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Study on the Influence of Soil and Water Conservation Treatments on Soil Loss and Land use Land Cover Change Detection using GIS Mapping in Microwatershed Area.

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ABSTRACT

Watershed is a natural hydrologic entity. Watershed management is the process to sustain and enhance watershed functions. Microwatershed is the smallest hydrologic unit ranges between 100-1000 hectares and it is generally governed by viability and working feasibility of implementation of various development programmes. Land irrigability and capability classification for micro level watershed planning are needed so that the farmers can use better parcels for intensive cultivation with proper conservation measures and soil improving practices. The main objective of this study is to analyse various factors that influencing the runoff and soil loss, detection on land use / land cover extents by using GIS tool in the rainfed, treated microwatersheds. The microwatershed area with coding 4B3B3r3 in Santhanapalli village, Krishnagiri district in Tamilnadu, India with an aerial extent of 4.4424 km² and the Silt Monitoring Station (SMS) at Bevanatham, Krishnagiri District of Tamilnadu, India have been considered in this study. Using GIS technologies microwatershed level database mapping has been developed and land use / land cover change detection in during the years 2005, 2010, 2014 have been mapped. Land cover change detection offers watershed planners a valuable tool for evaluating the land cover rehabilitation strategies in minimizing runoff and sediment yield during rainfall events in watershed ecosystems. Determination of Runoff, sediment rate and soil loss have been computed in the treated microwatershed areas.

Keywords: Watershed, Geographic Information System(GIS), Silt Monitoring Station(SMS), Microwatershed, Runoff, Sediment, Soil loss, Land use / land cover.

1. INTRODUCTION

Watershed management is the process of creating and implementing plans, programs, and projects to sustain and enhance watershed functions that affect the plant, animal, and human communities within a watershed boundary. (Wikipedia). It encompasses control of soil erosion and land degradation, moisture conservation, land use revisions in tune with land capability, optimal management of crop lands, grass lands, forest conservation, harvesting and management of water resources, etc. Also it leads to optimal biomass production and consequent economic and social well being of the populace in the watershed [1]. Watershed is a natural hydrologic entity that encompasses a “specific area” stretch of land surface where from rainfall or runoff flows to a “specific defined drain” be it a channel/nullah, small stream or river. In a geomorphic analysis of natural drainage system, basin, catchment, subcatchment, watershed,subwatershed and microwatershed are the various stages of delineation from macro to micro levels. Size of smallest hydrologic units called as microwatershed which are below subwatersheds generally governed by viability and working fesibility of implementation of various development programmes [2].

A microwatershed, as defined by Bali in 1978, ranges in between 100-1000 hectares. At microlevel, watershed development programme plays a major role for conservation of soil and water resources.

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Land and water are the two most valuable and essential resources. India is basically an agrarian country with a gross cropped area of 177 m.ha. out of the total geographical area 328.7m.ha [3]. Out of the geographical area (328.7 m.ha.) 47% is cultivated, 23% is forested, 7% under non-agri use, 23% waste. Out of cultivated area, 37% is irrigated which produces 55% of food ; 63% is rainfed producing 45% of food [4]. About 63% of Indian agriculture is rainfed (National Commission on Agriculture). Water is life. Water resource potential in India has been assessed as 186.9 million hectare meter (m.ha-m). Most of this comes from rainfall. India's annual average rainfall is 400 m.ha-m, out of which utilizable water is only about 112.3 m.ha-m. Utilizable water comprising 69.0 m.ha-m surface water and 43.3 m.ha-m ground water. Moreover, India's water requirement will be estimated about 84.3 m.ha-m by 2025 and 118.4 m.ha.m by 2050 due to increase in population and significant expansion of water use in agricultural and industries Now, India's annual availability is far more than the demand, researchers often argue that there should not be any scarcity of water in near future. Unfortunately, India is facing droughts almost every year in many water resource regions (SLUSI). In 2050, in India, withdrawl and availability of water status is predicted as (yearly requirement in BCM = km^3): Total requirement is 970-1200 BCM, where as availability is 1100-1400 BCM, which is almost equal to the requirement [4]. Most of this precipitation runs off to seas resulting severe drought in dry seasons particularly in regions where irrigation coverage is less. Global Runoff Data Centre, University of Hambshire and International Earth Science Information Networks have projected that around 30% area of India falls in the extreme water scarce zone having less than 500 m^3/ person / year supply of renewable fresh water (SLUSI). India is blessed with many major rivers and their tributaries but occurances of both flood and drought are regular causing tremendous adverse impact on food production besides yielding substantial loss of fertile top soil and countrie's wealth. Therefore, both development and management of water resources with scientific data base is pre-requisite for achieving sustainable achievement (SLUSI).

It is vital to carryout further studies, research analysis on the concepts and approaches of watershed management. Studies are required on what has been accomplished with existing ones and how these can be made even better. The challenging task for natural resources researcher is to combine all the concepts and to prepare entire spatial and non-spatial attribute database by amalgamating the leading edge technologies to form decision making analysis technique. Land irrigability and capability classification for micro level watershed planning are needed so that the farmer can use better parcels for intensive cultivation with proper conservation measures and soil improving practices [6]. India is well endowed with rainfall and is one of the wettest countries in the world with annual precipitation estimated at around 400 millions hectare-meters, however a vast area of the country is drought prone. The arid and semi arid regions of India covering 54% of the geographical areas are drought areas. Rainfed agriculture accounts for about two-thirds of total cropped area, nearly half of the total value of agricultural output. Nearly half of all food grains are grown under rainfed conditions, and hundreds of million of poor people depend on rainfed agriculture as the primary source of their livelihoods [6].

Keeping the above points in view, in this study, an attempt has been made in treated micro watershed having rainfed areas in respect of sedimentation study and the detection of Land use / Land cover changes using GIS.

2. OBJECTIVES OF THIS STUDY

Main objectives of this study are:

- To identify the land use / land cover changes for the considered microwatershed area for the years 2005, 2010, 2014 and developing the maps using GIS tool.
- To calculate the extent of each category of land for the years 2005, 2010 and 2015 using GIS tool.
- To identify the influence of various soil and water conservation treatment in soil loss.

- To compute the runoff–rainfall ratio of this treated study area.
- To compute the soil erosion for pre treatment, during treatment and post treatment periods.

3. STUDY DETAILS

3.1. Study area

The microwatershed area with coding 4B3B3r3 in Santhanapalli village, Krishnagiri district in Tamilnadu, India has been considered in this study. Details of the coding are detailed below.

4B3B3r3	–	Micro watershed, Santhanapalli village, Krishnagiri district, Tamilnadu, India.
4	–	Water Resource Region, Drainage flowing into Bay of Bengal.
4B	–	Cauvery basin–No. of catchments–4, No. of Subcatchment–17, No. of Watershed-103
Area of the basin	–	84,20,769 ha, Major River–Cauvery
4B3	–	Catchment–Stanley Reservoir to Krishnaraja Sagar, Area of this Catchment–31,47,868 ha
4B3B3	–	Watershed, Krishnagiri district, Denkanikottai block
4B3B3r	–	Sub-watershed
4B3B3r3	–	Microwatershed at Santhanapalli village

This microwatershed area is located at a distance of 92 km from Bangalore in Karnataka state and 114 km from Salem in Tamilnadu state, between North latitudes 12˚28′00″ to 12˚30′00″ and East longitudes 77˚50′00″ to 77˚51′30″ with an aerial extent of 4.4424 km². At present the most predominant land found is Barren, Fallow & Forest lands with an aerial extent of 71.50 percent of the total area while Agricultural land, Horticulture land, Rocky area, Settlement and Waterbodies identified to covering about 10.41, 9.16, 7.14,1.74 & 0.05 percent respectively. The Silt Monitoring Station (SMS) at Bevanatham, 58 km from Krishnagiri District of Tamilnadu, India (4B3B3r2- Longitude 77˚46′00″ *W* to 77˚47′00″E & Latitude 12˚30′00″S to 12˚32′00″N) with catchment area of 3927 ha. covering 4 No. of microwatersheds namely 4B3B3r3, 4B3B3r4, 4B3B3r5 and 4B3B3r6. The physiographical shape of the catchment area is triangle. The hydrological location map showing the exact details of this microwatershed is presented in Fig 1.

Hydrologic and sediment responses prior to treatment, during treatment and post treatment has been collected and observed from Silt Monitoring Station (SMS) established by Agricultural Engineering Department(AED) of Tamilnadu Government at Bevanatham village, Krishnagiri district.

3.2. Study period

This study has been done based on the data collected in the microwatershed area during the period between 2005 and 2014. Land use / land cover change detection studies have been done for the years 2005, 2010 and 2014 for different categories of land.

3.3. Field studies

In respect of the selected microwatershed, following observations have been made in this study.

a. The GIS based prepared maps for land use / land cover and treatments to the microwatershed have been verified with field for its correctness and if necessary corrections have also been carried out for better database mapping.

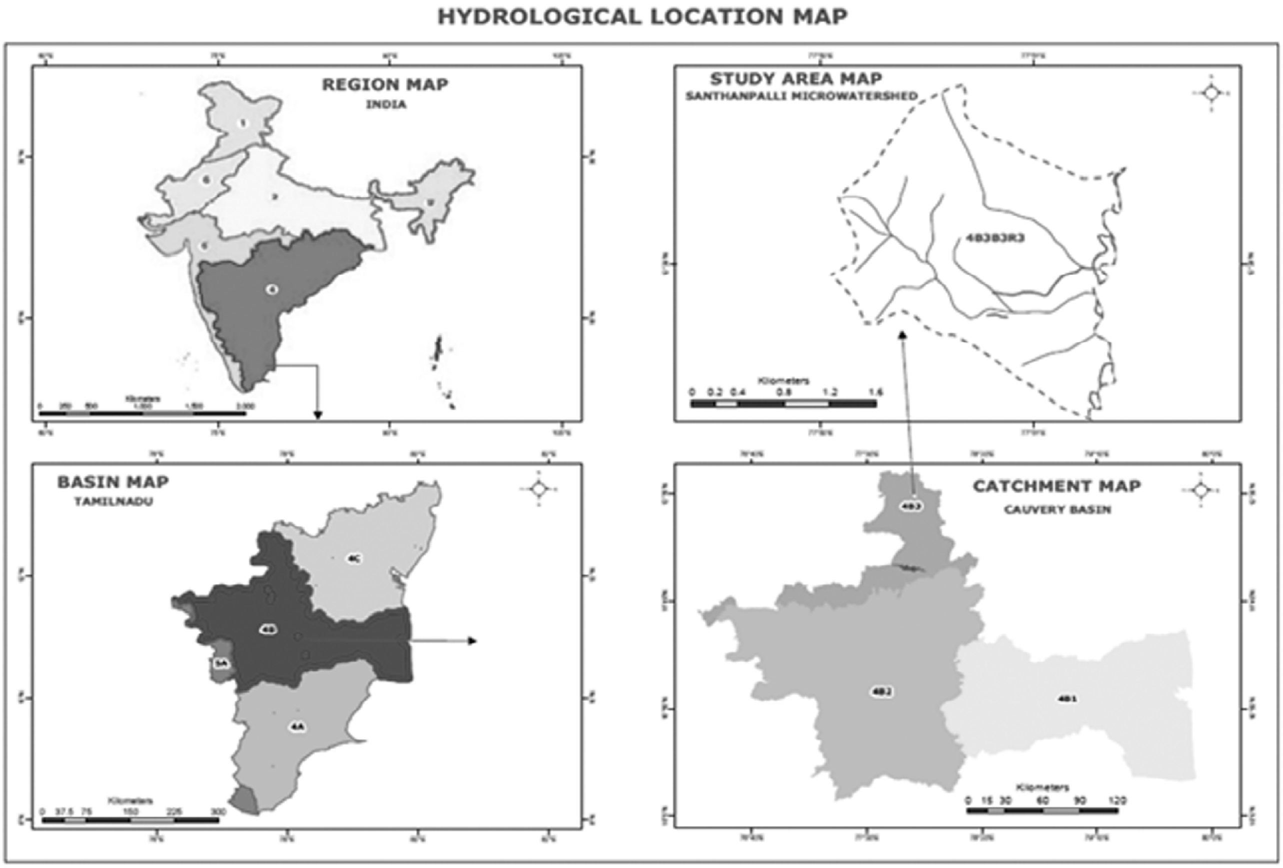

Figure 1: Hydrological location map

b. For all the treated soil and water conservation works, towards the correctness, the GPS reading has also been taken.

c. The rainfall details of the area covered under the SMS has been collected.

d. Sediment samples have been collected at different depths such as 0.20m, 0.40m, 0.60m and 0.80m of the depth of the flow, using Point integrated Punjab bottle Sampler.

e. Soil type, slope of the microwatershed, cultivation practices, type of common vegetation practice have been collected for the study period.

3.4. Maps utilized

Following maps have been considered in this study.

a) Cadastral, Drainage and Location maps provided by Deparment of Land & Survey, Tamilnadu.

b) Topographic map (57 / H / 15) on a scale of 1 : 50,000 provided by the Survey of India (SOI), in which the microwatershed boundary is marked.

c) Google & Bing maps for the year 2005, 2010 & 2014 have been used for land use classification.

d) Base maps including road, settlement, village location, microwatershed boundary extracted from the topo sheets have been converted into GIS database.

e) Elevation, Slope and Soil erosion maps provided by Shuttle Radar Topography Mission, United States Geological Survey (SRTM, USGS)

f) Land Capability Classification (LCC) maps provided by TamiNadu Agricultural University (TNAU).

g) Geology map provided by Geological Survey of India.

h) Watershed location map provided by Tamilnadu Watershed Development Agency (TAWDEVA).

i) Treatment works map provided by Agricultural Engineering Department, Tamilnadu.

4. METHODOLOGY

The soil loss occurred in the catchment area of SMS has been calculated based on the following formulae.

4.1. Determination of Runoff (Q_1) in ha.m

The runoff (Q) is calculated based on the following formula.

Runoff (Q) = $q * H * 60 * 60$ (in m^3)

Where, q = Rate of discharge (in m^3/s)

= $(2/3) * C_d * L * h^{3/2} *$ “ 2g

where C_d = Coefficient of discharge = 0.625

L = Length of weir = 10.00 m

h = Depth of flow in meters

g = Acceleration due to gravity = 9.81 m/s^2

H = Duration of flow for the day in hours

Hence, the runoff equation becomes,

Q = $(2/3) * 0.625 * 10.00 * h^{3/2} *$ “ $2 * 9.81 * H * 60 * 60$

= $18.46\ h^{3/2}\ m^3$ / sec

The runoff expressed in hectare-metre is generally expressed as Q_1. Hence, the above equation becomes, Runoff, $Q_1 = Q_1 / 10000$ (in hectare-metre)

Determination of sediment rate (S) in ha.m / 100 sq.km

The sediment rate is calculated based on the sediment concentration and runoff (Q) using the following equation

S = $s \times Q \times 100 / B_d \times 10^7 \times A_d$

Where s = Sediment concentration in gm/lit

Q = Runoff in m^3

B_d = Bulk density of fine sediment = 1.4 gm/cc

A_d = Drainage area in sq.km = 39.27

S = $s \times Q \times 100 / 1.4 \text{ x } 10^7 \text{ x } 39.27$

Soil loss in tones per hectare = $S / B_d = S / 1.4$

Total soil loss in the SMS catchment = $S / 1.4 * 3927$ tonnes

In this SMS, during the year 2005-06, before the treatment of soil and water conservation works, the soil loss has been monitored and estimated as 31.287 Tonnes/ha. From 2006-07 to 2010-11, out of the catchment area of 3927 ha, 1582.60 ha has been treated with soil and water conservation works in 4 microwatersheds of this SMS.

4.2. Sediment sample analysis

The collected sediment samples are analyzed in the laboratory. Three types of sediments such as coarse, medium and fine sediments are analyzed and the total sediment weight is calculated in gm/lit. The total sediment rate is expressed in ha.m/100 sqkm/year.

5. TREATMENT OF MICROWATERSHEDS UNDER SOIL AND WATER CONSERVATION MEASURES

The following treatments were carried out to conserve the soil and water in the studied microwatershed area.

a) Contour bunding–To improve insitu moisture conservation and control soil erosion.

b) Vegetative cover–Area based activities such as horticultural plantation (mango, sappota, amla, guava saplings), agro forestry (teak, pungan, silver oak saplings), afforestation (casurinas, pungan, neem saplings) are undertaken.

c) Contour trenching–To control the soil erosion by checking the velocity of runoff and for safe disposal of flood.

d) Drainage line treatment works-Loose rock checkdams in upper and middle reaches, loose rocks packed with chainlinks (Gabion) checkdams and water harvesting structures in lower reaches of the gullies are constructed for the control of runoff velocity and bank stabilization. Farm ponds and Silt detention structures are constructed at valley points in vulnerable areas for harnessing the runoff which, in turn, augments the ground water recharge besides soil moisture regime.

6. RESULTS AND DISCUSSIONS

Land use/land cover detection from the Micro watershed- 4B3B3r3

In the microwatershed 4B3B3r3, the land use / land cover change detection study has been done using satellite maps of Bing and Google maps for the years 2005, 2010 and 2015. Different categories of land use / land cover change detection observed in the microwatershed area of 4B3B3r3 have been mapped using GIS Tool, and presented in Fig. 2, Fig. 3 and Fig. 4.

The land use change detection observed and the increased or decreased area in different classification of land have been presented in Table.1 In the study area during the year 2005, the different kinds of lands, maximum portion is occupied by barren land (23.36%) and forest land is (22.64%). The minimum area is occupied by builtup land (0.87%) and waterbody (0.01%).

The area of agricultural land during the year 2005 was 77.24 ha and it reduced 73.21 ha during 2010. It further reduced to 46.26 ha during the year 2014 with a decrease of 40.11% over the study period . The area of barren land during the year 2005 was 103.785 ha and it increased 112.21 ha during 2010. It further increased to 113.44 ha during the year 2014 with a increase of 9.30%. The area of builtup land during the year 2005 was 3.88 ha and it is increased to 7.72 ha during the year 2014 with a increase of almost 100%. The fallow land during the year 2005 was 86.57 ha, and it is increased to 90.60 ha during the year 2014 with a increase of 5%. The forest land during the year 2005 was 100.56 ha and it is increased to 113.62 ha during the year 2014 with a increase of 13%. The horticulture land during the year 2005 was 23.705 ha and it is increased to 40.68 ha during the year 2014 with a increase of 71.60% due to treatment works have been made in this microwatershed. The rocky area during the year 2005 was 48.45 ha and it is decreased to 31.72 ha during the year 2014 with a decrease of 34.53%. The waterbodies occupies 0.05 ha during 2005, and it is increased to 0.20 ha during the year 2014 with a increase of 300% which develops the microwatershed areas as moisture regime as well as increased area in vegetative covers thereby reduction of soil loss happened in this study area.

It is also observed that, increased extents of horticulture, forestry and barren land leads to decreased volume of runoff due to vegetative covers and thereby the reduction of soil loss would happen. Post treatments make the microwatersheds as most vegetative covers through moisture development as well as control the runoff resulting to the control of soil erosion.

Different types of treatment works provided to the microwatersheds of Bevanatham SMS are listed in Table.2

UR–Upper Reaches loose rock check dam, MR–Middle Reaches loose rock check dam, LR–Lower Reaches Gabion structure, SDT–Silt

Detention Tank, WHS–Water Harvesting Structure, FP–Farm Pond. The runoff-rainfall ratio (Q/P) starting from the year 2005-06 to 2015-16 is shown in Fig. 5. The runoff- rainfall ratio during the year 2005-06 was high (29.09%) before the soil and water conservation works. During the treatment periods of 2006-07 to 2010-11, the runoff-rainfall was reduced considerably and in the year 2010-11, it was 3.63%. After that, during the post treatment period, the Q/P ratio was within 5% only which shows that minimum

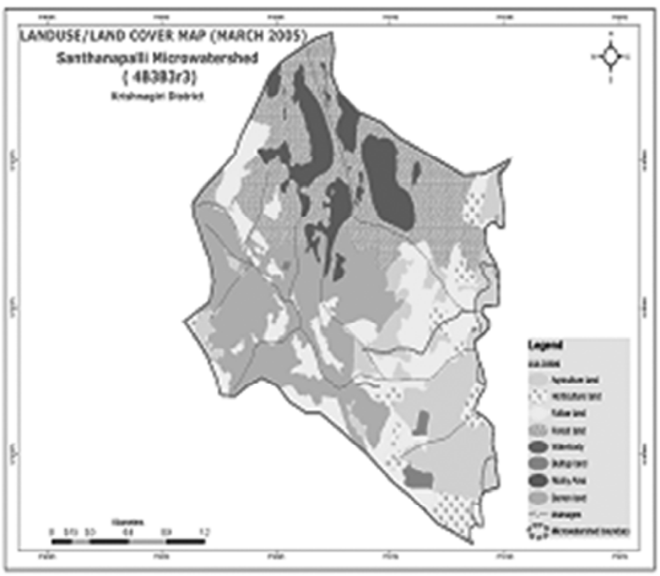

Figure 2: Land use/land cover map-2005

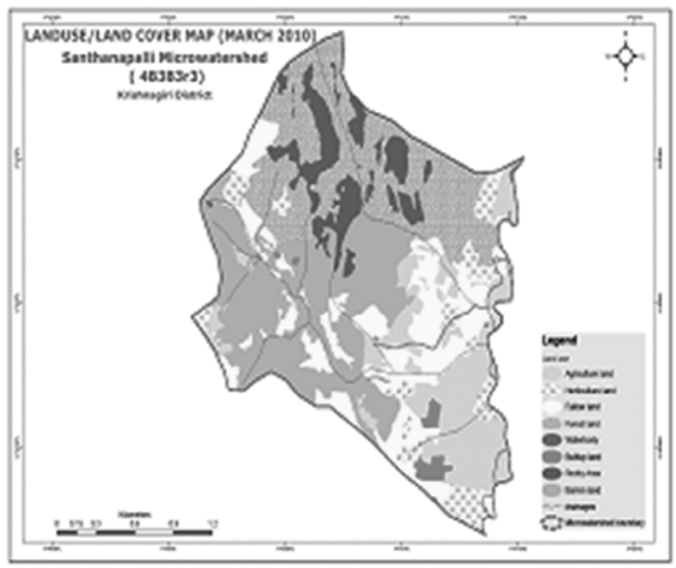

Figure 3: Land use/land cover map-2010

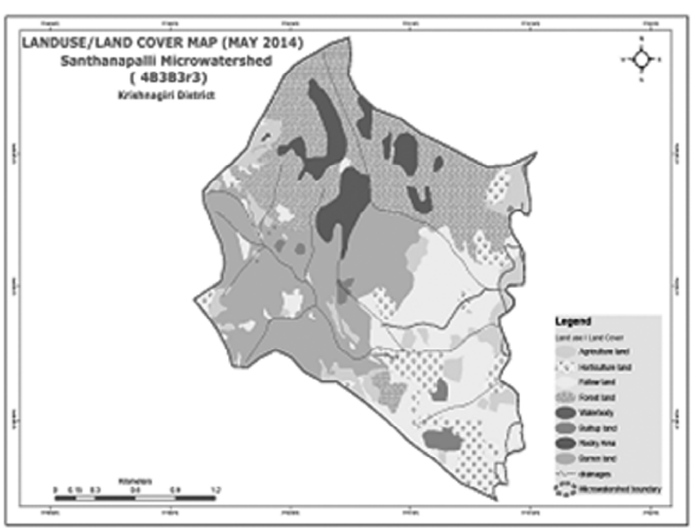

Figure 4: Land use/land cover map-2014

Table 1
Land use/land cover changes in different classification of land

S. no.	Land Use Classification	Land Use/Land Cover Changes Identified From Google & Bing Maps Using GIS Tool for The Period 2005, 2010 & 2014-Area in Hectares — Land Use Change Detection For The Years									
		2005		2010				2014			
		Area in hectares Area	% Against the Total	Area in hectares Area	% Against the Total	Area Increased	Area decreased	Area in hectares Area	% Against the Total	Area Increased	Area decreased
1	Agriculture Land	77.240	17.39	73.210	16.48		4.03	46.260	10.41		30.98
2	Barren Land	103.785	23.36	112.210	25.26	8.43		113.440	25.54	9.66	
3	Builtup Land	3.880	0.87	5.520	1.24	1.64		7.720	1.74	3.84	
4	Fallow Land	86.570	19.49	79.690	17.94		6.88	90.600	20.39	4.03	
5	Forest Land	100.560	22.64	102.910	23.17	2.35		113.620	25.58	13.06	
6	Horticulture Land	23.705	5.34	31.760	7.15	8.06		40.680	9.16	16.98	
7	Rocky Area	48.450	10.91	38.650	8.70		9.80	31.720	7.14		16.73
8	Waterbody	0.050	0.01	0.290	0.07	0.24		0.200	0.05	0.15	
	Total	444.240	100.00	444.240	100.00	20.710	20.710	444.240	100.00	47.71	47.71

Table 2
Treatment works provided to the microwatersheds

S. No.	Microwatershed Code	Area in hectares				Drainage line treatment in Nos.					
		Contour bunding	Horti. Plantation	Agro forestry	Total treated area	UR	MR	LR	SDT	WHS	FP
1	4B3B3r3	50.20	120.10	150.13	320.43	33	31	31	10	3	2
2	4B3B3r4	271.06	20.03	20.01	311.10	9	10	15	3	2	1
3	4B3B3r5	310.07	45.02	45.09	400.18	11	13	18	5	2	2
4	4B3B3r6	75.05	40.11	90.56	205.72	4	10	10	2	1	2
	Total	706.38	225.26	305.79	1237.43	57	64	74	20	8	7

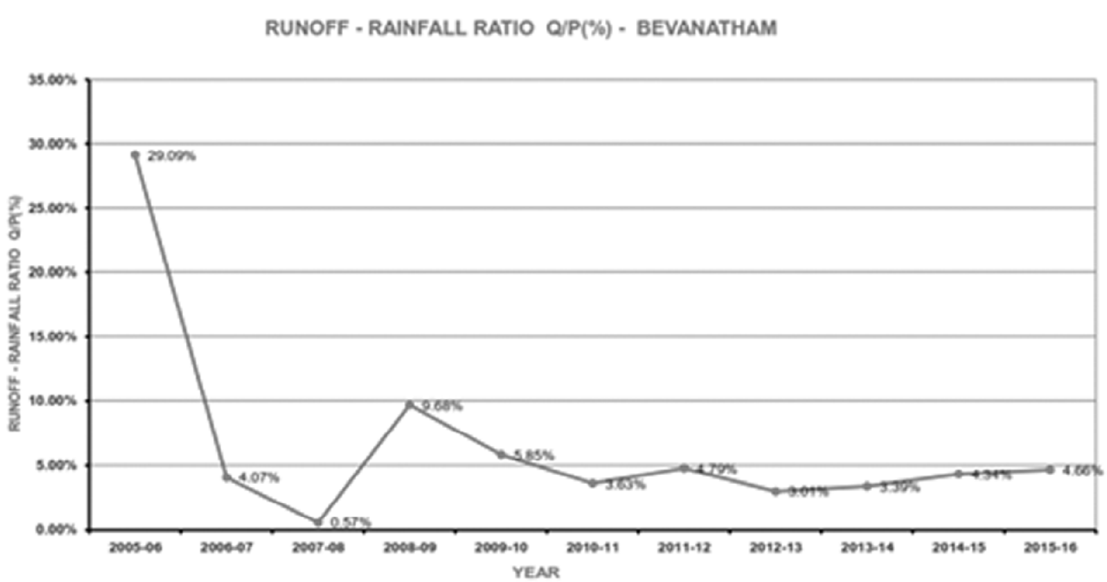

Figure 5: Runoff, Rainfall ratio Q/P

soil loss was achieved. This is absolutely due to the effective treatment of microwatersheds by both land and drainage line treatment measures carried out.

6.1. Rainfall, Runoff and Soil loss

From the collected rainfall data, the runoff and soil loss have been computed for the study area and presented in the Table 3. During the year 2005-06 in pre-treatment period, the rainfall was found to be 1079.9 mm and due to which the soil loss was about 31 t/ha. Subsequently, during the treatment periods, the soil loss was found to be less than 1 t/ha even the rainfall was above 500 mm. In the post treatment periods, the soil loss was also less than 1 t/ha. It clearly indicates that the soil and water conservation works carried out in the watersheds are very effective to control soil erosion. But the soil loss has some correlation with the rainfall and the increased rainfall resulting increased soil loss in the study area.

Table 3
Rainfall, runoff and soil loss

Year	Rainfall (P) in mm	Runoff (Q) in ha.m	Runoff in mm	Sediment Rate in ha.m /100 sq.km	Soil loss intonnes/ha	Q/P in %	Remarks
2005-06	1079.9	1233.83	314.19	22.34340	31.28070	29.09	Pre treatment
2006-07	512.3	81.895	20.85	0.09941	0.13920	4.07	During Treatment
2007-08	729.6	16.190	4.12	0.04275	0.05985	0.57	
2008-09	859.5	326.656	83.18	0.50137	0.70190	9.68	
2009-10	592.1	136.046	34.64	0.08200	0.11480	5.85	
2010-11	613.9	87.443	22.26	0.05904	0.08265	3.63	
2011-12	311.5	58.550	14.91	0.03258	0.04561	4.79	Post treatment
2012-13	253.0	29.8599	7.60	0.01139	0.01595	3.01	
2013-14	488.5	65.1266	16.58	0.016953	0.02373	3.39	
2014-15	619.0	105.5685	26.88	0.090331	0.12646	4.34	
2015-16	798.5	146.2505	37.24	0.18180	0.25452	4.66	

7. CONCLUSION

Based on the data collected and analysis, the following conclusions were made in this study.

1. Land use / land cover changes were identified for the considered microwatershed area by developing maps using GIS tool. The maps were developed for the years 2005, 2010 and 2014 by considering 8 categories of lands.
2. Based on the above maps, the extent of land use for each category of land was calculated for the years 2005, 2010 and 2014. In which, it was found that, the area of forest land, barren land, built up land, fallow land, horticulture land and waterbodies were increased during 2014 compared with 2005. However, the area of agricultural land and rocky area were decreased between the years.
3. Treatment methods such as contour bunding, horticulture plantation, agro forestry and drainage line were carried out during the treatment periods for the microwatershed area, and found that they were more effective in controlling the soil loss.
4. The runoff–rainfall ratio (Q/P) between the years shown that, during the treatment period Q/P was considerably reduced and in the post treatment periods the Q/P was achieved less than 5%.
5. In the pre-treatment period, during the year 2005-06, the soil loss was about 31 t/ha due to heavy rainfall of 1079.9 mm. Subsequent to the different kinds of treatments provided, the soil loss was achieved as less than 1 t/ha in the post-treatment periods. It was also observed that, the soil loss has

some correlation with the rainfall, and found that the increasing rainfall resulted in increasing soil loss.

6. Soil and water conservation works have make the microwatersheds as most vegetative covers. More vegetative covers control the runoff and more soil loss. This study results have clearly indicates, present land use with treated works are almost enough to control the soil erosion. For similar kind of microwatersheds, the decision makers and planners can follow this kind of procedure to minimize the soil loss.

Generally, all the above results aim for optimum development of land, water resources and to meet the minimum needs of people thereby improving their socio-economic conditions. The information generated from this studies can be applied for sustainable development of any similar kind of microwatersheds.

REFERENCES

[1] V. Venkateshwar Rao, Head, Water Resources Division, National remote sensing centre, Department of Space, Govt. of India, Hyderabad-500625, Article name: GIS & RS Applications in planning and conservation of resources in rainfed watersheds.

[2] Soil and Land Use Survey of India, Noyda, India.

[3] Yasir Arafat M.N, (2010), Watershed Management fpr Asifabad and Wankadi Taluks, Adilabad District-A Remote Sensing and GIS Approach : International Journal of Applied Engineering Research, Dindigul 1(1), ISSN-0976-4259.

[4] Dr. T.I. Eldho, (2010), IIT, Bombay, A.P. Department of Civil Engineering, Article of India's Land resource, Irrigation and Food production.

[5] Food and Agricultural Organisation, United Nations,

[6] P.D. Aher, J. Adinarayana, S.D. Gorantiwar, S.A. Sawant. P.K. Srivastava et al. (eds.), (2014), Remote Sensing Applications in Environmental Research, Society of Earth Scientists Series, DOI : 10.1007/978-3-319-05908_2,Springer.International Publishing Switzerland.

[7] Yugananth Pachiappan, Research Scholar, Anna university, Chennai, Tamilnadu, India, Regression modeling of traffic noise pollution, Journal of Gradevinar 12/2013.