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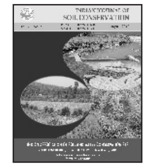

Planning of conservation measures using remote sensing and geographical information system in micro-watershed

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ABSTRACT

The present study was conducted in the Baliya micro-watershed of Udaipur district, Rajasthan for planning of appropriate conservation measures for resource conservation using Remote Sensing (RS) and Geographical Information System (GIS). RS and GIS helped in identification of different soil and water conservation (SWC) measures by considering the factors like physiography, soils, land use (LU) capability classes, slope, and drainage pattern. Rainfall data of 30 years period (1984-2013) was analyzed for planning of different SWC measures. The probability analysis and recurrence interval study of annual and seasonal rainfall for the period 1984-2013 was determined for effective planning of resource conservation. The appropriate agricultural and engineering measures adaptable in micro-watershed were contour bund (VI - 0.78 m, HI - 43.39 m, S - 1.84%), Purtorico terrace (VI - 2.02 m, HI - 21.49 m, S - 9.40%), Stone wall terrace (L - 2299 m, H - 0.25 m, S - 9.40%) for arable land whereas Contour trench (S - 19.58%, C/s area - 0.09 m^2, L - 6256 m), Staggered trench (C/s area - 0.09 m^2, S - 32.50%, A-285.17 ha), V-ditch (C/s area - 0.09 m^2, S - 32.50%, A - 601.12 ha) and Silvi-pasture (18.31 ha) for non-arable land. For the treatment of drainage line, loose stone check dams of different dimensions were proposed as per their available catchment area. For harvesting of excess runoff, one water harvesting structure (Anicut) having storage capacity of 1.61 ha-m was designed for supplementary irrigation to *rabi* crops.

1. INTRODUCTION

India's land resources are under immense pressure, it shares only 2% of the world's geographical area, but supports around 18% of world population and 15% of world's livestock (Kumar *et al*., 2012, Bhat *et al.,* 2015). The total geographical area (TGA) of India is 328 M ha, of which 69 M ha area critically degraded, while 106 M ha areas severely eroded (Singh, 2000). It has been estimated that about 16.4 t ha^{-1} of soil is detached annually because of various agents of destruction. Declining land availability for agriculture, which is expected to be only 0.15 ha $capita^{-1}$ by 203 shows these verity of the problem (Singh, 2000). It is estimated that out of 120.7 M ha degraded area in India, about 68% is affected by water erosion (Devnarayan *et al.,* 2014). Soil erosion is a challenging issue not only because it leads to productivity losses, but also because it is strongly linked to desertification and rural poverty (Ruben *et al*., 2004; Hugo, 2008; Jara-Rojas *et al.,* 2012).

Many traditional agricultural practices contribute to soil degradation (Solis *et al.,* 2009) while technologies designed to improve or conserve soil are not always adopted, even when their usefulness has been demonstrated (Amsalu and Graaff, 2007). Conservation of top fertile soil and rainwater are a major concern for resource conservation and greater productivity of rainfed areas that constitute nearly 60% of the net cultivated area in India (Narayan and Biswas, 2012). The severity of current degradation has inspired significant efforts to develop and promote the adoption of conservation strategies. However, the results are not always positive, and soil degradation continues to be a major problem worldwide.

Planning of various watersheds were done using RS and GIS techniques by several scientists (Sadgir *et al.,* 2006; Tiwari and Narayan, 2010; Kumar *et al.,* 2011) for optimum utilization of available natural resources. RS is largely concerned with the measurement of electro-magnetic energy from the sun which is reflected, scattered or emitted by the objects on the surface of the earth. (Czajkowski and Lawrence, 2013; Devnarayan *et al.,* 2014). During the systematic survey of watershed, factors like physiography soils, vegetation, land use, slope, drainage pattern etc. are considered simultaneously and huge amount of attribute data are required to be collected. There are difficulties in data management with conventional methods. Further, the presentation of results through maps, charts, diagrams, texts etc. and handling of voluminous data, its storage, retrieving and updating is also cumbersome and tedious. Use of RS and GIS in natural resource and environmental monitoring has been advocated strongly in recent years. The application of RS and GIS for management of wetlands by explaining geo-referencing of satellite data, creation of digital database, thematic map preparation from satellite data using digital analysis and generation of spatial framework in GIS environment on the basis of Survey of India grids. In natural resource management, RS and GIS is mainly used in the mapping process. These technologies can be used to develop a variety of maps; land cover (LC) maps; vegetation maps; soil maps and geology maps. One of the major advantages of GIS is its capability to overlay multi-thematic data, which could be used in hydrological models or in integrated watershed management planning. The results thus obtained are much more realistic, comprehensive and less time consuming.

GIS could help in identifying the problems of areas and planning to mitigate the problems (Ramchandran *et al.,* 2001; Sarangi *et al.,* 2000). Sadgir *et al.* (2006) analyzed that continuous contour trench helps to increase the water levels in the surrounding areas, dug wells and tube wells which increases the yield of farms due to change in crop pattern from food grains to cash crops. Soil conservation depends on vegetative development, natural undergrowth, soil surface management and performance of the associated crop (Spaan *et al*., 2005; Pansak *et al*., 2010). Devnarayan *et al.* (2014) investigated various watershed characteristics and their behaviour to evaluate the efficiency of conservation measures in reducing erosion losses and increasing sorghum yield on slopy agricultural lands in red soils. Results indicated that different conservation measures were effective in conserving higher rainwater, reducing soil and nutrient losses and increasing yield of sorghum over control.

The annual production loss in major rainfed crops due to water erosion in India is estimated around 15.7% of total production and is equivalent to 162 billion (Anonymous, 2010). In economic terms, farmers adopt technologies and conservation strategies that they perceive to be profitable (Amsalu and Graaff, 2007). The decision to adopt technologies and techniques is also influenced by a farmer's socio-economic status, cultural background (Soule *et al.,* 2000) and access to natural resources (Byrne *et al*., 2010). Moreover, the process of adopting interrelated conservation strategies is more complex than the decision to adopt a single technology. The single decision is usually based on short-term profitability considerations, while interrelated adoption implies a more substantial and longer-lasting change in farming conservation (Caswell *et al*., 2001; Boyd *et al*., 2000).

The careful management and increased efficiency of irrigation water is a relevant component of any plan of action that helps to understand the benefits of irrigation and conservation (Kumar *et al.,* 2017). Such benefits include higher land productivity (Hussain and Hanjra, 2004). Most of the literature treats the adoption of SWC as separate decisions (Staal *et al.,* 2002; Kim *et al.,* 2005; Anley *et al.,* 2007; Calatrava-Leyva *et al.,* 2007; Kabubo-Mariara, 2007). Natural resource conservation has been found to have a positive impact on the productivity of annual crops (Gupta and Seth, 2007) and even to increase farm income (Bravo-Ureta *et al.,* 2006). Despite the potential complementarity of SWC, very few studies have modeled the determinants of farm-level decisions to conserve soil and water simultaneously. Keeping in view the present study was conducted to evaluate strategy and planning of conservation measures for resource conservation using RS and GIS.

2. MATERIALS AND METHODS

Study Area

The present study was conducted at Baliya micro-watershed. It is located between 24°54' to 25°01'N latitude and 73°20' to 73°25'E longitude in Gogunda block of Udaipur district, Rajasthan (Fig.1.). The study area falls under agro climatic zone - IV A (sub humid climate) of

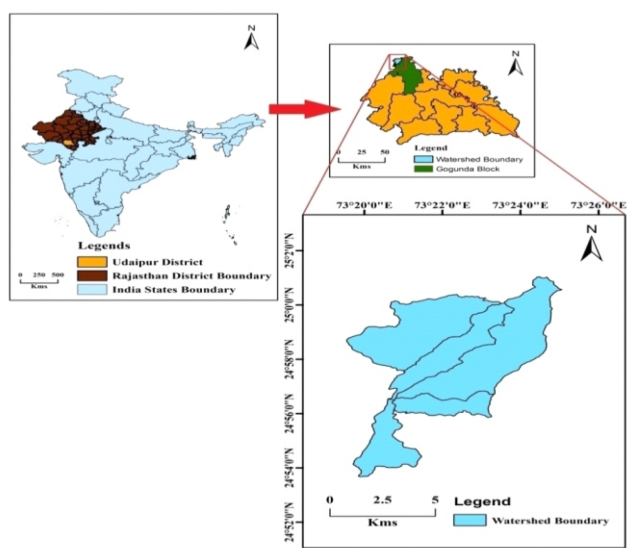

Fig. 1. Location map of the study area

Rajasthan. The average annual rainfall of study area is 633. The Baliya watershed comprises of undulating upland fields and hills. The average maximum temperature of the area in summer goes upto 40ºC and in winter the average minimum temperature goes upto 5.4ºC. Distribution of rainfall in monsoon season is uneven and erratic marked by prolong dry spells. Udaipur district is part of the peninsular region of India and thus possesses peninsular characteristics. Logically, it consists of rock groups of Archean system.

The watershed consists of 3 ponds and 106 wells in which groundwater table varies from 12 to 17 m with the seasonal fluctuation of 2-3 m. The quality of water is good and the wells have moderate yields. The general slope of the area is north-east to south-west direction as shown in (Fig.2). The slope of the arable land varies from 1.84-15% and for non arable land varies from 16-33%. Maize, black gram and green gram are the commonly grown crops in *kharif* season whereas, wheat, mustard, gram, linseed are grown in *rabi* season. Due to lack of irrigation facilities mostly rainfed farming is in common practice in the area. *Kharif* crops are mainly depending on the monsoon. Total treatable area of the watershed is 1410 ha, out of which 346 ha land is under cultivation. Area under arable land is 410 ha where as under non-arable land is 1000 ha as shown in (Fig. 3). The non-arable land is totally degraded and forest cover area is poor.

The Survey of India toposheet No 45 G/08 and 45 H/05 on 1: 50,000 scales were used to delineate the Baliya micro-watershed of Udaipur region for geo-morphological analysis, LU capability classification and LU pattern. It was updated by using LISS - IV and Cartosat-1 merged data of the year 2012. The digital satellite data was geometrically rectified and geo-referenced by taking ground control points using UTM projection and WGS 84 datum. Since it is used as a standard parameter under National Spatial Framework of NNRMS as well as by Department of Space, Government of India. The base map of the watershed was prepared using Survey of India toposheet and remote sensing image from (IRS) LISS - IV and Cartosat - 1 of the year 2012 having a spatial resolution of 2.5 m. The study was carried out in GIS environment. Digital Terrain Model (DEM) was used for preparation of slope and relief map as terrain plays a fundamental role in modulating Earth surface and atmospheric processes. Terrain parameters, or topographic indices, are descriptions of surface form that can be computed directly at every point on a DEM. Slope is important in identifying constraints and evaluating potential environmental impacts related to landform alteration. Slope map is excellent tools to look for potential erosion areas, drainage patterns, landform and soil patterns, land use suitability, etc.

To construct a slope map select specific slope categories to map. The easiest approach to mapping slope is to measure slope between two contour lines. LU/LC mapping studies using RS have been attempted by NRSA by visual and digital interpretation with multi spectral data analysis system for smaller areas on an operational basis in India. Lands at thematic mapper at a resolution of 30 m of 2012 was used for LU/LC classification. The satellite data covering study area were obtained from global land cover facility (GLCF) (http://glcfapp.glcf.umd.edu:8080/esdi/) and earth explorer site (http://earthexplorer.usgs.gov/).

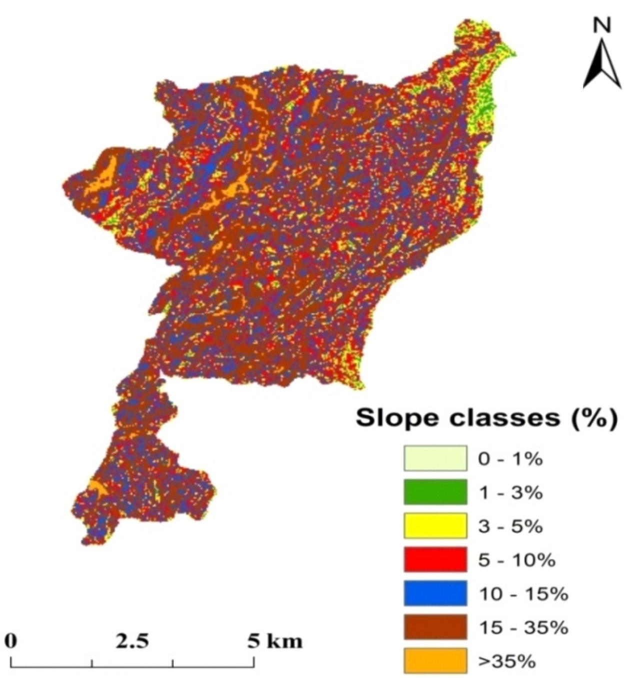

Fig. 2. Slope map of study area

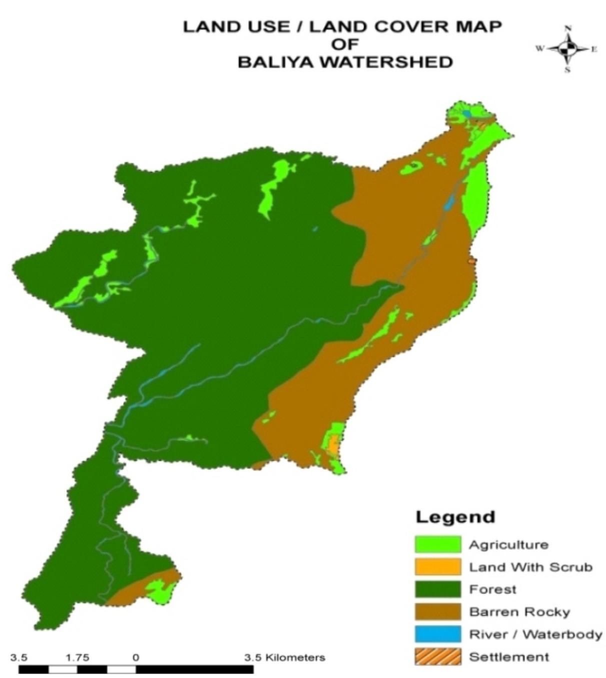

Fig. 3. Land use and land cover map of study area

These data sets were imported in ERDAS Imagine version 9.3 software to work out the LU/LC classification. RS and GIS are the most handy and accurate tools to measure the various earth resources and their potentials. On the basis of the topography of the area, LU capability classification, rainfall pattern, various SWC measures suitable for the area were proposed. Land capability classification map of Baliya watershed was prepared in Arc-GIS 10.1 software and it is based on several factors such as soil texture and structure, soil depth, slope and degree of erosion. These parameters are assessed by applying RS and GIS techniques (Panhalkar, 2011), as they are powerful tools for collecting information at a very low cost and high accuracy. For harvesting excess runoff water harvesting structure were also proposed for which rainfall data of 30 years (1984-2013) were collected and analyzed by Weibull's probability techniques. The rainfall data collected from Gogunda rain-guage station, Udaipur were used for the present study. Nearly 90% of the total precipitation is received during monsoon period (from middle of June to September) with long dry spells causing frequent crop failure. The distribution of annual rainfall for 30 years (1984-2013) is illustrated in (Fig. 4).

There is a criteria for selection of different SWC measures and water harvesting structure based on slop of land, rainfall/runoff and infiltration rate of soil.

3. RESULTS AND DISCUSSION

The results obtained through the analysis are diagrammatically illustrated in Figs. 2, 3 and 7 and data are registered in Tables 1, 2, 3, 4 and 5. Fig. 2 depicts slope of the study area and Fig. 3 depicts LU/LC change in different land use categories while Fig. 4 illustrates distribution of annual rainfall in 30 years. Brief accounts of these results are discussed in the following paragraphs. The digitally delineated watershed is covering an area of about 5578 ha. Total treatable area of the watershed is 1410 ha, out of which 346 ha land is under cultivation. The morpho-metric analysis shows the elongated shape of watershed with permeable subsoil material under poor vegetative cover. The resource inventory of Baliya micro-watershed is shown in Table 1. Lands are utilized for multiple purposes. They are mainly used for agriculture, pastures and forestry. Depending on the nature and properties of soils, they are suitable for one or other uses. Based on the capability or limitations, the study area has LU capability classification of III, VI, and Rock outcrop (Fig. 7). Among them, class III is used for agriculture or cultivation of crops. The class III land is differentiated based on the extent of soil slope, erosion, depth, structure, soil reaction and drainage. The classes VI and Rock outcrop are not capable of supporting cultivation of crops. They are used for growing grasses, forestry and supporting wild life. The results are supported by Kumar (2006) and Panhalkar (2011).

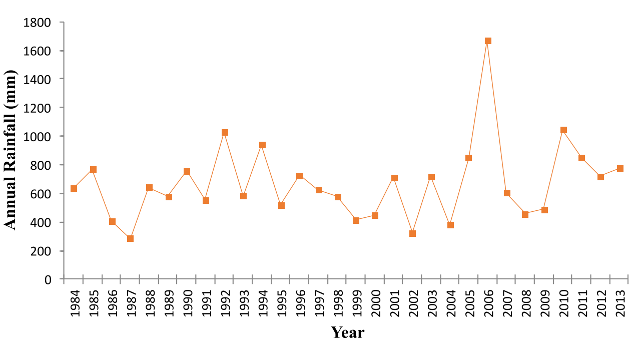

Fig. 4. Distribution of annual rainfall for 30 years (1984-2013)

Analysis of rainfall data of 30 years period (1984-2013) revealed that the maximum annual rainfall in the last 30 years was found 1670 mm in the year 2006 and the minimum was 283 mm in the year 1987. Whereas the maximum monsoon season rainfall was 1647 mm in the year 2006 and the minimum monsoon seasonal rainfall was 181 mm in the year 1987 as shown in Fig. 4. The probability analysis and recurrence interval study of annual and seasonal rainfall for the period 1984-2013 are summarized in Table 2 and 3. It is evident from Table 2 and 3 that at 75%

Table: 1
Resource inventory of Baliya micro-watershed

S.No.	Geographical Parameters	Description
1	Location	Panchayat Samiti Gogunda, Dist. Udaipur (Rajasthan)
2	Total area	5578 ha
3	Forest land	3828 ha
4	Waste land	349 ha
5	Treatable area	1410 ha
6	Cultivated land	Arable land = 410 ha, Non-arable land = 1000 ha, Irrigated = 146 ha, Rainfed area = 239 ha
7	Shape of watershed	Elongated, with permeable sub-soil under poor vegetative cover Elongation ratio = 0.68; Circulatory ratio = 0.27
8	Groundwater potential	Poor to Moderate
9	Land use capability classification	Class - III; Class - VI; Rock outcrop
10	Slope	Arable land: 1.84-15%; Non-arable land: 16-33%
11	Soil erosion hazard	Moderate to High
12	SWC measures	Arable land: Contour bund-295.16 ha; PRT- 191.56 ha; SWT- 191.56 ha. Non-arable land: Contour Trench-18.3 ha; Staggered Trench- 285.17 ha; V-ditch-601.12 ha; Loose Stone Check Dam - 27.50 ha; Silvi-Pasture - 18.31 ha

Table: 2
Probabilities and recurrence intervals of annual rainfall for the period (1984-2013)

Annual Rainfall (mm) in Descending Order	Rank (m)	P = m/ (n+1)	Recurrence Interval (T = 1/P) (year)	Probability (%)
1670	1	0.0323	31.00	3.23
1046	2	0.0645	15.50	6.45
1028	3	0.0968	10.33	9.68
941	4	0.1290	7.75	12.90
851	5	0.1613	6.20	16.13
850	6	0.1935	5.17	19.35
776.8	7	0.2258	4.43	22.58
768	8	0.2581	3.88	25.81
757	9	0.2903	3.44	29.03
729	10	0.3226	3.10	32.26
721	11	0.3548	2.82	35.48
720	12	0.3871	2.58	38.71
712	13	0.4194	2.38	41.94
642	14	0.4516	2.21	45.16
639	15	0.4839	2.07	48.39
626	16	0.5161	1.94	51.61
606	17	0.5484	1.82	54.84
581	18	0.5806	1.72	58.06
579	19	0.6129	1.63	61.29
577	20	0.6452	1.55	64.52
557	21	0.6774	1.48	67.74
519	22	0.7097	1.41	70.97
489	23	0.7419	1.35	74.19
459	24	0.7742	1.29	77.42
448	25	0.8065	1.24	80.65
416	26	0.8387	1.19	83.87
406	27	0.8710	1.15	87.10
382	28	0.9032	1.11	90.32
325	29	0.9355	1.07	93.55
285	30	0.9677	1.03	96.77

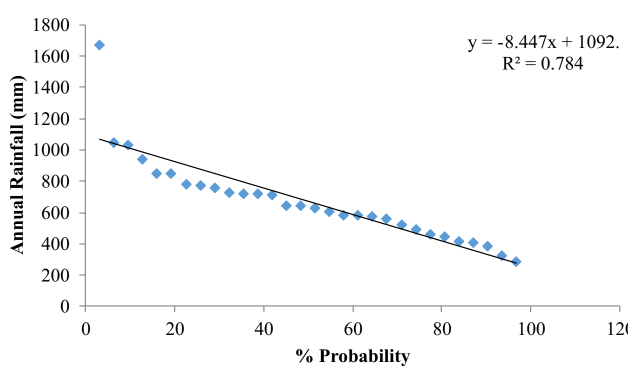

Fig. 5. Annual rainfall at different percent of probability based on 30 years (1984-2013)

Table: 3
Probabilities and recurrence intervals of seasonal rainfall for the period (1984-2013)

Seasonal Rainfall (mm) in Descending Order	Rank (m)	P = m/ (n+1)	Recurrence Interval (T = 1/P) (year)	Probability (%)
1647	1	0.0323	31.00	3.23
949	2	0.0645	15.50	6.45
907	3	0.0968	10.33	9.68
882	4	0.1290	7.75	12.90
837.4	5	0.1613	6.20	16.13
825	6	0.1935	5.17	19.35
737.9	7	0.2258	4.43	22.58
730	8	0.2581	3.88	25.81
707	9	0.2903	3.44	29.03
703	10	0.3226	3.10	32.26
692	11	0.3548	2.82	35.48
681	12	0.3871	2.58	38.71
647	13	0.4194	2.38	41.94
639	14	0.4516	2.21	45.16
619	15	0.4839	2.07	48.39
580	16	0.5161	1.94	51.61
572	17	0.5484	1.82	54.84
564	18	0.5806	1.72	58.06
551	19	0.6129	1.63	61.29
524	20	0.6452	1.55	64.52
478	21	0.6774	1.48	67.74
475	22	0.7097	1.41	70.97
458	23	0.7419	1.35	74.19
400	24	0.7742	1.29	77.42
382	25	0.8065	1.24	80.65
377	26	0.8387	1.19	83.87
374	27	0.8710	1.15	87.10
306	28	0.9032	1.11	90.32
303	29	0.9355	1.07	93.55
181	30	0.9677	1.03	96.77

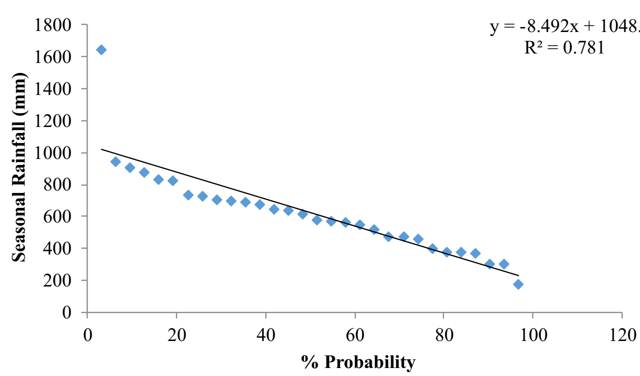

Fig. 6. Seasonal rainfall at different percent of probability based on 30 years (1984-2013)

probability level, annual and seasonal rainfall are 480 and 450 mm, respectively, while at 50%, these are 632 and 590 mm, respectively. The study supported results were found by Kumar (2006) for Karola-II micro-watershed of Udaipur district, Praveen *et al.* (2011), Subudhi *et al.* (2012) and Sharma and Dubey (2013). Runoff depth decreased with the introduction of vegetative barriers and further using mechanical measures. The graphical representation of annual and seasonal rainfall at different percent of probability based on 30 years (1984-2013) are illustrated in Fig. 5 and 6.

On the basis of rainfall, slope and LU capability classification various SWC measures have been recommended which are shown in Table 4. The LU capability classification map of the study area is shown in (Fig. 7). Different SWC measures in different blocks of Baliya micro watershed is shown in Table 5. Contour bund, Puerto Rico Terrace, Stone Wall Terrace were proposed on arable land and Contour trenches, Staggered Trenches and V-ditches were proposed for non-arable land at selected site. Loose stone check dams were proposed in small cultivated gully. The class VI was proposed to be treated with afforestation cum pasture development with fencing wall to protect the area from animals (Mittal, 2002, Amsalua and Graaff, 2007 and Singh, 2012). The total length of contour bund was worked out to be 44275 m; out of which 4257 m is in Block-A, 14315 m is in Block-B and rest 25703 m is in Block-G. The cost of contour bund per hectare was estimated as ₹ 11088.

Contour bunds checked the velocity of flowing water, increased the time of concentration and allowed higher infiltration into the soil consequently reduced the runoff and soil loss. The area proposed under PRT is 191.56 ha. The total length of PRT is 28734 m and the total length of Stone

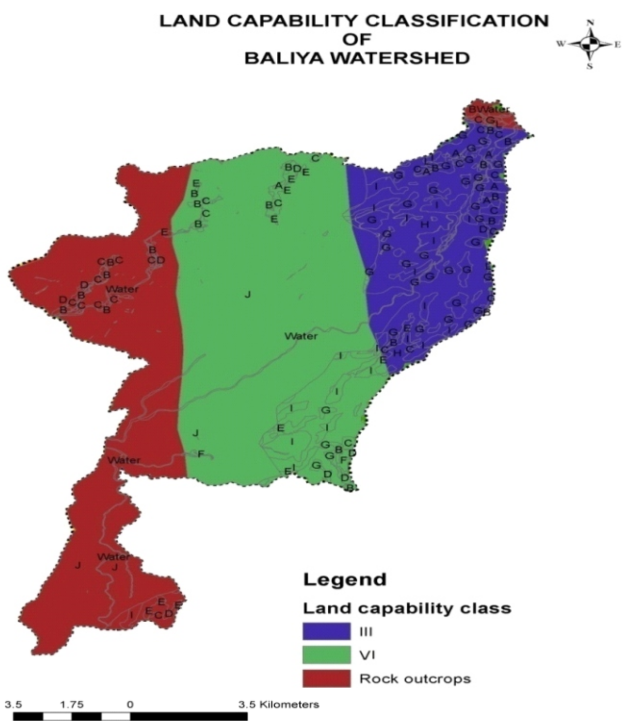

Fig. 7. Land capability classification map of the study area

Table: 5
Soil and water conservation measures in different block of Baliya micro watershed

S.No.	Proposed measures	Block	Slope (%)	Area (ha)
1	Contour Bund	A, B, G	1.84, 4.98, 2.96	295.16
2	Puerto Rico Terrace	C	9.40	191.56
3	Stone Wall Terrace	C	9.40	191.56
4	Contour Trench	E, F	19.58, 26.15	18.31
5	Staggered Trenches	I	32.50	285.17
6	V-Ditch	H	12.62	601.12
7	Loose Stone Check Dam	D, E	14.60, 19.58	27.50
8	Afforestation Cum Pasture Development	E, F	19.58, 26.15	18.31
9	Anicut	G	-	364

Table: 4
Criteria for selection of different soil and water conservation measures and water harvesting structures

S.No.	Structure	Selection Criteria						
		Rainfall/runoff (mm)	Slope	Infiltration rate/ seepage	Soil depth	Desired use	Economy	Others
1.	Contour bund	<600	<6%	Moderate	Must not be Black cotton soil	*In-situ* moisture conservation	-	Construction
2.	Puerto-rico terrace	400-800	>6%	Moderate	Shallow soil depth	Protection of valley slopes	Availability of loose stones	-
3.	Stonewall terrace	400-800	>6%	Moderate	Shallow soil depth	Moisture conservation in valley	Availability of loose stones	-
4.	Continuous contour trench	400-1200	10-30%	Good	-	*In-situ* moisture	- conservation	-
5.	Staggered contour trench	400-1200	>20%	Moderate	Shallow soil depth	*In-situ* moisture conservation	-	Hilly condition
6.	V-ditch	<800	15%	Good	-	*In-situ* moisture conservation	-	-
7.	Loose stone check dam	400-1200	>6%	Good	Shallow soil depth	*In-situ* moisture conservation	Availability of loose stones	-
8.	Anicut	Large	<2%	Moderate	-	Water harvesting for supplement irrigation and ground water recharge	Natural sub-mergence to be utilized	Where bank is available with deep gullies of good storage

Wall Terrace was worked out to be 2299 m covering an area of about 191.56 ha in Block-C. The cost of SWT per hectare was ₹ 4879. The total area under contour trench is 18.31 ha and the total length of contour trench that has to be constructed is 14648 m while the cost per hectare was ₹ 10797. The total numbers of staggered trenches proposed in the area are 57034 and the cost per hectare was ₹ 9522. Total length of V-ditch is 480896 m for 601.12 ha area. The cost of V-ditch per hectare was ₹ 6748.0. Loose stone check dam was proposed for the Block-D and Block-E having total area of 27.50 ha. The cost per hectare worked out to be ₹ 3760. The total length of stone fencing wall to be constructed is 1831 m covering an area of about 18.31 ha. The cost per hectare was ₹ 32523. Afforestation cum pasture development control erosion by slowing and filtering runoff and reducing the slope of the land which tends to reduce erosion rates. Similar results were found by (Bhanavase *et al*., 2007; Guto *et al.,* 2011; Mohapatra *et al.,* 2006; Prasad *et al.,* 2005) as there is a reduction in soil loss with the introduction of vegetative barriers. Average cost of watershed treatment excluding the cost of water harvesting structure was estimated to be ₹ 11390 ha^{-1}. For harvesting of excess runoff water harvesting structure (Anicut) of capacity 1.64 ha-m was proposed. The stored water would be useful for supplemental irrigation to *rabi* crops.

4. CONCLUSIONS

Conservation of natural resources of micro-watershed is crucial for making recommendation of appropriate SWC measures based on the rainfall, topography, LU capability classification, soil erosion hazard and LU pattern of the study area. For arable land Contour bund, Puerto rico terrace and Stone wall terrace were proposed whereas for non-arable land Contour trench, Staggered trench, V-ditch and Afforestation cum pasture development were proposed. For the treatment of drainage line and harvesting of excess runoff, loose stone check dams and Anicuts of different dimensions were proposed as per topography of catchment area. The study was demonstrated the versatility and utility of RS and GIS for sustainable management of natural resources on watershed basis.

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