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Land Resource Inventory and Characterization for Planning Soil Conservation Measures in Aravalli Hill Slopes

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A B S T R A C T

The Aravalli region in India is very prone to soil erosion and low hydrological regimes. The present study has been carried out in the Aravalli hill slopes to characterized land resources, identified soil problems to establish appropriate soil conservation measures in risk prone areas and appropriate land management practices. The integrated remote sensing (IRS-P6-LISS-IV and cartosat-1 merged data) and GIS based methodologies were employed for terrain analysis, identification of slope, landform, land use/land cover classes, hydro-geomorphology. Detailed soil resource characterization generated soil depth, texture, drainage condition, soil erosion status, and their related site-specific problems. The soils of the region are varied as per their physiographic set up. Soils of hill/ hill slopes are very shallow to shallow, excessively drained, gravely sandy loam, very severely eroded soils while upper piedmont plains are moderately deep to deep, somewhat excessively drained, loamy sand to sandy loam, moderately eroded while, soils of lower piedmont plains are deep to very deep, well drained, slightly eroded, sandy loam in texture and soils of fluvial channels or abandoned channels are moderately deep to deep, moderately well drained, stratified soils and severely eroded. The site-specific problems/potentials and thematic information generated were integrated, and suggested need based soil and water conservation measures such as contour bunding, staggered contour trenches, mechanical trenches, gully plugging, vegetative bunds, and field bunding to enhance the hydrological regime of the watershed and to check degradation and restore the eroded area for management of soil resources for sustainable production for improving socio-economic condition of the farmers in Aravalli region.

Keywords

Land resource characterization, Soil resource assessment, Soil erosion, Soil conservation measures, Remote sensing approach, Aravalli region

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Introduction

Land resources of the country are its most precious and sacred endowment. Land and water are most important natural resources play a vital role in agricultural development. But land is continuously under threat of degradation through various erosional activities. In India, total of 148.9 million ha of land, representing 45% of the total geographical area is subjected to soil erosion and land degradation (Sehgal and Abrol, 1994). Water erosion alone is estimated to cause loss of 5.334 million tonnes of top soil annually alongwith 5.37 to 8.4 million tonnes of plant nutrients (Dharuvanarayana and Rambabu, 1983). Run-off loss and soil loss is especially more in an area covered with meager vegetation/forest cover. Beside this, the burgeoning human population, in the pursuit of meeting the fuel and fodder demand, indiscriminately destroy vegetation cover. In Aravalli plains major chunk of land is affected by various forms of land degradation. Nutrient depletion and land use change witness the area. The land use pattern changes regularly. In this region, because of severe degradation majority of area is under barren stony and affected by stone mining activities. Hill slopes fields are under single crop or kept under fallow because of water scarcity. The region is under rainfed farming and receives annual rainfall of <600 mm.

Therefore, an imperative stage has come where suitable soil and water conservation measures on watershed basis are immediately warranted to reduce soil erosion, restore land productivity and improve socio-economic strata of the area. With the general acceptance of watershed as principal unit of planning, many developmental activities has based on suitable utilization of locally available natural resources, hence the watershed requires the detailed characterization and Inventorization of natural resources (Sharada *et al.,* 2005; Patil *et al.,* 2010 ; Manchanda *et al.,* 2002). Soil resource mapping by using geo-spatial techniques, identification of constraints/ potentials, delineation of erosion prone areas are pre-requisite for suggesting conservation measures (Surya *et al.,* 2008) and several studies reported potentials use of remote sensing for characterization and management of land resources at watershed level (Srinivasa *et al.,* 2008; Elvis *et al.,* 2009; Solankhe *et al.,* 2009). Several researches suggested, advent of remote sensing provides precise delineation of landform - soil units and GIS environment proves the appropriate and faster mapping of natural resources and better option for management. The present study was carried out to generate the land resources characterization, identify soil and water related constraints and suggests location specific conservation measures for management of natural resources of the watershed by using geospatial techniques. The study also demonstrates the utility of remote sensing data (IRS LISS-IV + Cartoat-1 data) for delineation of distinct topographic features by using interpretation techniques.

Materials and Methods

The study area, Richhoha micro-watershed, Kheragarh tehsil, Agra district, Uttar Pradesh is situated in Aravalli hill slopes (26^{o}52'16" to 26^{o}55'20" N latitude and 77^{o}27'50" to 77^{o}34'15" E longitude), covering an area of 1763.76 ha. Study area comprises six villages *viz.,* Richhoha, Tarhat, Thansara, and part of Gugawand, Chahchand, and Bhopur (Fig.1) and bounded by Rajasthan state in two sides. Geology is mainly alluvium and sandstone (Aravalli sandstone). The area is drained by Richhoha River and its channels which are seasonal in nature. The drainage density in the hilly areas and upper slopes are high and moderate to low in lower reaches. The elevation rages from 180 to 289 m amsl. The climate is hot semiarid with mean annual rainfall of 600 mm. Area qualifies ustic moisture regime and hyperthermic soil temperature regime. The length of growing period (LGP) is 90 to 120 days. Majority crops are pearl millet, pigeon pea, lentil, linseed, wheat and mustard. Double cropping is restricted along the drainage channels and lower reaches.

The satellite imageries, Cartosat-1 and Geo-coded IRS-P6 LISS-IV sensor data merged with pan data of February, 2015 and May, 2015 was used for present study. The remote sensing data was Georeferenced and interpreted visually as well as digitally in ArcGIS (10.2 version) software on basis of photo elements like tone, texture, size, shape, pattern, association etc. for delineation of slope, drainage, land use/ land cover, hydro-geo-morphology. Cartosat-1 steriopair data was processed to generate Digital Elevation Model of 10 m spatial resolution and further interpreted for terrain and landform analysis. The ancillary data namely Survey of India (SOI) toposheets, cadestral maps and other legacy data on land resources at various scale were used as reference materials. The detailed soil resource mapping of study area was carried out using base maps prepared by integrating data for landform, slope, land use/land cover by adopting digital interpretation procedure. The representative soil profiles and random observation were studied during detailed soil survey by using standard soil survey procedures (Natarajan, 2014; and AIS & LUS, 1971) and horizon wise soil sample were collected. Soils were analyzed for physico-chemical properties (Jackson, 1973). Soils were correlated and classified as per Soil Taxonomy (Soil Survey Staff, 2012). The soil erosion status, irrigability class (AIS & LUS, 1971) and soil problems were identified and evaluated. The thematic information on slope, contours, landform, drainage, land use/land cover, hydro-geomorphology, soil, soil texture *etc.* on the scale of 1:10,000 scale were generated in GIS environment. The rainfall analysis was carried out for last 25 years in 5 years interval. The socio-economic data collection was carried out in the cultivar families of the villages. The collateral data base containing crops and cropping pattern, irrigation status, dug well density, observation well data etc. for Richhoha micro-watershed have been collected from respective sources. By integrating resources information suitable conservation measures were suggested for watershed development and increasing sustainable.

Results and Discussion

Resource characterization and thematic information generation for watershed planning

Slope categories

The slope of land has a great influence on soil runoff and loss from the area and thereby influences the land use. The general slope of watershed is towards north to north-east direction. In the micro-watershed, slope analysis was carried out using the Cartosat-1 DEM, expressed as a percentage and reclassified into slope classes. Most of the watershed area under 5-10% slopes (26.85% TGA) followed by gently sloping upper piedmont plains (3-5 % slope) and strongly sloping hill side slopes (24.92 and 17.99 %, respectively). (Fig 2). The area under moderate slopes (26.85%), abandoned channels (13.17%) and gentle slopes (24.92%) are prone to erosion and need conservation measures. Similar results were reported by Singh *et al.*, 2004 in Aravalli and its surrounding areas. Nearly, 15.73 % watershed categorized into 1- 3% slopes. The cultivable area restricted in lower slopes. These areas need conservation practices for in-situ moisture conservation to increase agricultural production.

Landform analysis

The delineation of landforms was done using both visual as well as digital image interpretation technique. Geomorphic features were analyzed and interpreted based on key image elements. Terrain attributes like contours, slope, drainage, and hill shades are treated as input layers for landform delineation. It was carried out using elevation information available in the DEM generated from the cartosat-1, and the contours were generated from the cartosat-1 DEM. Using landform analysis in conjunction with detailed ground truth data delineated five landform units i.e. hill/hill slopes, upper piedmont plain, lower piedmont plain, nearly level plain, narrow/ broad abandoned channels (Fig 3). The dominant area 473.71 ha (26.85 %) is under moderately sloping hill side slopes followed by upper piedmont plains (439.61 ha), and strongly sloping hill slopes (317.44 ha). Very gently to nearly level lower piedmont plains plain occupied 277.74 ha (15.03%) area of the watershed. Strongly to very strongly sloping hill/ hill slopes are part of Central Highland Aravalli ranges elevated far above the surrounding areas. Lower hills are reached or lateral extension descending from upper piedmont plain having lesser elevation. Moderately steep slopes to very gentle slopes the occurs from differential erosion and separates relatively level areas of differing elevations Similar results were also reported by Singh *et.al* (2004). Gently sloping fluvial channels formed as erosional features in upper reaches and abandoned channels in lower level are formed by deposits of sediments by erosional processes. Physiographic mapping involves the identification and characterization of the fundamental units of the landscape (Srivastava *et.al* 2004).Upper piedmont plains, lower piedmont plains are formed by as a result erosional process. The lower piedmont plains unit characterized as depositional features. The scope has further expanded with the landform maps widely used in various fields of resource surveys, environmental analysis, hydrological studies and many more applications.

Land use/land cover

The spatial distribution of land use/ land cover of the micro watershed as interpreted from satellite imagery is presented in Fig 4. The data revealed that, out of 1763.76 ha area of the watershed, 949.61 ha (53.84 %) was under cultivation and mostly under single kharif cropped (29.67 %) kharif crop which reflects that there was shortage of water for irrigating these crops. followed by stony waste/ pasture (37.33 %) followed by pasture/grazing/ thin shruby forest (7.51 %). Under the cultivated area. Agricultural practices with dominance of *Kharif crops* like pearl millet, pigeon pea, and sorghum, with sprinkle of vegetables, linseed in the irrigated areas. In *Rabi* season, wheat, mustard and lentil are sown. Double cropping is observed all along the drainage and lower reaches only (Fig. 4). The area mainly rainfed and irrigated by limited bore well. Patches of open scrub forest and scrub lands were seen over higher slopes while protected forest under bushy vegetation is in limited lower reaches.

Hydro-geomorphology

Entire watershed is underlined by Aravalli - sandstone formation over which various geomorphic processes resulted into various physiographic settings. The groundwater potential has been assessed considering weathered thickness of each zone and observation well data. Among these moderately dissected hill slopes has categorized into ‘C’ zone is most predominant (44.84 %) followed by moderately dissected upper and dissected denudational slopes of fluvial channels piedmont is under ‘B’ zone (24.92 %.) while lower piedmont plain and alluvial plain are categorized into A zone (Table 2). The Denudational hill/hill slopes have poor ground water potential while, fluvial channels have moderate groundwater potentials. MDP’A’ has good groundwater potential to sustained crop. The groundwater potential in the zone C and B has urgent need to improve groundwater potential and the storage.

Soil resources characterization

The soil resource characterization and mapping was done on 1:10,000 scale for mapping of soils, assessment of soil erosion status, evaluation of soil irritability class and identification of problems and potential areas. The soil map prepared after establishing physiography-soil relationship indicates the kind and distribution of soils in the micro-watershed along with their extent (Fig 4. and Table 2).

In total, 7 soil series have been established and mapped as associations of soil series. Soil depth, drainage and texture were demarcated in fig. 5, 6, and 7 respectively. Soil of upper reaches of the watershed (Hasanpur and Gugawad soil series) are skeletal to very shallow, mixed, isohyperthemic Lithic Ustorthents, occupied an area of 791.15 ha (44.84%) of TGA. These soils are occurring over steep slopes interspersed with rock-out crops and hence have low water holding capacity and prone to excessive erosion. The cultural use of these soils restricted to scrub/ pasture lands. Very shallow depth, steep slope and severe erosion are the major problem of these soils. As per soil irrigability class, these soils are under non-irrigable soils with very high run-off potential zone. Soils over gentle slopes of upper piedmont plains (Sonikhera series) are coarse loamy, mixed, isohyperthemic, Typic Ustorthents) are moderately deep, occupied 24.92 % area of Richhoha watershed and under cultivation with single crop. These soils have low water holding capacity and have moderate erosion hazards. The hydrological grouping these soils comes under high run-off potential zone. Soil of Middle reaches of watershed (Naglamadho series) is coarse loamy, mixed, isohyperthemic, Typic Ustifluvents, occupied an area of 143.39 ha (8.12%). These soils have moderate water holding capacity and are susceptible to slight to moderate erosion. Presently under single crop and patches of double crops has been taken over this soils. The major problem of soils is coarser surface texture (loamy sand), excessively drained and moderately low run-off potential. Soil of Fluvial/Abandoned channels (Nagla-Makaran series) are coarse loamy, mixed, isohyperthemic Typic Ustifluvents, occupied an area of 13.17 % which mainly occurs along the Richhoha river and its channels mainly under single cropping. These are stratified soils (sandy loam to clay loam) having low to medium water holding capacity and susceptible to slight to moderate erosion hazards. These soils have moderate limitations for sustained use under irrigation.

The major problems of these soils are coarser texture, calcareous with lime nodules, moderate drainage and medium water holding capacity. Singh *et al.,* 2004 also reported the same findings. In hydrological grouping, these soils are shown to have medium run-off potentials. Soils of lower reaches are on very gently to nearly alluvial plain coarse loamy, mixed, isohyperthemic, Typic Haplustepts (Bhirbham series) occupied an area of 7.61 %. Double cropping is common in this series. These soils have medium to high water holding capacity and susceptible to slight erosion hazards. These soils have moderate to slight soil limitations for sustained use under irrigation and slight to moderate limitation for sustained land under irrigation. The major problems of these soils are slightly calcareous, drainage and high water holding capacity. In hydrological grouping of these soils have low run-off potentials.

Soil and water conservation measures

Soil types, their potentials and problems call for planning appropriate soil and water conservation measures. The information, thus, generated was used to suggest suitable conservation measures (Table 2).

Fig.1 Location map of study area

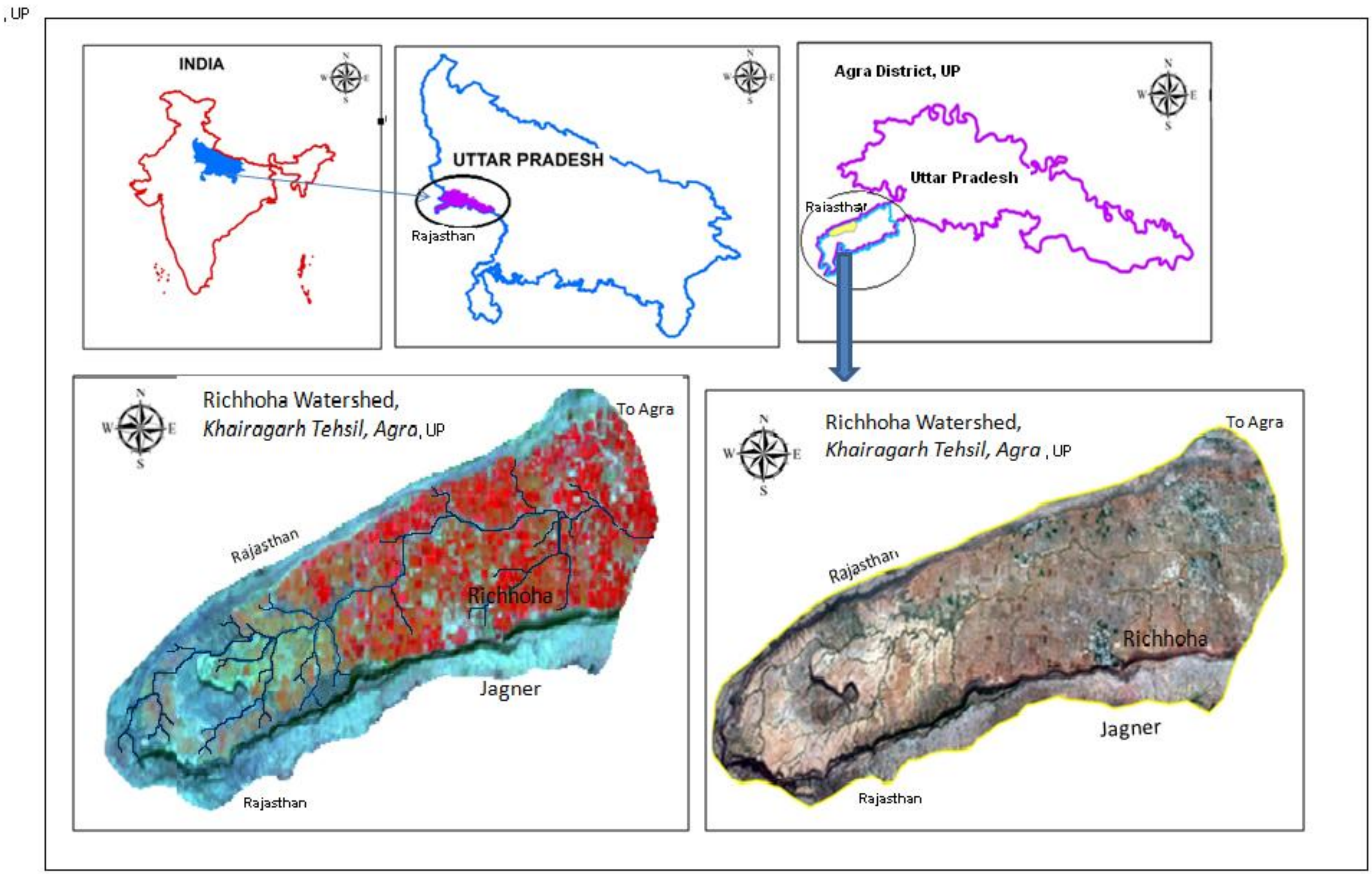

Fig.2 Slope map of Richhoha watershed, Agra

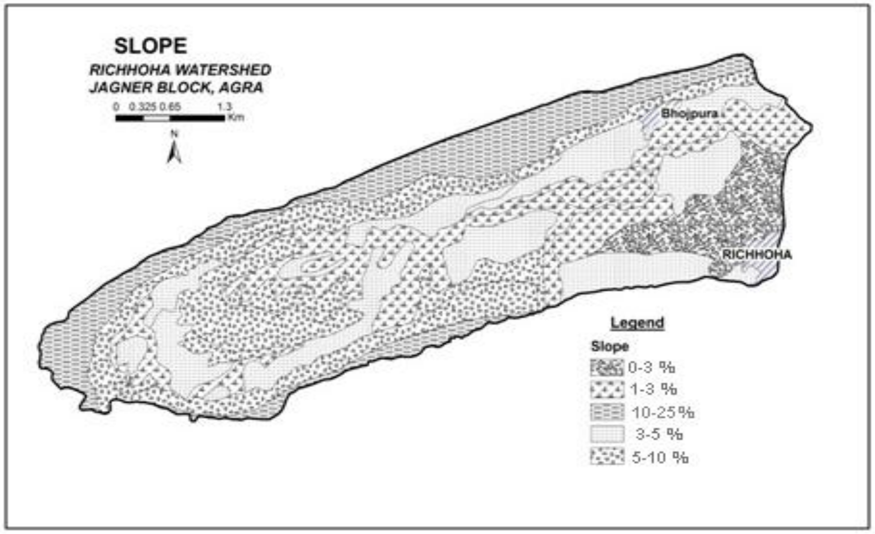

Fig.3 Landform map of Richhoha watershed Richhoha watershed, Agra

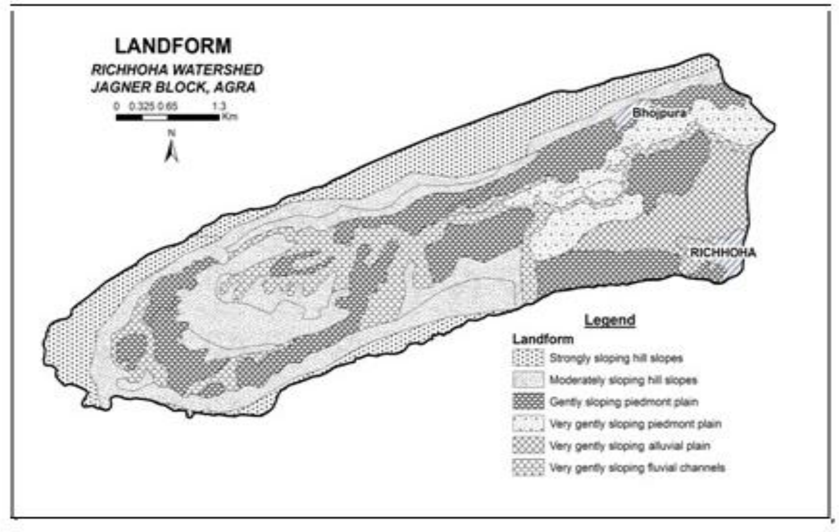

Fig.4 Soil map, Richhoha watershed

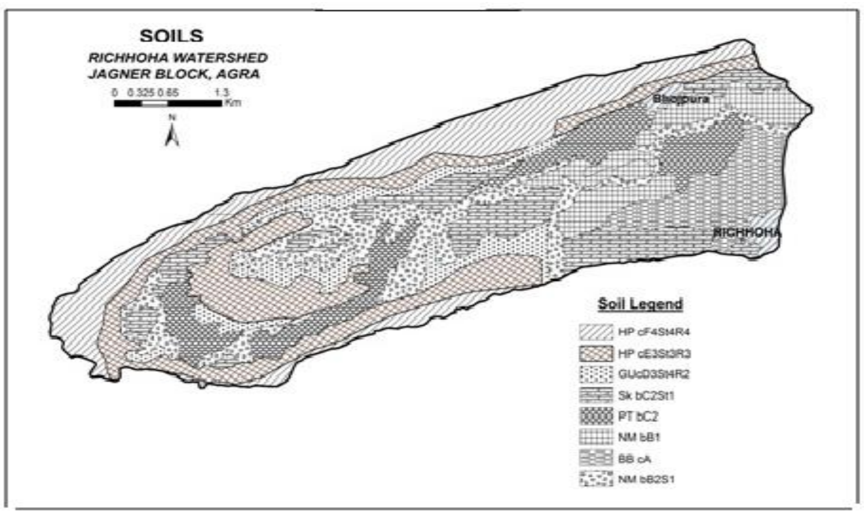

Fig.5 Soil depth map of Richhoha watershed

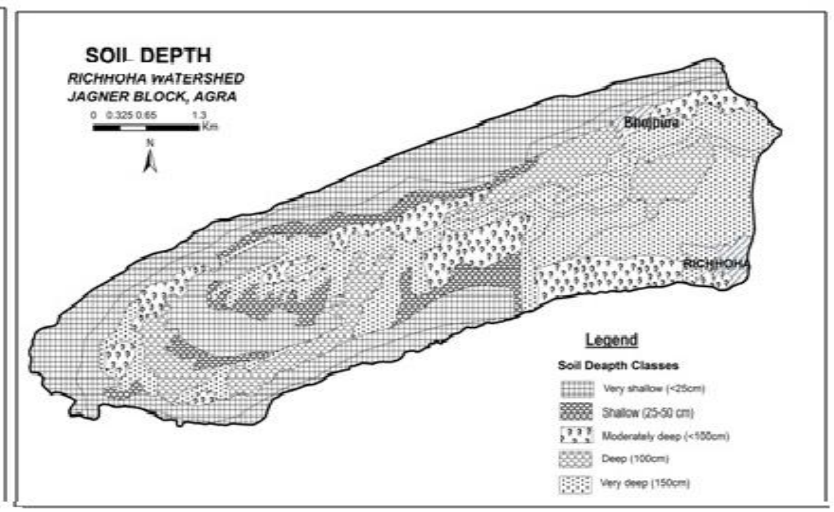

Fig.6 Drainage map of Richhoha Watershed

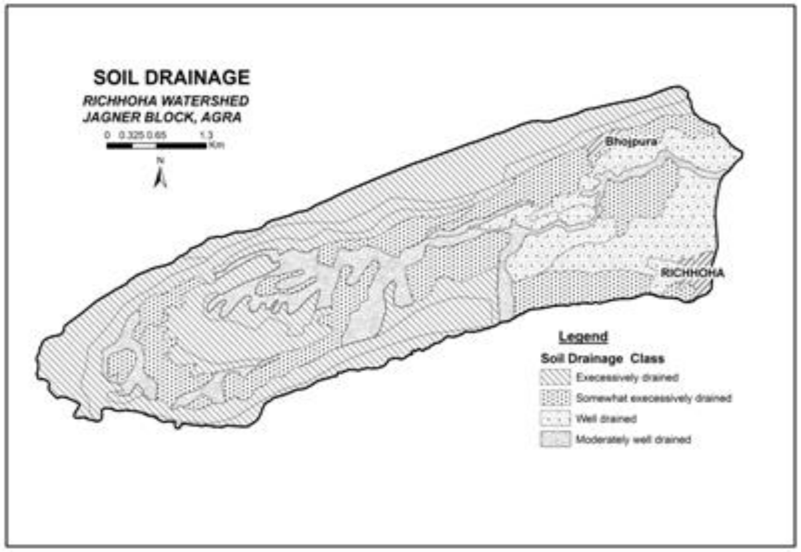

Fig.7 Texture map of Richhoha Watershed

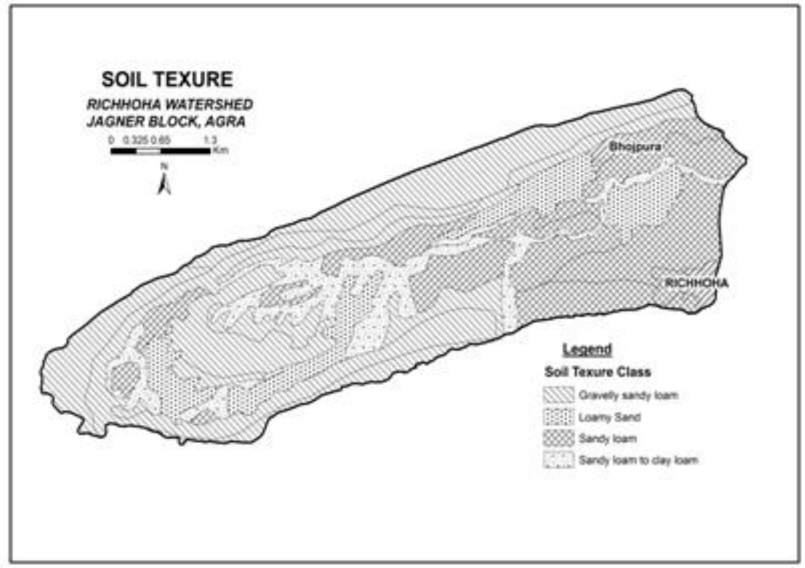

Table.2 Details of soil series its problems, hydrogeomorpholgy, and ground water potentials with suggested measures

Soil Series	Erosion	Irrigability class		Soil problems	Geomorphic Unit	Hydrological grouping	Groundwater potentials	Conservation measures
		Soil class	Land Class					
Hasanpur Series	Severe	E	6	Very shallow to shallow depth	DH, DS,	High run-off potential	Poor, Poor to moderate poor	GP, ENB Series, CCT, CNB, Stone checkdams
Gugawad Series	Severe	D	6	Mode slopes, severe erosion	DS, DH, MDH	High run-off potential	Poor	GP, CCT Series, Stone checkdams VB /VH
Sonikhera and Pipreta Series	Moderate to severe	D	4	Gentle to very gentle slopes	MDPP ‘C’ MDPP ‘B’	Moderately high run-off potential	Moderately Good to Moderate	CNB, UGB Series, CNB, PT
Nagla Madho Series	Moderate	D	3	Very gentle slopes, slight to mod. erosion	MDLP ‘B’	Moderately low run-off potential	moderate	ENB, Series GP, CCT, VB
Bhirbham Series	Slight to moderate	B	2	High clay content, well drainage	MDP ‘B’ MDP ‘A’	Low run-off potential	Good to Moderately Good	Dugout ponds, FB, Land leveling,
Nagla Makaran Series	Moderate to severe	C	4	Mod slopes, mod to severe erosion	MDP ‘C’ MDP ‘B’	Moderately to high run-off potential	Poor to moderate	ENB & GP Series, VB/VH

*Conservation measures: GP-Gully plugs; UGB-Underground Bandharas/Bunds; PT- Percolation Tank; ENB.- Earthen Nalla Bunds; CNB- Cemented Nalla Bunds; C.C.T. - Continuous Contour trenching; VB/VH- Vegetative bunds/ Vegetative hedges, FB- Field Bunding

Table.1 Slope classes and its distribution in study area

Sr. No.	Slope class	Slope (%)	Area	
			ha	%
1	Strongly to very strongly sloping hill/ hill slopes	(10-25%)	317.44	17.99
2	Moderately sloping side slopes	(5-10%)	473.71	26.85
3	Gently to very gently sloping fluvial/abandoned channels	(3-5%)	232.34	13.17
4	Gently sloping upper piedmont slopes	(3-5%)	439.61	24.92
5	Very gently to nearly level lower piedmont plains	(1-3%)	277.74	15.03
Habitation and other miscellaneous use			22.92	1.29

Resource based conservation planning is being advocated by various agencies and expected to yield better results from soil and water conservation measures in the watershed.

The various structures recommended in Richhoha watershed area are based on data correlated on slope, contour and soil characteristics. In the upper reaches, soils are very shallow to shallow in depth and suffer from moderate to severe erosion. However these have very high run-off potential. In such areas scrub/ pasture land is observed. These areas require measures like gully plugging (GP), gully (nala) bunding and continuous contour trenching. Vegetative bunds on contour/bund are needed to reduce soil erosion. In lower slopes of these areas area requires measures like continuous contour trenching, contour vegetative hedges, vegetative bunds (like bushy false-fruit crop), cultivation across slope, restricted cultivation with monocots, plantation activities is also needed to reduce soil erosion.

In the middle reaches, where soil is moderately deep with moderate erosion prone and moderate erosion with moderately high run-off potential, conservation measures like nala bunding, percolation tanks and stone check dams are required to reduce soil erosion and increase soil moisture. Over such area, the current agriculture practice is mostly single cropping. Cultivation across slope, land leveling, vegetative bunds, crop rotation and mixed cropping is essential in such areas to reduce soil erosion. For cultivation of cereals, oilseeds along with peas, chillies (Shimla Mirch) have great potential in these areas.

In the lower reaches, where soil is deep to very deep having slightly erosion prone and low runoff, various measures like earthen bunds, underground bandharas/bunds dugout ponds, field bunding and land leveling are required mainly to harness surface water and conserve groundwater. Such areas are experiencing high ground water exploitation, hence measures like underground bunds, ponds would be useful to arrest the sub-surface flow. Over such areas adoption of alternate beds and farrows, crop rotation and mixed cropping, drip irrigation are recommended to facilitate irrigation.

Characterization of land resources and identification of soil problems is a prerequisite for the selection of suitable soil and water conservation (SWC) measures to enhanced the hydrological regime of the watershed, to reduce soil erosion and improves socio-economic condition. Problems related to soil and water is interrelated for which an integrated approach is necessary to arrive at definite action plan for soil and water conservation such planning calls for a holistic approach towards watershed management. Use of remote sensing data and related modern tools and techniques resulted in preparation of land resource inventory of Richhoha watershed for conservation planning. It delineated various slope, contours, landform features and geo-morphological classes of the watershed. landform-soil relationship was established which revealed occurrence of very shallow skeletal, severely eroded soils on upper reaches and coarse loamy soils on middle reaches of the watershed. Coarse loamy soils belonging to Entisol order were occurring on piedmont plains while coarse loamy Inceptisols occurred in old alluvial plains. Land along fluvial channels has stratified coarse loamy soils belongs to Inceptisols. By integrating slope, contours, landform features and soil characteristic provide an appropriate base for suggesting appropriate soil and water conservation plan which was helpful for watershed development in participatory mode. The combined use of the high-resolution satellite data (LISS-IV and Cartosat-1 data) and GIS has immensely helped in understanding the landscape attributes, identification of soil parameters for precise and faster mapping compared to conventional soil mapping and conservation measures.

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