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Soil and Water Conservation of Manimuktha Watershed – A Case Study

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Abstract— Watershed is a collection of water related components that include climate, water, soil and plants. The behavior of each component is controlled by its individual nature as well as by its interaction with other components. Watershed management implies the proper use of all land, water and natural resources of a watershed. In India, watershed based activities were initiated in 1956 by Central Soil and Water Conservation Research and Training Institute, Dehradun, followed by operational research projects in 1974. It is a well known fact all forms of natural resources are being rapidly exploited due to growth in population, increased industrial activities, urbanization, etc. But many of the natural resources available in the earth, including the precious water is finite one. So as to satisfy the growing needs of mankind in the areas of food, clothing and shelter the agricultural lands are being over exploited in the present situation, which leads to degradation of all forms of cultivable lands. This is mainly due to modern agricultural practices such as chemical fertilizers, pesticides, water logging, salinity problems, mono cropping, and climatologically imbalances. This results in soil erosion, depletion in soil fertility and total degradation of land environment. Keeping these factors in mind, this project work is aimed to study the soil properties and farm practices in a watershed, and it is proposed to recommend suitable conservation measures and techniques to sustain the wealth of the soil. This study will be carried out by watershed approach. In Tamilnadu most of the districts are drought prone. Therefore a drought prone rural ungaged watershed, a sub watershed of Manimuktha watershed (4C1A2c) of velar basin, Tamilnadu, India is taken up in this study. A watershed database is created using remote sensing data and GIS. A rainfall – runoff model is constructed on the basis of the Soil Conservation Service - Curve Number (SCS-CN) technique by using GIS. Monthly and annual runoff values are obtained from the daily runoff values of the watershed. In this study, water and land resources are attempted for soil and water conservation and management. PC Arc/Info GIS software is used for analysis. The developed rainfall – runoff model can be used for better water resources management of the watershed.

Index Terms— Watershed, Modelling, Soil Consrvation and Management.

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1 INTRODUCTION

Water is the main life supporting ingredient of world. Its availability varies from spatially and time to time and depends upon the precipitation. Its life cycle is characterized by hydrologic cycle, which has neither origin nor destination; therefore water is called the elixir of life. The quality and quantity of water resources in the developing countries are reduced and degraded due to rapid growth in population, urbanization and industrialization. Nowadays researchers emphasize watershed based water resources planning and development for successful management practices. A watershed is a topographically delineated area that is drained by a stream system, i.e. the total land area above some point on a stream or river that drains past that point. The watershed is a hydrologic unit that often is used as a physical-biological unit and a socio-economic political unit for the planning and management of natural resources. The watershed characteristics such as size, shape, slope, drainage, vegetation, geology, soil, geomorphology, climate and land use pattern affect the disposal of water from the watershed (**Murthy, 1994**). The watershed management is to protect the proper utilization of all land, water and natural resources of a watershed. The international classification and codifications of watershed are insisted recently for proper planning and better management of water resources on global basis (**Khan, et al. 2001**).

Remote sensing and GIS are playing a rapidly increasing role in the field of hydrology and water resources planning and development. Remote sensing and GIS, with the integration of socio-economic data is very useful for watershed planning and management. The combined GIS and remote sensing technology is an excellent tool for monitoring, land degradation, land use changes as well as soil and water resource changes over space and time. Remote sensing is used for data acquisition on earth resources whereas GIS is used for data analysis. When these two tools are integrated in the research programme, an efficient solution is arrived at to solve any complex problem (**Burrough, 1996**). Watershed management demands large volumes of data that are not practical to work within a non-computerized setting. GIS has proven ability to handle such spatial and non-spatial data analysis issues. The Spatial data sets are heterogeneous in nature and may be derived from text, maps, charts, ground information, organization, aerial photographs and satellite imageries. The management and analysis of such large volumes of spatial data requires a computer-based system called Geographic Information System (GIS), which can be used for solving complex geographical and hydrological problems. (**Agarwal and Garg, 2000**).

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2 SOIL AND WATER CONSERVATION – AN OVERVIEW

Land and water are the most precious natural resources, the importance of which in human civilization needs no elaboration. The total available land area in the State sets the limits within which the competing human needs have to be met. The needs of agricultural, industrial, domestic and others often result in diversion from one use to the other.

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Diversion of land from agriculture to non-agriculture uses adversely affects the growth in agriculture sector. Even the available land is subjected to soil-erosion of varying degrees and degradation problems of different magnitudes. Water supports all forms of life on this mother earth and it plays a vital role in agricultural and industrial development and sustaining human life.

2.1 Soil Conservation Measures

Crops and vegetables which cover the ground surface well and have extensive root system reduce soil erosion. Plant canopy protect the soil from the adverse effect of rainfall. The grasses and legumes produce dense sod which helps in reducing soil erosion. The vegetation provides organic matter to the soil. As a result, the fertility of soil increases and the physical condition of soil is improved. Following cropping systems help in controlling soil erosion,

Crop rotation: Crop rotation is planned sequence of cropping. Rotation of crop is an important method for checking erosion and maintaining productivity of soil. A good rotation should include densely planted small grain crops, spreading legume crop etc. which may check soil erosion.

Strip Cropping: It consists of growing erosion permitting crop (e.g. Jowar, Bajra, Maize etc.) in alternate strips with erosion checking close growing crops (e.g. grasses, pulses etc.). Strip cropping employs several good farming practices including crop rotation, contour cultivation, proper tillage, stubbles mulching, cover cropping etc. It is very effective and practical means for controlling soil erosion, specially for gently slopping land.

Cultivation of dense plant and grasses: Sod forming crop such as lucern (medicago sativa L), Egyptian Cloveror. Berseem (Trifolium alexandrinum), ground nut (Arachis hypogea L), Sannhemp (Crotolaria juncea), grass etc. cover the surface of the land and their roots bind the soil particles to form soil aggregates, thus preventing soil erosion.

Cultivation of proper crops: Cultivation of row crop in sloppy lands permits soil erosion. In this filed, the crops particularly cereals, fodder crop etc. should be broadcasted and the plants remain haphazardly in field. As a result, the movement of water gets obstacle and more water is absorbed in the soil, thus reducing soil erosion.Mixed and intercropping (Cowpea-Vigna catjang, with cotton – Gossipum Sp, maize – Zea mays with soyabean – Glycine max etc.) practice checks the soil erosion and avoids the risks of the crop failure.

The land should not be kept without crop: There is very scope of soil erosion if there are no crops on the land. The soil erosion decreases in different way of cropped land.

Afforestation: Afforestation means growing of forests where there were no forests before owing to lack of seed trees or due to adverse factors such as unstable soil, aridity or swampiness. Along with afforestation, reforestation should be undertaken which means replanting of forests at places where they have been destroyed by uncontrolled forest fires, excessive felling and lopping. Afforestation is the best means to check the soil erosion.

Mulching: Mulches of different kinds such a leaves, straws, paper, stubbles, etc. minimize evaporation and increase the absorption of moisture and protect the surface of the land against the beating action of rain drops. Later on they decay to form humus which improves the physical condition of soil. Natural mulching also helps in the infiltration of water and the reduction of evaporation.

Organic manure: Organic manures improve the soil structure. The crumb and granular structure increases the infiltration and permeability in the soil and conserve the soil water. Consequently soil erosion decreases.

Control of grazing: Grazing increases the soil erosion. But the grazing cannot be completely stopped in all areas. So the restricted and rotational grazing may be helpful in checking soil erosion to some extent. The area open to grazing for sometimes should be closed for the following year to facilitate regeneration of forests and to maintain thick ground vegetation.

Good tillage: Tillage is the mechanical manipulation of soil by different kinds of implements. Tillage makes the soil loose and friable which helps in retention of water. The special method of tillage practices should be followed for the conservation purposes. Tillage may consist of several types of soil manipulation such as ploughing, harrowing, cultivation etc.

Contour bunding: Contour bunding consists of building earthen embankment at intervals across the slope and along the contour line of the field. A series of such bund divide the area into strips and act as barrier to the flow of water. As a result, the amount and velocity of run-off are reduced, resulting reducing the soil erosion. Contour bunding is made on land where the slope is not very steep and the soil is fairly permeable. Contour bunds are also called level terraces, absorbtion type terraces or ridge type terraces.

Terracing: A terrace is an embankment of ridge of earth constructed across the slope to control run off and to minimize soil erosion. A terrace reduces the length of the hill side slope, thereby reducing sheet and rill erosion and prevents formation of gullies. There are different types of terraces as follows:

Bench terracing: It consists of transforming relatively steeps land into a series of level or nearly level strips or steeps running across the slope. The soil materials that are excavated from the upper part of the terrace is used in filling the lower part and a small bund is also raised along the outer edge of the terrace to check the downward flow of rainwater and also soil erosion.

Channel terrace: It consists of making of wide but shallow channels across the slope of the land either exactly on contour line or with a slight grade (0.1 to 0.2 per cent). In this process, the excavated soil is placed along the lower edge of the channel in the form of low ridge.

Narrow based terrace: It consists of making a number of narrow based ridges or bunds at a distance of 1m to 2m across the slope of the land at suitable intervals in high rainfall areas.

Broad based ridge terrace: It consists of making wide but low bunds on the contour lines by excavating soils from both sides of terrace. This is practiced in areas where the rainfall is relatively low.

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Contour trenching: It consists of making a series of deep pit (i.e. 2ft. wide and 1ft. deep) or trenches across the slope at convenient distance. The soil excavated from the trenches is deposited on the lower edge of the trenches where forest trees are planted.

2.2 Appripriate Strctures and Their Functions

To increase the period of water availability and overcome water scarcity in drought years, the following activities can be implemented in the field for a compact, viable watershed of about 200 - 500 ha. Soil and water conservation can be approached through agronomic and engineering procedures. Agronomic measures include contour farming, off season tillage, deep tillage, mulching and providing vegetative barriers on the contour. These measures mainly prevent soil erosion but will also help in improving soil moisture availability in the watershed.

The engineering measures adopted differ with location, slope of the land, soil type, amount and intensity of rainfall. Depending on these parameters, the methods commonly used are contour trenching, contour stone walls, construction of temporary and permanent check dams and gully plugging structures. Additionally, percolation ponds, silt detention tanks and irrigation tanks are constructed to harvest water and recharge it to the groundwater for use in agriculture (irrigation).

2.3 Study Area

A sub watershed of Manimuktha watershed (4C1A2c), Vellar Basin, Tamilnadu, India is considered for this study. The study area extends between North Latitudes 11° 30′ to 11° 53′ and East Longitude 78° 55′ to 79° 13′ with an area of 295.852 km^2 (Figure 1). The main tributaries of Vellar are Vasista nadhi, Sweta nadhi, Manimuktha nadhi and Gomukhi. The Vellar river flows through the Cuddalore, Villupuram, Salem and Trichy districts of Tamil Nadu. The river originates from the Southern slopes of Kalrayan hills at the Northern boundary of Attur Taluk of Salem District. The river then flows in an easterly direction, crosses the Kumbakonam–Villupuram road through Sethiyathope regulator and finally empties into the Bay of Bengal near Portnovo in Chidambaram Taluk of Cuddalore district. Basically this is rural watershed with more than 67% of croplands. The main water source is tanks and dug wells apart from rainfall. The study area comprises Kallakurichi, Rishivandiam and Tiyagaidurgam blocks. The watershed experiences tropical monsoon climate, with not much variation in temperature, humidity and evaporation throughout the year. The monsoon season in the watershed is from June to December and non-monsoon season from January to May. The Northeast monsoon (October-December) is hydrologically significant for this watershed. The temperature is generally high during the months of April, May and June with maximum of 40° C during summer and minimum of 20° C during winter. The Manimuktha Nadhi rain gauge station is considered for this study. The maximum rainfall of 1737.5mm was recorded in the year of 1996 and the minimum rainfall of 329.5mm was recorded in the year 1974.

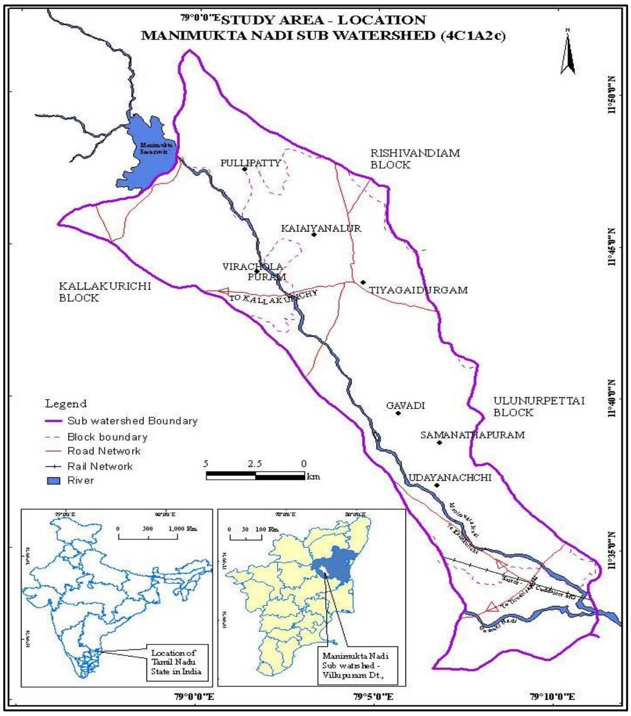

Figure 1 Location map of the study area

2.3.1 Climate and Rainfall

Throughout the year this watershed experiences tropical monsoon climate without much variation in temperature, humidity and evaporation. Both Northeast monsoon (October-December) and Southwest monsoon (June-September) are hydrologically significant in this watershed. The temperature is generally high during the months of April, May and June with a maximum of 40° C during summer and a minimum of 20° C during winter. This is an ungauged sub-watershed. The rainfall is generally heavy during low pressure depressions and cyclones during the Northeast monsoon period.

2.3.2 Physiography and Drainage

The area is physiographically characterized by an undulating terrain. The terrain between plains and the hills are generally 90m to 600m above mean sea level with a low lying plain at the central part of the area. The ground slope is gentle towards coast. The residual hills, shallow pediments and buried pediments are common in central part of the district. The central part of the area is drained by Manimuktha Nadhi. Southeastern part of the area is drained by Vellar River. There are a number of non-system tanks, which carry only flood waters during rainy season as shown in drainage map of the study area (Figure 2). The drainage pattern is mostly parallel to sub-parallel and drainage density is low.

2.3.3 Geology and Geomorphology

Geologically, hard rocks such as Charnockite and Hornblende Biotite Gneiss with weathering depth varying from 1 – 20 m underlie the area. This formation was deeply weathered in the Tertiary period. Hard crystalline metamorphic rock types,

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underlain by charnockite and gneissic rocks, cover the area. Arechaean crystalline Gneissic rocks are the oldest rocks in this area (Figure 3). The largest group of rocks is charnockites exposed in residual hills. Different geological environs like hard crystalline formations etc. underlie this watershed. The landforms are also quite varied from mountainous regions, residual hills, pediplains etc. The geomorphological set up in this area vary from dissected hilly regions in the west to undulating plains with residual hills in the middle portion and gently sloping ground towards coast. Buried pediment deep and buried pediment shallow, pediments with low lineament density exist in this hard rock region.

2.3.4 Soil

Chromic Haplusterts, Typic Haplustalfs - Chromic Haplusterts, Typic Haplustalfs - Typic Rhodustalfs, Typic Rhodustalfs, Typic Rhodustalfs - Typic Ustropepts, Typic Rhodustalfs-Vertic Ustrapepts, Udic Haplustalfs - Udic Rhodustalfs, Udic Rhodustalfs, etc are found in the study area (Figure 4). Soil is inherently low in fertility and has sandy texure, with low cation exchange capacity. The common colour of soil found in the study area is reddish brown.

2.3.5 Land Use/ Land Cover

The most predominant land use found is agricultural land covering 77% of the area. Water bodies and wastelands were identified to covering about 6% and 7% area respectively.

2.3.6 Slope

Major part of the area falls under nearly level sloping (0-1%) to very gently sloping (1-2%) category.

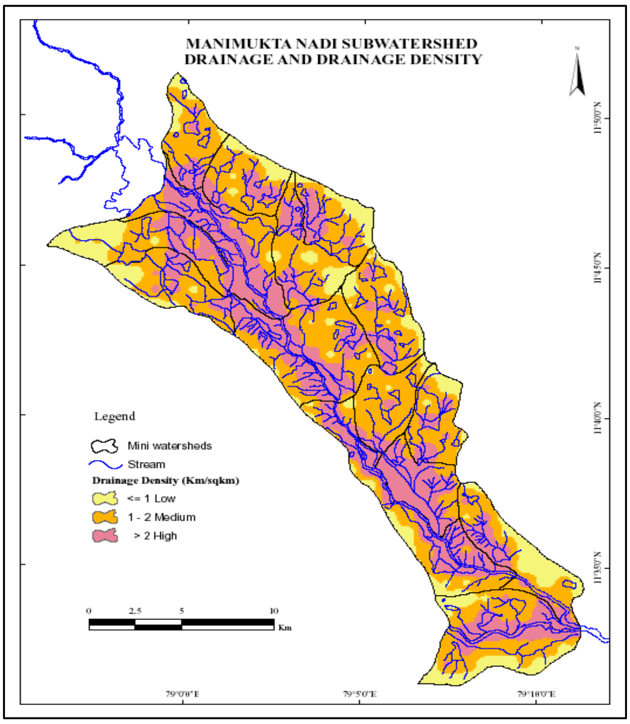

Figure 2 Drainage map

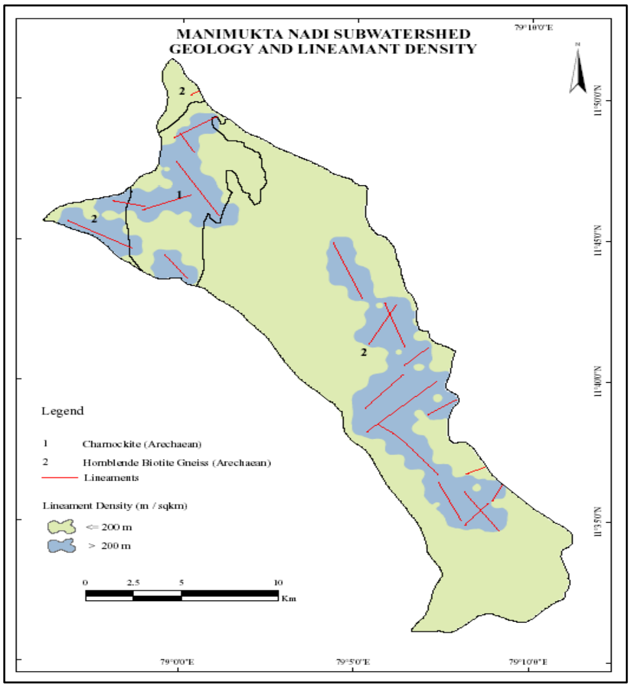

Figure 3 Geology and Lineament map

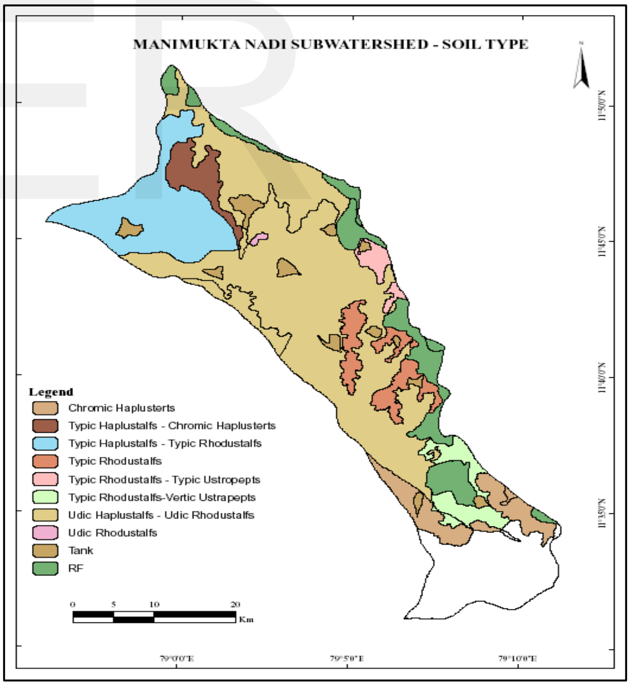

Figure 4 Soil map

3 DATABASE AND METHODOLOGY

Assessment of water resources of a watershed is vital for its sustainable development. The water resources development programmes for a watershed can be done effectively by developing water resources database of the watershed, which needs a large volume of multidisciplinary data from various sources.

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A detailed watershed database is created using remote sensing data, GIS, data from various Government departments, field verification and personal enquiries. Surface water resources are to be quantified properly to narrow down the gaps between demand and supply in the watershed. GIS based SCS method is used to compute the daily runoff from the study area. The SCS method may be used as a tool to define the effects of Best Management Practice (BMP) on direct runoff of watershed efficiency **Park, *et al*. (1994)** and **Karmegam, *et al*. (1994)**.

3.1 SCS – CN Method: An Overview

The Soil Conservation Service (SCS), United States Department Agriculture (USDA), is used to estimate surface runoff volume from the rainfall depths. This method takes into account the land use, hydrological soil cover and antecedent moisture conditions for predicting the yield from the basin. The empirical relationship is:

$$Q = \frac{(P - 0.3S)^2}{(P + 0.7S)}$$

which is the rainfall-runoff relation used in the SCS method of estimating direct runoff from storm rainfall.

3.2 Watershed Database

This study was largely based on secondary data sources and their analysis. Some of the data collected from secondary sources included rainfall, land use, cropping pattern etc. The verification of secondary data is done during field visits and personal enquiries and observation. The following data re used in this study:

- The study area has been delineated from four Survey of India (SOI) Toposheets (1971-72), namely 57 I/13, 14, 58 M/1 and 58 M/2 of scale 1: 50,000. The mini and micro watershed map is also prepared.
- Remote Sensing Data**:** The IRS I - C, False Colour Composite, LISS – III data of scale 1: 50,000 (Table 1) is used to study the soil type and land use of the watershed.

Table 1 Details of remote sensing data

Sl. No.	Topo Sheet No.	Date of Pass	Path and Row	Source
1	57 I/13,14	05-05-96	101/065	Institute of Remote Sensing (IRS), Anna University, Chennai
2	58 M/1,2	05-05-96	102/065	

- Daily rainfall data (1995-2004) and Monthly rainfall data (1971-2003) of Manimuktha Nadhi rain gauge station are used. (Source: Ground Water Division, PWD and Department of Statistics, Chennai).
- Soil and water conservation practices (4C1A2 c_1) in the study area are collected (Source: Agricultural Engineering Department, Kallakurichi).
- Agricultural data on cropping pattern and crop Calender details of the study area (Table 2).
- The annual and seasonal rainfall (1971-2002) in Manimuktha-nadhi rain gauge station.

Table 2 Cropping pattern and crop calendar

Sl. No.	I Crop	II Crop
1	**Paddy**	
	Kuruvai (June – October)	**Thaladi** (October – February)
	Samba (July – December)	**Navarai** (December – May)
	Swarnawari (April – August)	-
2	**Groundnut** (January – May)	-
	Sugarcane (March – December)	-
	Cotton (February – August)	-
	Ragi (January – April)	-

4 RESULTS AND DISCUSSION

This methodology utilized the commonly available database of watershed and analyzed for developing runoff watershed models. A lumped parameter runoff watershed model is constructed to estimate the daily runoff from the watershed by using USDA – SCS Curve Number technique. This method is widely used to estimate runoff volume from the daily rainfall depths. For computing runoff land use, hydrological soil cover and antecedent moisture condition factors are to be considered for predicting the yield from the sub watershed.

4.1 Hydrological Soil Map

The area of hydrological soil groups B, C and D are found in the entire study area of sub watershed (4C1A2c) in the proportion of (1.35), (72.19) and (26.46). The major portion of hydrologic soil group 'C' is under the characteristics of moderate runoff potential and slow water transmission and the soil groups 'B' and 'D' is minimum area occupied which has moderate and high runoff potential and very slow transmission of water.

Generally in this sub watershed of Manimuktha watershed area, (4C1A2c) the rate of infiltration is Moderate (3.81 to 7.81mm) to Very slow (0 to 1.24 mm). The Figure 5 shows the soil map of hydrological soil group in the study area.

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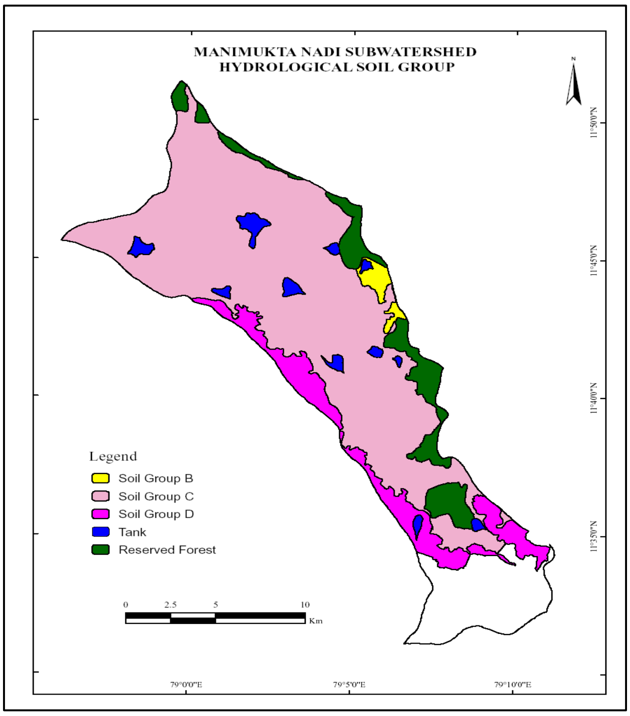

Figure 5 Hydrological soil group map

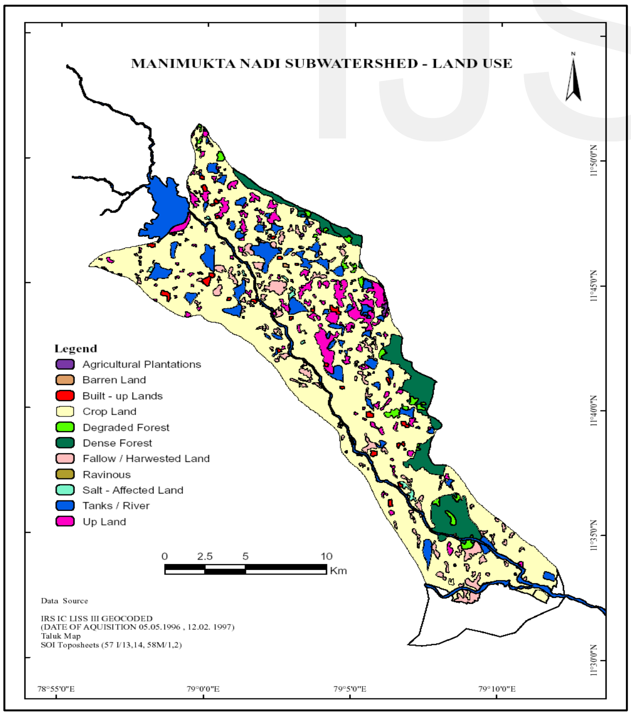

Figure 6 Land Use map

4.2 Land Use Map

The analysis of land use map prepared for the year 1996 from IRS-1C, FCC, LISS-III satellite imagery indicates that the study area is having the area of land use of eleven categories viz. Agricultural plantations, Built-up lands, Crop Lands, Degraded Forest, Dense Forest, Fallow\Harvested Land, Gullied\Ravinous Land, Salt Affected Land, Tanks\Lakes, Upland with\without scrub and Barren Land are in the ratio of (0.09 : 0.89 : 66.60 : 1.29 : 7.44 : 10.48 : 0.02 : 0.43 : 6.38 : 6.35 : 0.03) for sub watershed of Manimuktha sub watershed (4C1A2c) and Figure 6 shows the Land use map of the study area. The integrated map of Land use and Hydrological soil group of the study area is shown in Figure 7.

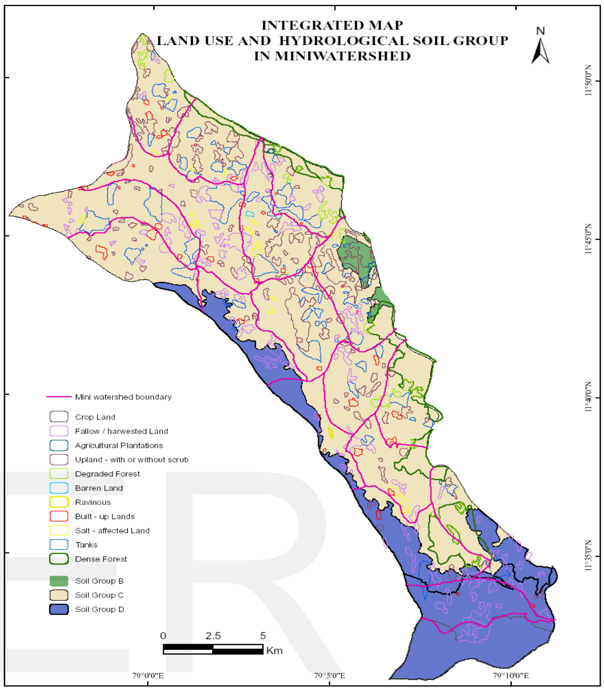

Figure 7 Integrated map of Land Use and Hydrological Soil

4.3 Surface Water Assessment

A lumped parameter runoff watershed model is constructed and loosely coupled with GIS to estimate the daily runoff from the watershed. Regression analysis of monthly and annual rainfall runoff values is done and a linear regression equation is obtained. The results are obtained is useful for water management and irrigation scheduling of the watershed.

4.3.1 GIS based SCS – CN Model

The monthly and annual rainfall runoff values are presented in Table 3 and 4. Monthly maximum runoff of 423.690mm (125.35 Mm3) is noted during December 1996 and a monthly minimum of 0.050mm (0.015 Mm3) is noted during September 1999. From the monthly values of runoff the irrigation scheduling and crop rotation can be carried out successfully. Accordingly in the study area, proper water management for irrigation can be planned efficiently (Figure 8). The annual runoff is more during 1996-97 (247.152 Mm3) and less during 1998-99 (20.479 Mm3) vide Table 4. By using more number of years of rainfall data, a realistic rainfall runoff modeling is possible for better watershed management.

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From the annual values of runoff, the good, average or bad year with reference to the rainfall runoff occurrence may be categorized for the watershed. By assessing the variation in annual runoff, water allocation for irrigation can be done. If the runoff is poor, then the farmers could be informed in advance to use groundwater or rotation of cropping pattern for their cultivation instead of surface water. Thus a real world model can be arrived at for the efficient water management of the watershed. A monthly and annual runoff regression model is developed as shown in Figures 9 and 10.

4.3.2 Monthly Rainfall and Runoff Values

The monthly rainfall and runoff values for the period of 1995-2004 (Table 3) are considered in the regression analysis. The monthly regressed values are furnished in Figure 9. An expression $y = 0.3469x$ is obtained, where x represents rainfall in mm and y represents runoff in mm. The correlation coefficient is found to be 0.8296, which is highly satisfactory.

Table 3 Monthly rainfall – runoff

Sl. No	Year	Month	Rainfall (mm)	Runoff (mm)	Runoff (Mm^3)
1	1995	June	73.500	2.264	0.670
2	1995	July	70.500	0.055	0.016
3	1995	Aug	136.000	9.916	2.934
4	1995	Sep	121.000	1.558	0.461
5	1995	Oct	102.000	2.591	0.767
6	1995	Nov	144.000	54.174	16.027
7	1995	Dec	0.000	0.000	0.000
8	1996	Jan	0.000	0.000	0.000
9	1996	Feb	0.000	0.000	0.000
10	1996	Mar	0.000	0.000	0.000
11	1996	Apr	25.000	0.000	0.000
12	1996	May	19.500	0.000	0.000
13	1996	June	192.000	56.040	16.580
14	1996	July	53.500	0.800	0.237
15	1996	Aug	198.400	37.540	11.106
16	1996	Sep	395.500	228.370	67.564
17	1996	Oct	211.000	82.680	24.461
18	1996	Nov	71.700	4.700	1.391
19	1996	Dec	568.000	423.690	125.350
20	1997	Jan	0.000	0.000	0.000
21	1997	Feb	0.000	0.000	0.000
22	1997	Mar	0.000	0.000	0.000
24	1997	May	0.000	0.000	0.000
25	1997	June	109.500	1.130	0.334
27	1997	Aug	119.000	47.990	14.198
28	1997	Sep	233.000	172.720	51.100
29	1997	Oct	150.500	8.210	2.429
30	1997	Nov	236.000	36.990	10.944
31	1997	Dec	163.000	59.350	17.559
32	1998	Jan	0.000	0.000	0.000
33	1998	Feb	0.000	0.000	0.000
34	1998	Mar	0.000	0.000	0.000
35	1998	Apr	0.000	0.000	0.000
36	1998	May	20.000	0.000	0.000
37	1998	June	0.000	0.000	0.000
38	1998	July	52.000	0.320	0.095
39	1998	Aug	108.000	3.180	0.941
40	1998	Sep	0.000	0.000	0.000
41	1998	Oct	48.000	1.330	0.393
42	1998	Nov	130.000	4.690	1.388
43	1998	Dec	115.500	59.700	17.662
44	1999	Jan	0.000	0.000	0.000
45	1999	Feb	0.000	0.000	0.000
46	1999	Mar	0.000	0.000	0.000
47	1999	Apr	0.000	0.000	0.000
48	1999	May	43.500	0.000	0.000
49	1999	June	28.500	0.000	0.000
50	1999	July	13.000	0.000	0.000
51	1999	Aug	91.000	0.000	0.000
52	1999	Sep	88.000	0.050	0.015
53	1999	Oct	72.900	0.000	0.000
54	1999	Nov	192.300	57.860	17.118
55	1999	Dec	167.000	69.210	20.476
56	2000	Jan	0.000	0.000	0.000
57	2000	Feb	33.000	0.000	0.000
58	2000	Mar	0.000	0.000	0.000
59	2000	Apr	23.000	0.000	0.000
60	2000	May	24.000	0.000	0.000
61	2000	June	80.500	4.270	1.263
62	2000	July	9.500	0.000	0.000
63	2000	Aug	133.000	21.440	6.343

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Sl. No	Year	Month	Rainfall (mm)	Runoff (mm)	Runoff (Mm³)
64	2000	Sep	197.500	16.210	4.796
65	2000	Oct	176.500	68.460	20.254
67	2000	Dec	59.000	0.270	0.080
68	2001	Jan	0.000	0.000	0.000
69	2001	Feb	0.000	0.000	0.000
70	2001	Mar	0.000	0.000	0.000
71	2001	Apr	95.000	12.940	3.828
72	2001	May	7.000	0.000	0.000
73	2001	June	17.000	0.000	0.000
74	2001	July	262.500	127.550	37.736
75	2001	Aug	37.000	0.000	0.000
76	2001	Sep	202.500	50.530	14.949
77	2001	Oct	142.500	2.400	0.710
78	2001	Nov	72.500	1.690	0.500
79	2001	Dec	133.500	58.080	17.183
80	2002	Jan	0.000	0.000	0.000
81	2002	Feb	30.000	0.000	0.000
82	2002	Mar	0.000	0.000	0.000
83	2002	Apr	5.000	0.000	0.000
84	2002	May	113.500	9.380	2.775
86	2002	July	57.000	1.700	0.503
87	2002	Aug	54.500	2.560	0.757
88	2002	Sep	107.000	2.380	0.704
89	2002	Oct	190.500	91.120	26.958
90	2002	Nov	183.500	60.330	17.849
91	2002	Dec	44.000	0.830	0.246
92	2003	Jan	0.000	0.000	0.000
93	2003	Feb	0.000	0.000	0.000
94	2003	Mar	3.000	0.000	0.000
95	2003	Apr	44.500	0.000	0.000
97	2003	June	36.500	0.000	0.000
98	2003	July	209.500	146.290	43.280
99	2003	Aug	241.000	63.780	18.869
100	2003	Sep	59.500	2.720	0.805
101	2003	Oct	137.500	2.910	0.861
102	2003	Nov	226.300	107.830	31.902
103	2004	Dec	12.500	0.000	0.000
104	2004	Jan	0.000	0.000	0.000
105	2004	Feb	0.000	0.000	0.000
106	2004	Mar	0.000	0.000	0.000
107	2004	Apr	0.000	0.000	0.000
108	2004	May	0.000	0.000	0.000

Table 4 Annual rainfall – runoff (1995 – 2004)

Sl. No	Year	Annual Rainfall (mm)	Annual Runoff (mm)	Annual Runoff (Mm³)
1	1995-96	691.50	70.56	20.875
2	1996-97	1738.60	835.39	247.152
3	1997-98	1060.00	326.39	96.563
4	1998-99	497.00	69.22	20.479
5	1999-00	732.700	127.12	37.609
6	2000-01	844.30	123.98	36.680
7	2001-02	1016.00	249.63	73.854
8	2002-03	768.00	160.13	47.375
9	2003-04	922.80	323.53	95.717

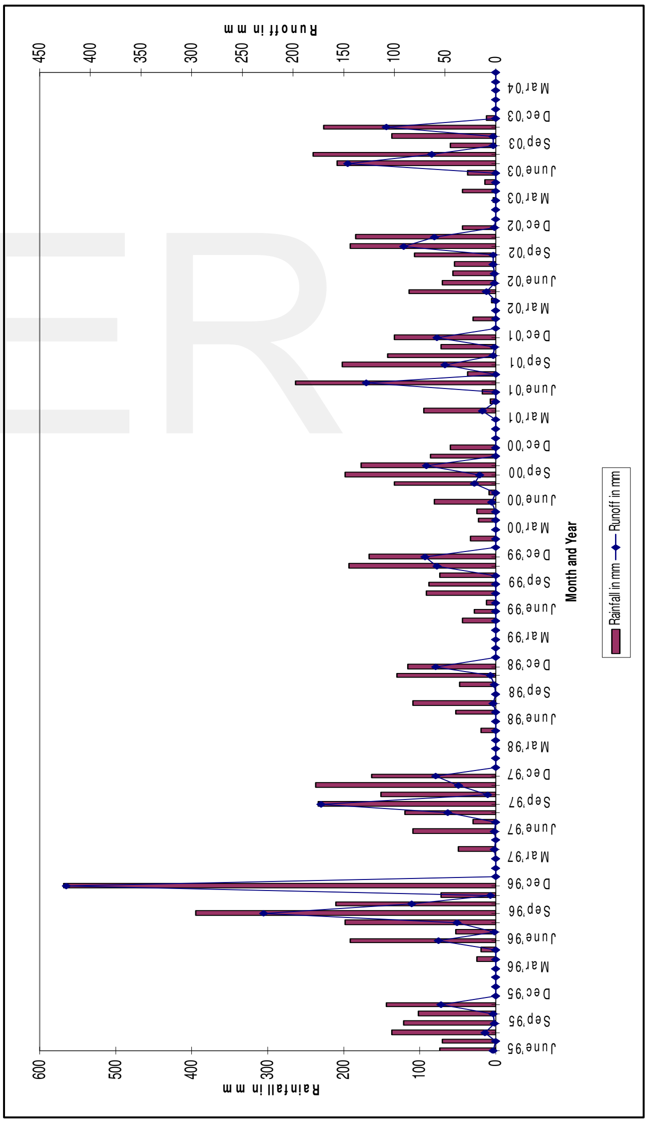

Figure 8 Monthly rainfall runoff (1995-2004)

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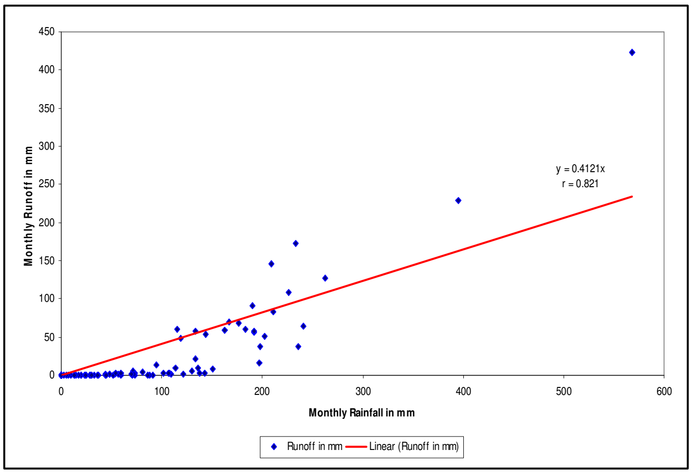

Figure 9 Regression of Monthly rainfall runoff

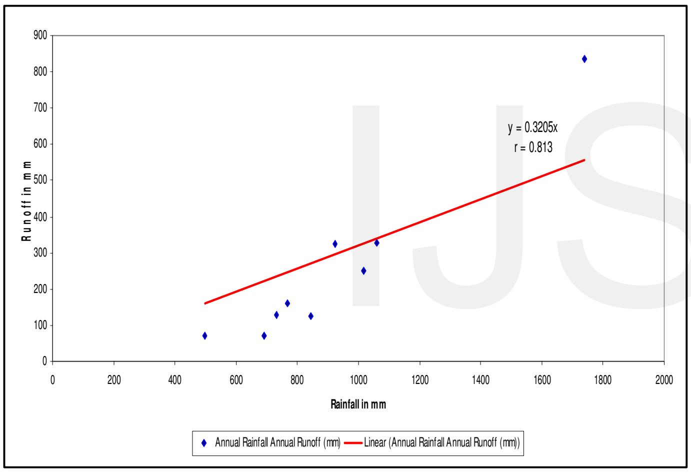

Figure 10 Regression of Annual rainfall runoff

4.3.3 Annual Rainfall and Runoff Values

For annual values of rainfall and runoff for the watershed and the results are presented in Table 4 (vide Figure 10). A Straight line equation y = 0.3205x, where x represents rainfall in mm and y represents runoff in mm is obtained. The correlation coefficient is found to be 0.813, which is highly satisfactory. From this watershed rainfall runoff regression model the values of runoff can be predicted. It may be inferred that estimation of runoff using GIS based SCS method can be used in watershed management effectively. From the monthly values of runoff and seasonal runoff in the watershed can be studied with reasonable accuracy as the spatial variation of soil type and land use are incorporated using GIS in the modeling process. Also from these values of runoff, it is possible to assess the months of poor runoff, moderate and better runoff. Accordingly irrigation scheduling, rotation of cropping and selection of appropriate crops can be decided in the watershed. After assessing the available flow in the watershed, a realistic irrigation scheme can be drawn for the benefit of the farmers.

4.3.4 Mini-Watersheds of the Study Area

In this study area there are 18 nos. of Mini watershed and are delineated ranging from 9.833 sq.km to 25.979 sq.km of Manimuktha sub-watershed (4C1A2c). The individual Weighted Curve number is computed for all the mini watersheds in the study area of Manimuktha sub watershed (4C1A2c) for AMC-II, AMC-I and AMC-III conditions and the computed. According to the weighted curve number (AMC-II) of the runoff potential for the miniwatersheds are classified as Moderate, High and Very high as given in Table 5.

Table 5 Classification of Runoff Potential (AMC-II)

Sl. No	Range of Weighted Curve Number	Classification of Runoff Potential	Mini-watersheds	Area (%)
1.	75.0 – 85.0	Moderate	C_1, C_6, C_{15}	15.58
2.	85.1 – 95.0	High	C_1 – C_5, C_7 - C_{11}, C_{13}, C_{14}, C_{16} - C_{18}	79.07
3.	Above 95.1	Very high	C_{12}	5.35

5 CONCLUSION

The following conclusions are derived from this study are,

- The watershed characteristics are studied from IRC-IC, FCC, LISS – III, 1996 using RS and GIS. Various thematic maps such as drainage, watershed, soil and land use are prepared. These maps can be used to study the spatial distribution of the watershed characteristics of the study area.
- The daily runoff values are estimated using GIS based SCS method and it is used to calculate monthly and annual runoff values.
- The treated mini-watershed "C_1" and untreated mini-watershed "C_{10}" of cumulative annual rainfall runoff values are linearly regressed with r > 0.96 which is highly satisfactory.
- The derived regression equation can be effectively used to predict the runoff from the given rainfall values and suggest the soil conservation structures such as Contour bunding, Tractor ploughing, percolation pond, Land leveling etc. (vide Table 6 and Figure 11).

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Table 6 Treated and Untreated mini-watersheds of annual rainfall – runoff values

Year	Annual rainfall of the study area in mm	Treated watershed Annual Runoff in mm "C1"	Untreated watershed Annual Runoff in mm "C10"
1995-96	691.50	48.74	108.42
1996-97	1778.60	705.53	959.79
1997-98	1060.00	267.89	388.70
1998-99	497.00	54.56	92.31
1999-00	732.70	96.11	159.33
2000-01	844.30	85.76	175.29
2001-02	1016.00	197.83	310.33
2002-03	768.00	123.86	206.38
2003-04	922.80	279.53	368.88

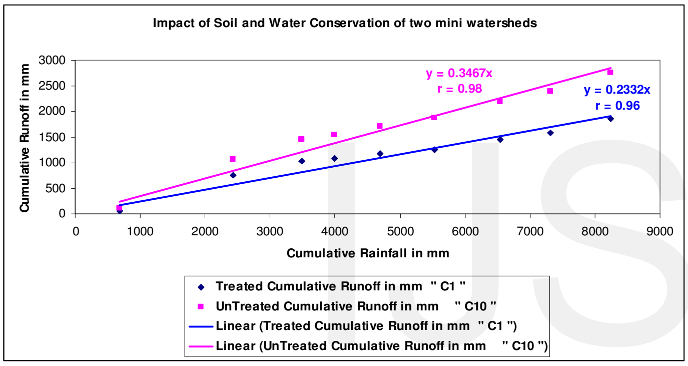

Figure 11 Impact of Soil and Water conservation on runoff

- From the runoff values, it is possible to assess which month has a better runoff, which month has a moderate runoff and which month has a poor runoff. With the help of these values, irrigation scheduling, rotation of cropping pattern and selection of suitable crops can be suggested.
- From the annual values of runoff, the good, average (or) bad year with reference to the rainfall runoff occurrence may be categorized in the study area. If the year is poor, then the farmers could be informed in advance to use ground water (or) rotation cropping pattern for their cultivation instead of depending on surface water.
- Crop productivity as well as crop production have registered increment through better soil, water and crop management.
- To access to drinking water has improved because of water conservation measures.
- Since the soils have pH more than 8.0. The soil has the exchangeable sodium in higher proportion. The presence of sodium in soil normally prevents infiltration in soil which ultimately results in surface runoff because of deflocculating character of sodium.

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