainage density varies from one watershed to function infiltration capacity, or the soil's ability to absorb water. When the infiltration is low, the water surface of the flow and shape of currents. Some types of geology (such as sand, gravel, or limestone) have high infiltration, while others (such as shale or clay) have low infiltration. High density with watersheds of rivers has the highest runoff and land that is more susceptible to erosion. The topography and slope also affect infiltration, with greater flux density occurring in areas with steep slopes.

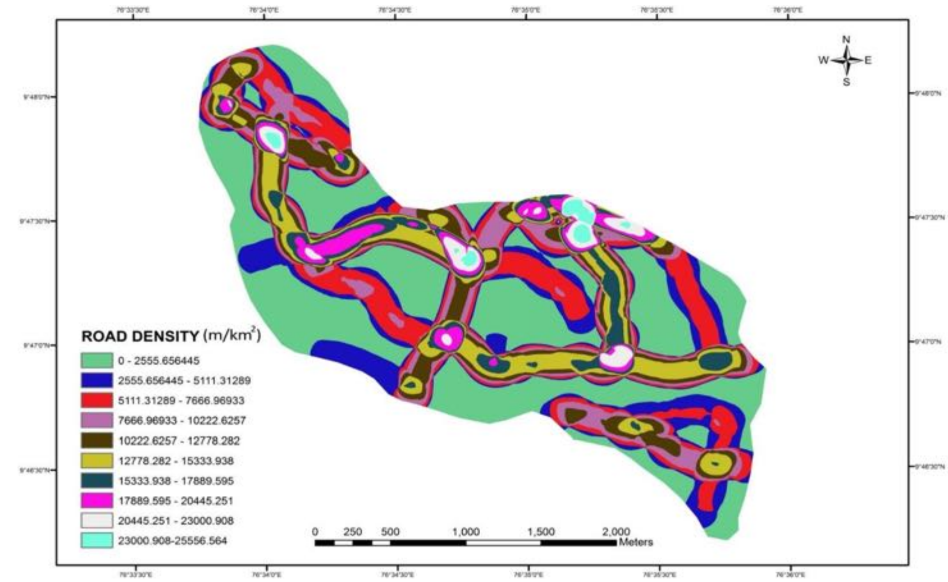

Figure 7. Distribution of road density

Heavy rainfall tends to increase the density flow, but in areas where the highest rainfall, the flux density can be reduced; dense vegetation in these zones subject to rain reduces the flow surface and evapotranspiration increases (the transfer of water from the earth in the atmosphere by evaporation and transpiration from plants leaves). Current density is an important characteristic watershed which may be a power indicator potential water. About 60% of the drinking water supplied to the public, most of the water. A settlement is a place where people live. A settlement could be something of an isolated.

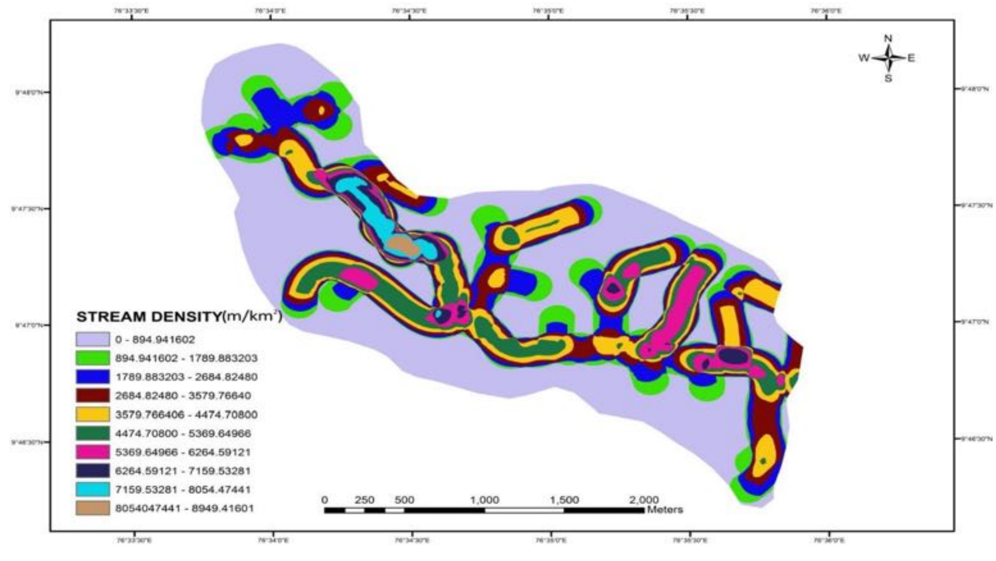

Figure 8. Distribution of stream density

farm in a megacity (settlement with more than 10 million people). Regulations can be temporary or permanent. Temporary facilities include items such as refugee camps. Some temporary settlements have become permanent over time. The reason why a first developed settlement is said to function. The pattern made by the way of man is distributed over the surface of the world's land surface is of prime importance to the geographer and is at the heart of its contribution to any analysis of the man and his behavior. A score range of 1.5 to 8.9 was shown by the resultant cumulative conservation priority raster (Figure 10). This was further divided into five conservation priority zones. The percentage of the area with the total area and the area priority zones are listed below (Figure. 11, Table 6). Percentage based on the area of the entire study area.

3.3. Watershed treatment plan

The unscrupulous exploitation of natural resources of the land posed a threat to sustainable development. The primary concern of the Department of Soil and soil conservation is to ensure that our natural resources are conserved dwindling today and kept for posterity. Human existence requires intervention. Water is the most critical input for agriculture. Sixty percent of our farms are rainfed. Inventorying resources undertaken as part of the soil survey work sheds light on the state of natural resources, limitations, and improvement measures. Stress is now given for the management of the Trinity valuable resources of soil, water, and biomass through the conceptualization of various soil conservation programs and water. It also promotes in situ conservation and harvesting rainwater to increase the surface and groundwater resources (Figure 12).

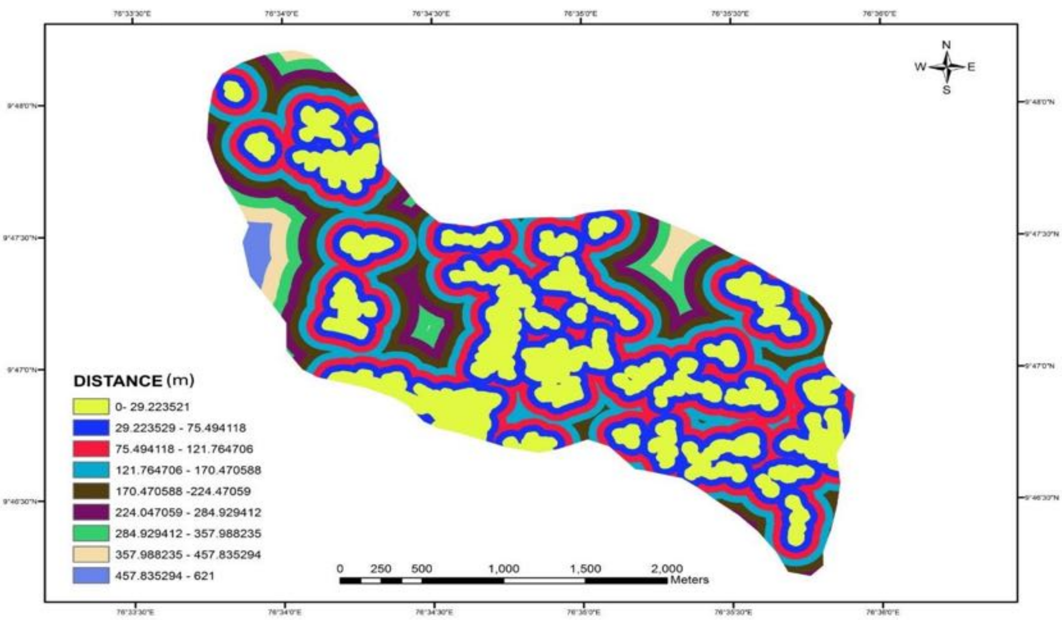

Figure 9. Distribution of distance from settlements

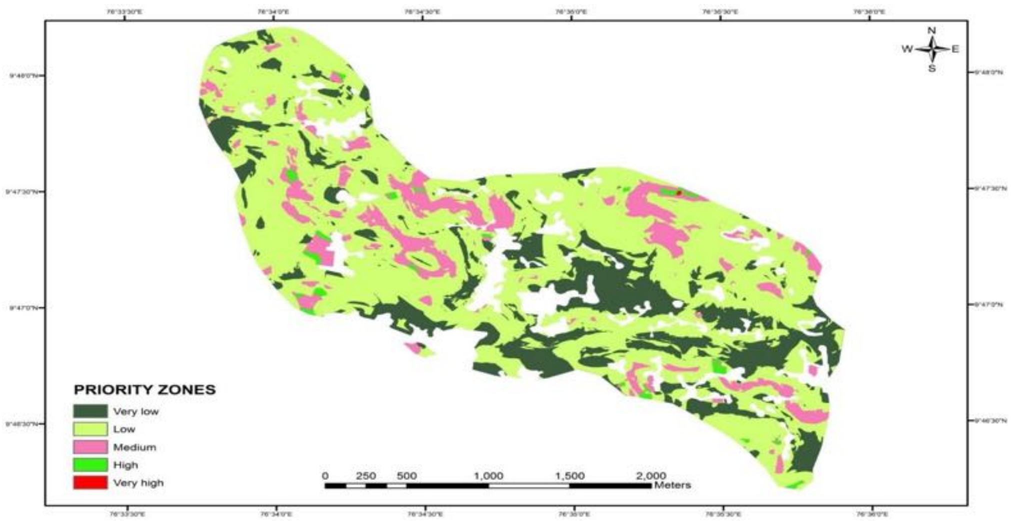

Figure 10. Priority zones for soil and water conservation in the study area (White areas indicate areas covered with built-up)

Table 6. Details of a conservation priority zone

Sl. No.	Priority Zones (Cumulative Priority Score)	Area (ha)	Area (%)
1	Very high (7.42 – 8.9)	0.086	0.013
2	High (5.94 – 7.42)	5.81	0.88
3	Medium (4.46 – 5.94)	64.31	9.83
4	Low (2.98 – 4.46)	383.31	58.61
5	Very low (1.5 – 2.98)	126.18	19.29

Site-specific watershed treatment plans proposed are depicted in the map given below. The check dam submergence area and volume were found out using the 'surface volume' tool in GIS (Table 7-8).

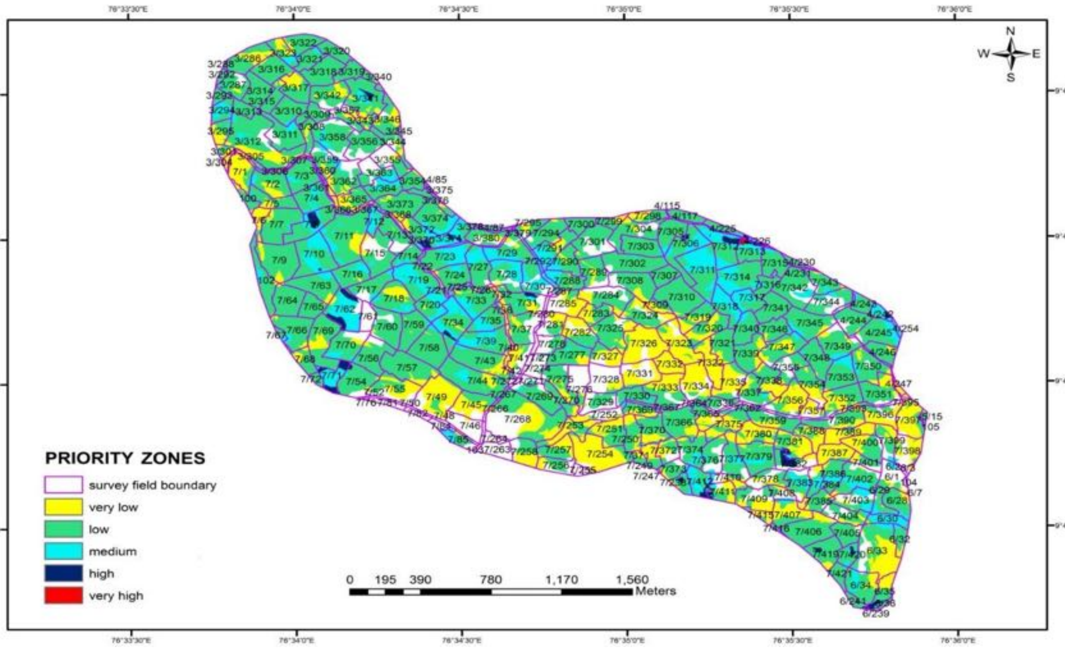

Figure 11. Priority zones with survey plots (White areas indicate areas covered with built-up)

The success of watershed development depends primarily on the holistic approach in which arable and non-arable land given priority in treatment. The positive impact of the watershed program reflected in the increased number of beneficiaries adopting soil conservation measures such as contour bunds, earthen dike construction, and mulching, terracing.

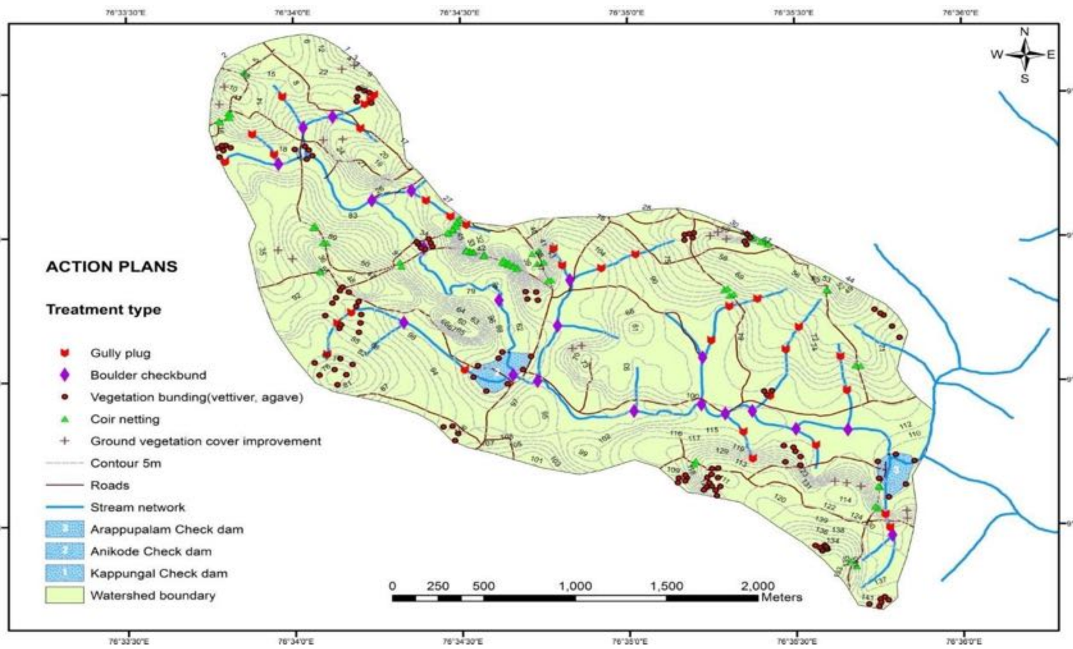

Figure. 12 Watershed treatment plans proposed along with check dam submergence area

Water harvesting techniques like rain bites, dig wells, and renovation contributed to enhancing the depth of the water in the watershed web. There was a significant increase in water resource levels of the beneficiaries, indicating a positive effect on the regime of moisture and groundwater recharge. There has been an increase in job creation due to the increased use of labor in activities related to agriculture during the post-project period. Increasing crop productivity due to various factors such as work-human use has increased, increased manure application, and increased moisture availability were translated into higher farm incomes in nominal terms and the real terms.

Table 7. Conservation methods used and its count

Sl. No.	Conservation Methods	Count
1	Check dam	3
2	Gully plug	32
3	Boulder check bund	20
4	Vegetation bund (Vettiver and Agave)	118
5	Coir netting	75
6	Ground vegetation cover improvement (Pea)	18

Table 8. Check dam - submergence analysis results

Sl. No.	Check Dam	Surface Area (m2)	Volume (m3)
1	Kappungal	5071.10	2149.68
2	Anicode	20103.18	11671.49
3	Arappupalam	12320.76	7731.92

4. Conclusion

Watershed development programs have shown some changes in livestock production systems using the increased amount of feed, improved livestock management systems, etc. However, the project could have a significant impact on the distribution of crops and cropping intensity in the watershed area. No effort was made to implement conservation measures in non-arable land. The project has not responded to women based activities, landless households, and fuel wood availability. However, people were women who benefited indirectly through livestock-related activities. There was a reasonable level of public participation in project planning and implementation of the project. The nonavailability of water for irrigation, inputs, and unavailability grant, failure of the approved amount, lack of awareness about the beneficial program, lack of supervision and monitoring, and lack of technical advice are the main constraints perceived by the beneficiaries. To summarize, the watershed development program has resulted in increased production, productivity, job creation, agricultural income, and status of groundwater leading to overall rural prosperity in the region.

Hydrological analysis done by using the detailed topographic survey was very much accurate and the results obtained are very useful for detailed treatment and operational planning of the selected micro-watershed. Hydrological analysis using the SRTM DEM or DEM created from contours and spot heights from toposheets will not give pleasing results as it does not have exact elevation data or resolution like detailed topographic survey. The treatment plans adopted in our study area using DEM (created using toposheet) will not be as effective as results of detailed topographic survey. Soil data was not used in the analysis process as it was not available in time; this is the major drawback of the results obtained. The result does not consider the soil type of the location which is a limitation; soil type can affect the runoff, erosion, water holding of the region. Even then, the watershed treatment plan generated through this study can be used for field implementation because there is no much variation in soil characteristics as revealed by local farmers.

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