Remote sensing and GIS for natural resource inventory of hilly terrain-a case study of Kakrorasa sub-watershed, Ranchi district, Jharkhand

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Abstract

Spatial information on natural's resources and its severity is essential for sustainable utilization of land resources and for formulation of proper management/conservation programs. The rapid evolution in satellite Remote sensing and Geographical Information System (GIS) have made possible the development of new techniques for inventory of degraded/eroded lands. The present study deals with the assessment of natural resources, like land use/ land cover, Slope, Drainage order, Geomorphology and communication of road network in Kakrorasa Sub-watershed, Ranchi district, Jharkhand using Remote Sensing and GIS techniques. The land use/ land cover study reveals ten land use classes up to level-II viz. crop land, fallow land, land with scrub, plantation, marshy land, forest, crop land in forest, rock, sandy/ paddy crop, cultivated land, tank, river, reservoir, mixed built up land, quarries, paddy filled/ fallow/ scrub, forest/ scrub forest outside notified forest area, built up land, bamboo trees, scrub with vegetative cover, rock in forest, cultivated single/ doubled crop land, paddy single crop, quartzite rock. Drainages are identified and classify sixth categories in order wise. Slope map has prepared using contour available on Survey of India Toposheet on 1:50,000 scale and SRTM information. Slope are classified in five classes viz. nearly level (0-1%), very gently sloping (1-3%), gently sloping (3-5%), moderately sloping (5-10%), strongly sloping (10-15%), moderately steep to steep sloping (15-35%) and very steep sloping (>35%) sloping lands were identified in the area. Geomorphologically, the area has been divided into eleventh dominant geomorphic unit viz. hill top weathered, inselberg, plateau moderate dissected, plateau slightly dissected, plateau weathered shallow, residual hill, structural valley, structural hill, valley fill shallow, valley gullied.

Keywords: GIS, Remote Sensing, LULC, Sub-watershed, Drainage order, Slope, Geomorphology, Natural Resources Inventory.

1. Introduction

Land and water are the two basic natural resources which are being exploited for various developmental activities. As the population increases, the exploitation of these resources is also increasing and in this process they are subjected to stress (Panda, et al. 2014). The land is the most valuable and basic natural resource, which embodies soil, water, drainage, slope, geomorphology, transportation and associated flora and fauna, involving the total environment. As the sustainable development has become the current theme of prime importance, it focuses on the proper sustainable planning utilization and management of land resource. It becomes more important when the areas of natural beauty, environmental importance and conservation values, like Kakrorasa Sub-watershed the study area of the present study, are concerned. Here the resource managers face the problem of balancing ecosystem and human needs. At this juncture, comprehensive information on the spatial distribution of Land use/land cover (LULC) categories and monitoring there pattern of change over time becomes a prerequisite for effective planning, utilization and management of land resources. The pattern of land use/land cover is associated with other natural resources including slope, etc are changing over period of time. The slope also governs the general drainage/ river patterns and drainage of this region have some special characteristics (Nag, et al. 2003).

The rapid evolution in satellite remote sensing and Geographical Information System (GIS) are help us to extract the information Keeping this fact in view, the present investigation has been planned using remote sensing and GIS techniques to evaluate the natural resources of Kakrorasa Sub-watershed, Ranchi district, Jharkhand with following.

Objectives

To prepare detailed land use/ land cover inventory of the area.

To prepare detailed slope inventory of the area.

To characterize and classify the drainage occurring on different Sub-watershed units.

To characterize, classify and mapping of different Geomorphic features occurring in study area.

2. Study area

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The study area is situated at Ranchi district; Jharkhand which is 354.4 sq. km partially covers three Survey of India (SOI) Toposheets viz. 73E/7, 73E/11and 73E/15. Geographically, the Kakrorasa Sub-watershed which is part of Subernrekha Sub- catchment is located between 23o15' to 23o 25'N Latitude and 85o 30' to 85o 50' E Longitude.

The study area is a part of Chotanagpur plateau that is the North-Eastern projection of the peninsular table land which has remained part of the Gondwanaland. It, therefore, consists of geological and structural formations ranging from the earliest period to the recent. It, however, contains more than ninety percent of Archean formations dominated by granite and gneisses. No doubt, the area has been stable but minor structural changes have taken place in the form of faulting, warping, tilting, igneous intrusions, etc. Erosional agents have also made additions to geology in the area during recent geological periods. The Archeans form the basement over which other geological formations have taken place.

The soil and climatic conditions of an area largely determine the cropping pattern and crop yields. Study area is endowed with healthy climate. The area receives rainfall almost throughout the year, though the concentration is during the monsoon months from June to September. During the monsoon months the area receives about 82 percent of the annual rainfall. July and August are the rainiest months. The total annual rainfall in Kakrorasa Sub-watershed is 1293 mm. (Table 1). The climatic year is divided in to three broad seasons, the winter season lasting from November to February, the summer season from March to May and rainy season from June to October.

Broadly the forest of the study area falls in two categories: Tropical Moist deciduous forest and Dry deciduous forest. Some areas also represent Mango, Mahua, Bamboo, etc. of tropical evergreen forest. Among the forests three categories of vegetation are found. This vegetation includes tall trees, dense bushes and the grasses and gives look of three layers. Sal (Shoria robusta) is the dominant forest tree species widely found in the study area. Other important natural vegetation includes Tendu (Diospyrus melanoxylon), Kusum (Schleichera oleosa), Pyar (Buchanania lanzan), Sidha (Anogeissus pendula) and Palas (Butea monosperma).

3. Methodology

The materials used and procedures followed during the course of this investigation are described under the following heads.

3.1. Remote Sensing and Collateral Data Used

The geo-coded IRS P6 LISS-IV satellite data were used in the present study (Table 2). The satellite data is collected in three spectral bends- band (a) band 4 green 0.52-0.59 micrometer (b) band 5 red 0.62- 0.68 micrometer (c) band 6 0.77- 0.86 micrometer in the infrared region. The standard false colour composites (FCC's) were generated by bands 1, 2 and 3 using ERDAS IMAGEN 8.7 software.

Survey of India (SOI) Toposheet No.73E/7, 73E/11 and 73E/15 on 1:50,000 scale was used to collect topographic and as a collateral data for location information. The toposheet was also used to prepare base map, identification of sample areas, and generation of slope and drainage maps.

3.2 Data preparation

After collecting the data; the images are registered with respect to toposheet. Next, identify or delineate the boundary of study area and extracted the images (clipped) by using ERDAS IMAGINE 9.2 and ArcGIS 9.3.1. Primarily, all layers of Drainage, Forest, Geomorphology, Settlements and Roads etc are created base on SOI toposheet. After that all layers are updated base on satellite image by visual interpretation.

3.3 Satellite Data Interpretation and data base generation

The land use/land cover mapping of Kakrorasa Sub-watershed area, IRS-P6 LISS-IV satellite data were used in the project. The image interpretation key for land use/land cover mapping was prepared and used during satellite data interpretation *(Interpretation key Sources: Joseph G., 2005, Fundamental of Remote Sensing)*. The tonal variations, texture and association were the prime interpretation keys in differentiating various land use/ land cover classes (Lillesand et al. 2000). Finally geographical area under each land use/land cover class were computed and tabulated. The classification followed is based on the NRIS scheme of National Remote Sensing Agency, Department of Space (DOS), Govement of India, Hyderabad (NRSA, 1995).

Survey of India topomaps on 1:50,000 scales and SRTM data were used for driving the information on slopes category (Slope %). Topographical maps on 1:50,000 scale having contours with 20 meter interval or its multiple 40m, 60m etc. the vertical drop can be estimated/measured from the contour intervals and the horizontal distance in between the contours can be measured from maps by multiply the maps distance with the scale factor. Close spaced contours on the map have higher percentage slope as compared to sparse contours in the same space (Table 3). Thus density of contours on the map can be used for preparing the slope map that gives various groups/ categories of slopes and corresponding contours spacing on 1:50,000 scales. The method used to determine the slope percentage:

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$$\text{Slope \% = (VI * 100/ HI)} \qquad (1)$$

Where, HI= Horizontal Inclination, VI= Vertical Inclination Vectorization was carried out on the scanned data using Arc GIS. The ordering was given to each stream, by following Strahler (1952) stream ordering technique. A total of 3 mini-Sub-watersheds and 33 micro-Sub-watersheds were delineated for the study.

The geomorphic units were delineated by using counter drainage and soft information from SOI sheets. Theses visually interpreted sheets were overlayed on IRS P6 LISS-IV satellite data and boundaries were refined and modified as per image characteristics (NRIS, 1995). The geomorphologic units area to be delineated based on the image characteristics like tone, texture, shape, color, association and background etc (Rao, et al. 2003).

Survey of India topographical maps on 1:50,000 scale was used for preparation of road network of the study area. This road map was update and classify by using IRS P6 LISS-IV satellite data.

4. RESULT AND DISCUSSION

The present investigation was carried out in Kakrorasa Sub-watershed, Ranchi district, Jharkhand characterize and mapping of natural resources by using IRS P6 LISS-IV of satellite data. The results of the study have been discussed under the following heads.

4.1 Land use/ land cover

Image characteristics of different land utilization (Burley, 1961) types identified on IRS P6 LISS-IV geo-coded data have been given in Table 4. The land use/ land cover classes identified are agricultural land (single crop and double crop lands), notified forest land and wastelands with or without scrub, habitation and water body Fig 2. The different land use/ land cover categories identified in the study area discussed below.

4.1.1. Agricultural land

Agricultural lands mainly occur in very gently sloping plateau, pediments and valley areas. Agricultural lands are categorized under deferent classes viz. crop land, fallow, poor cultivated land, paddy field, scrub with vegetation cover, cultivated land, single crop, double crop and paddy single crop land based on their image characteristics and subsequent ground truth verification.

On satellite data the single crop land exhibits light bluish green with patches of light gray tone, diffuse parceling and medium texture whereas double crop land shows medium pink tone mixed with light blue tone, diffuse parceling and medium texture. The double crop land exhibits bold checkered board pattern with mixed tone of medium red to dark gray it depicts dark red tone, medium texture and checker board pattern. The single crop/ double crops occupy the area of 3.32 sq. km. in Sub-watershed which 0.93 percent. The crop land exhibits the dark tone, smooth texture along stream line, white tone fine texture in between small valleys, medium dark tone, along stream line with fine texture, light pinkish and yellow tone with small texture it exhibits poor cultivated land, reddish and yellow color medium texture trees and fields in which image character indicate crop land with trees. Further, it has been observed that double crop mainly occurs in the valley land whereas single crop lands are on very gently sloping plateau and pediments. The crop land in the study area occupies 91 sq. km. which is 25.9 percent to the total geographical area of Sub-watershed. The paddy/single crop/cultivated agricultural land which is yellowish blue, pinkish tone with clear and blue checker board and light pinkish color very diffused checker board It cover the area of the 5.06 sq. km. in Sub-watershed which is 1.42 percent of total study area. The total agricultural land in the Sub-watershed occupies an area of 162.88 sq. km., which only 46.96 percent of the total geographical area of the Sub-watershed.

Fallow land includes agricultural lands, which is taken up for cultivation but is temporarily left uncropped. They are recognized by shape and their regular pattern. The fallow land, uncropped for one or more seasons, occupies 1.4 percent of total area. This land is described as agricultural land, which is taken up for cultivation but is temporarily allowed to rest, uncropped for one or more seasons, but less than one year. These lands are particularly those, which are seen devoid of crops at the times when the imagery is taken of both seasons.

Scrubs with vegetative cover indicate the yellowish, dark tone and no checker board that occupies area of 14.26 sq. km., which is 4.31 percent of total study area. Plantations are the area under agricultural tree crops, planted adopting certain agricultural management techniques. In the study area, plantations are mapped in only 3.2 sq. km. which is 0.91 percent of the study area.

4.1.2. Built up land

The Built-up land includes Residential (Urban), Industrial, Transportation, Restricted areas, Open space/ vacant land and Villages (Rural). Built-up land occupied a total of 25.4 sq. km area which is 7.1 percent of total geographical area of the Kakrorasa Sub-watershed. All manmade construction covering the land surface is including under this category. These are human settlements comprising residential areas, transportation and communication lines industrial and

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commercial complexes, utilities and services, etc collectively, cities, towns and habitation are included under this category. Their shape and high reflectivity differentiated them from other classes. Enhancement techniques and bend combinations help segregation of different parcels on imagery from other parcels.

4.1.3. Forest area

The boundaries of notified forest lands were transferred from Survey of India (SOI) toposheet on 1:50,000 scale of the area. Forest areas in the Sub-watershed are mainly located in the western part of the Sub-watershed and occupy an area of 122.42 sq. km. constituting 34.54 percent of total area of the Sub-watershed. Based on image characteristics, they are further categorized into six classes, viz. dense forest, open forest, scrub forest, forest blank, crop land in forest and forest blank/ rock out in forest. Dense forest exhibits pinkish reddish tone smooth texture, open forest exhibits light pinkish tone, scrub forest exhibits pinkish tone smooth texture, forest blank exhibits in between light tone on the forest and crop land in forest it exhibits dark tone texture in forest land with checker board. The crop land in forest covers an area about 4.66 sq. km. Which is 1.31 percent of the total forest and forest blank/ rock out in forest indicates bluish tone smooth texture in forest area, with no checker board. Forest blank/ rock out in forest occupies the area of 7.12 sq. km., which is 2.01 percent.

4.1.4. Wastelands

Wastelands demarcated in the area include lands with and without scrub, gullied/ ravenous lands, and barren rocky/ stony waste and mining/ industrial wastelands. Land with and without scrub are prevalent in relatively higher topography, excluding hilly and mountainous terrain. These lands are generally prone to erosion. Area mapped as land with or without scrub are 34.24 sq. km. In which only 9.66 percent area is marked as land without scrub. The lands which are degraded and are presently lying unutilized except that of current fallow owing to different constraints are considered as wastelands. It exhibits light bluish green with patches of light pink tone and medium texture.

4.1.5. Water body

Rivers and water bodies include reservoirs, tanks, streams, lakes, canals, abandoned quarry with water etc. which comprises 1.26 percent of the total geographical area of the Sub-watershed. It depicts black to dark blue tone on the satellite imagery.

The relative other land like quarries, quartzite rock and rock out crops which cover 4.99 sq. km., which is1.48 percent of the total area. Rocks out crops occupy the area 2.19 sq. km., which is 0.61 percent of total study area.

4.2. Slope

Slope map of the Sub-watershed was prepared based on contour information available on SOI toposheet and subsequently validated using ground truth information. Seven slope classes were identified in the study area. The slope map of the Sub-watershed is shown in Fig 3.

The data in Table 5 reveal that nearly level (0-1%) occupied the area 3.25% which is 11.54 sq. km, very gently sloping (1-3%) occupied 50.44 sq. km, gently sloping (3-5%) occupied the 26 percent in which 92.17 sq. km, nearly 27.5 percent area of the Sub-watershed is under moderately sloping (5-10%), strongly sloping (10-15%) occupy the area of 57 sq. km. which is 16.13 percent, moderately steep to steeply sloping (15-35%) occupy the area 20.7 sq. km. which is 5.84 percent, very steeply sloping (>35) it occupy the area 24.61 sq. km. which is 6.94 percent of the total Sub-watershed area.

4.3. Drainage

The drainage order map of the Sub-watershed was prepared based on SOI toposheet. The ordering was given to each stream, by following Strahler (1952) stream ordering technique.

The streams of this region have some special characteristics and except a few most of them remain dry except during rainy season. Certainly these streams become turbulent during rainy season particularly at the time of heavy rainfall. The drainage of this region is basically rain-fed and there are hardly any other sources of water giving rise to surface flow of water. Fig 4 shows the drainage order map and Table 6 shows the drainage order statistics of the Sub-watershed area.

4.4. Geomorphology

Using counter drainage and information geomorphic unites were delineated. Theses visually interpreted sheets were overlayed on IRS P6 LISS-IV satellite data and boundaries were refined and modified as per image characteristics. These visual interpreted maps were scanned, geo-referenced and vectorized by using Arc GIS software. The distribution pattern of different physiographic units and their image characteristics are given in Table 7 and the physiography map is shown in Fig 5. Landform type as described are hill top weathered landform cover the study area of 5.8 sq. km. which is 1.6 percent, inselberg cover the total area of 1.7 sq. km. 0.48 percent, plateau moderate dissected cover area 46 sq. km. the percentage 13 percent of the total area, plateau slight dissected cover area of 16 sq. km. of the total area, which is 4.6 percent, plateau weathered moderate (5-20M) occupied 6.5 percent area

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which is 23 sq. km. plateau weathered shallow (<5M) cover area of 4 sq. km residual hill cover 3.5 sq. km. of the Sub-watershed, structural valley area covered 8.7 sq. km. area, the structural hill covered highest area of 151 sq. km. of the Sub-watershed which is 42.6 percent of the total geographical area. Valley fill shallow (<5M) cover area 97 sq. km. area and, valley gulled area cover the negligible of the Sub-watershed area.

4.5. Road network

Survey of India topographical maps on 1:50,000 scales were used for preparation of road network of the study area. This road map was update by using IRS P6 LISS-IV satellite data. The road network of the Sub-watershed is grouped into five categories like national highway which is having length of 36.5 km., District road is having length of 8.6 km. which is 1.8 percent of total road length and state highway cover the area of 2.3 percent whose length is 10 km. of the total road. Few new roads are the updated from the satellite image that cover the maximum area 62.4 percent whose length is 294.3 km. Other road include cart track in hilly area, cart track in plain, footpath in hill, pack track in hill. Total length of other road is 120.8 km. which is 25.5percent of the total road length in the Sub-watershed.

5. CONCLUSION

The land is the most valuable and basic natural resources, which embodies land, water, soil, slope, geomorphology, road network, and associated flora and fauna, involving the total environment. So the Land use/ land cover planning and management has become an important issue in order to ensure proper utilization, management and conservation of land resources. The present investigation was carried out in Kakrorasa Sub-watershed of Jharkhand, to characterize the natural resources, viz. land use/land cover, Slope, drainage, geomorphology and road network using IRS P6 LISS-IV data. The land use/ land cover ware evaluated according to land capability, land irritability and land suitability for growing cultivated land, agriculture land, built-up land etc. The results of the present investigation have been summarized below.

Visual interpretation of the multi-date IRS P6 LISS-IV (1:50,000 scale), supported by SOI toposheet in the area, revealed twenty six categories of land use/land cover, viz. crop land, fallow, poor cultivated land, land with scrub, plantation, marshy land, forest, crop land in forest rock, sand, cultivated land, tank, river or drainage (with sixth major drainage order), reserve, mix built up land, quarries, paddy field/ fellow/ scrub, forest blank or rock, paddy crops/ cultivated, built up land, bamboo trees, scrub with vegetative cover, rock in forest, single crop/ double crop along the nala, paddy single crop, quartzite rock. The visual interpretation of the SOI toposheet revealed seventh category of slope viz. gently sloping, moderately sloping, moderately steep to steeply sloping, nearly level, strongly sloping, very gently sloping, and very steeply sloping. Landform units viz. hill top weathered, inselberg, plateau moderate dissected, plateau slight dissected, plateau weathered moderate (5-20M), plateau weathered shallow (<5M), residual hill, structural valley, structural hill, valley fill shallow (<5M), valley gulled.

For appropriate management of thematic (naturals resources) mapping of the Sub-watershed, suggested land use map was prepared after integrating all the thematic maps viz. present land use/land cover, slope, drainage, geomorphology and road networking GIS environment using Arc GIS, ERDAS IMAGIN. The map demarcates the potential areas for afforestation, intensive cultivation, double cropping, single crop, and agro-horticulture and silvi-pasture development. From the study, it can be concluded that, Visual interpretation of false color composites of IRS P6 LISS-IV merged data supported by reference map facilitates precise mapping of thematic natural resources of Sub-watershed. Integrated approach of remote sensing and Geographical Information System (GIS) helps in faster mapping, monitoring and evaluation of spatial data for deriving useful information for agricultural planning.

Table 1 Climatic data for Kakrorasa sub-watershed (average) 1994-2002

Month	Mean Max. Temp. (°c)	Mean Mini. Temp. (°c)	RH (%)	Rainfall (mm.)
January	24.8	7.9	68.4	16.2
February	26.8	11.7	74.3	19
March	31.4	16.3	70.9	17.8
April	38.5	20	69.3	17.1
May	38.4	23.1	72.9	52.9
June	33.6	23	81.3	261.8
July	30.9	22.9	82.2	312.6
August	31.1	24.4	87.5	292.8
September	30.8	22	83.6	236
October	30	18.9	76.8	57.7

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November	27.8	13.3	73.9	5
December	25.4	8.4	71.6	3.6

Table 2 Details of satellite data.

Satellite	Sensor	Path-Row	Month of Acquisition	Year
		5755_56	November	
		2814_77	May	
IRS-P6	LISS-IV	5755_57	November	2004
		2132_88	March	
		1791_82	February	
		2132_87	March	

Table 3 Vertical drop of Slope base on contour intervals and the horizontal distance

Slope Category	Lower and upper limit of slope %	Lower and upper limit of contour %
1	0 – 1%	More than 4cm
2	more than 1% up to 3%	more than 1.33 cm And up to 4 cm
3	more than 3% up to 5%	more than 0.8 cm And up to 1.33 cm
4	more than 5% up to 10%	more than 0.4 cm And up to 0.8 cm
5	more than 10% up to 15%	more than 0.26 cm And up to 0.4 cm
6	more than 15% up to 35%	more than 0.11 cm And up to 0.26 cm
7	more than 35%	0.11 cm and less

Table 4 Land use/ land cover data of Kakrorasa Sub-watershed

Type	Land use	Area in sq. km.	Percentage
Agriculture land	Crop land	91.82	26.27783184
	Fallow	5.07	1.450975903
	Cultivated land	39.21	11.22145269
	Wasteland with/ without scrub	34.24	9.799095644
	Scrub with vegetation cover	14.26	4.081048595
	Double crop	3.32	0.950145956
	Paddy-single crop	5.06	1.448114018
	Plantation	3.24	0.927250873
Forest area	Dense forest	110.64	31.66390018
	Crop land in forest	4.66	1.333638601
	Forest blank/ rock out in forest	7.12	2.037662412
Built up land	Mixed built up land	24.1	6.897143838
	Built up land	1.34	0.383492645
Water body	Sand	0.9	0.257569687
	Tank	0.84	0.240398374
	Reservoir	0.11	0.03148074
	River	3.49	0.998798008
Total		349.42	100

Table 5 Slope data of Kakrorasa Sub-watershed

Category (Slope %)	Area in sq. km.	Percentage

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Nearly Level (0-1)	11.54	3.26
Very Gently Sloping (1-3)	50.44	14.23
Gently sloping (3-5)	92.17	26.01
Moderately Sloping (5-10)	97.75	27.58
Strongly Sloping (10-15)	57.16	16.13
Moderately Steep to steeply sloping (15-35)	20.69	5.84
Very Steeply Sloping (>35)	24.61	6.94

TABLE 6 Drainage data of Kakrorasa Sub-watershed

Drainage type	*Length in m.*	*Count*	*Percentage of length*	*Percentage of count*
First order	472685.27	766	56.22	48.39
Second order	180994.05	421	21.53	26.59
Third order	81044.41	193	9.64	12.19
Fourth order	47981.91	120	5.70	7.58
Fifth order	16929.30	39	2.01	2.46
Sixth order	41158.95	44	4.89	2.78

TABLE 7 Geomorphology data of Kakrorasa Sub-watershed

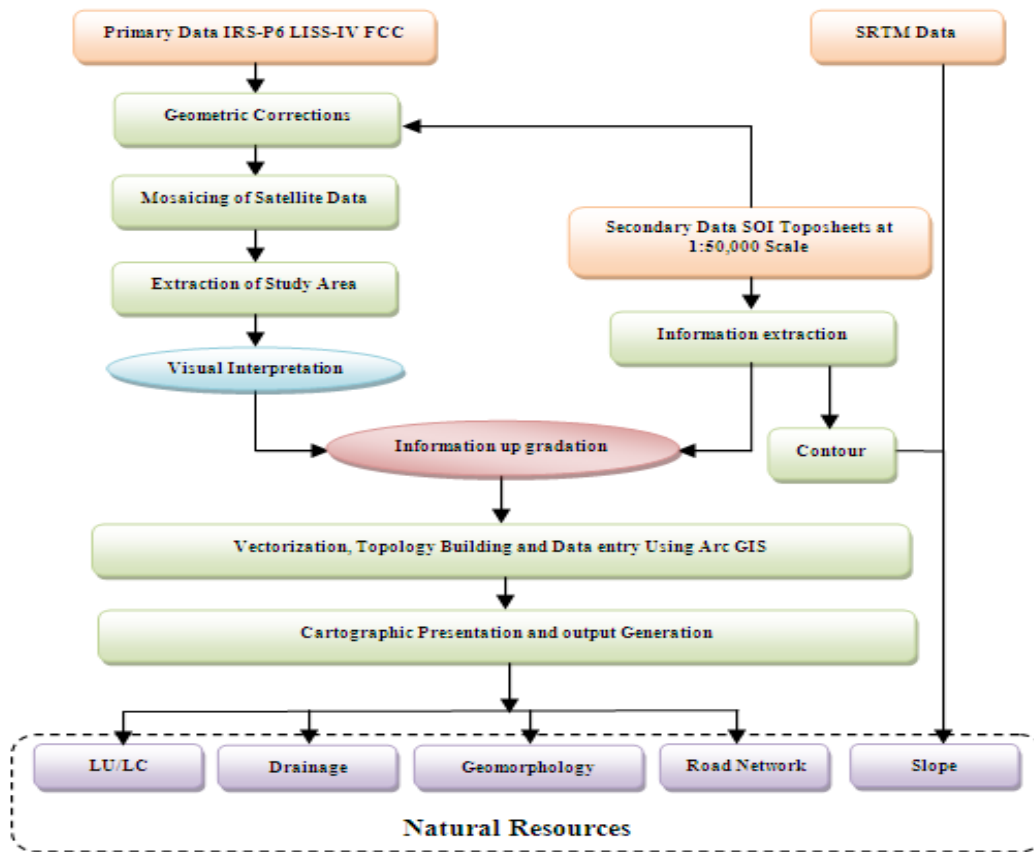| *Land form*	*Area in sq. km.*	*Percentage*
Hill Top wetherd	5.81	1.64
Inselberg	1.71	0.48
Platue moderate dissected	46.16	13.03
Platue slight dissected	16.42	4.63
Platue weathered moderate (5-20 M)	23.10	6.52
Platue weathered shallow (<5 M)	0.43	0.12
Residual hill	3.06	0.86
Sturicteral valley	8.72	2.46
Structral hill	151.24	42.69
Valley fill shallow (<5 m)	97.58	27.54
Valley gulled	0.01	0.001

Fig 1. Flow chart of the methodology.
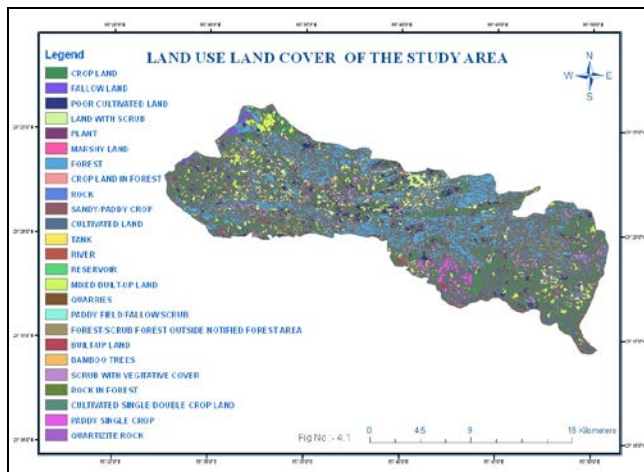
Fig 2. Land use/ land cover map of the study area
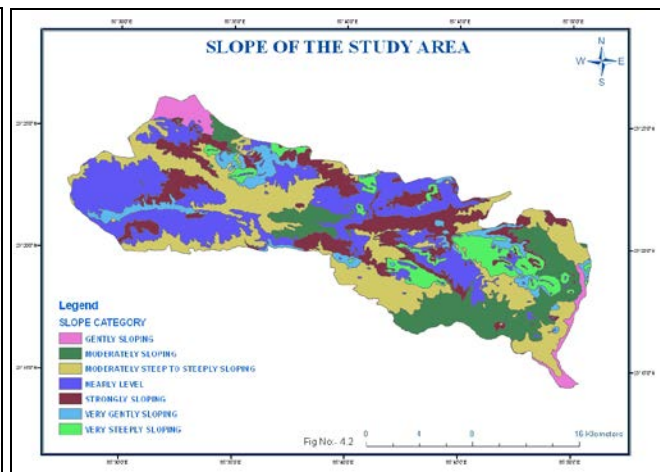
Fig 3. Aerial view of Slope of the study area

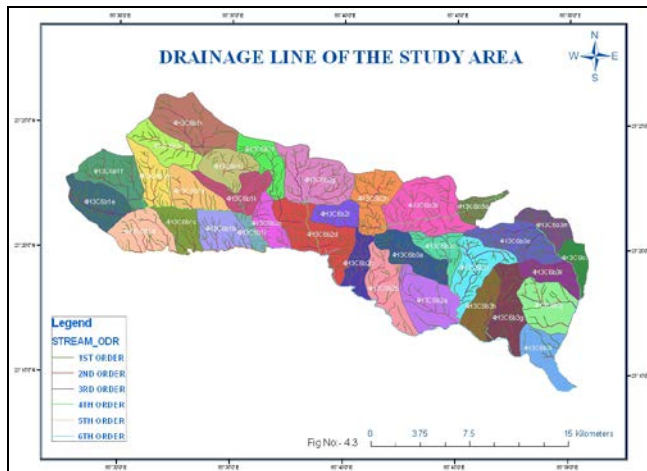*International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-1, Issue-2, May 2015*
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Fig 4. Aerial view of Drainage of the study area   **Fig 5**. Aerial view of Geomorphology of the study area
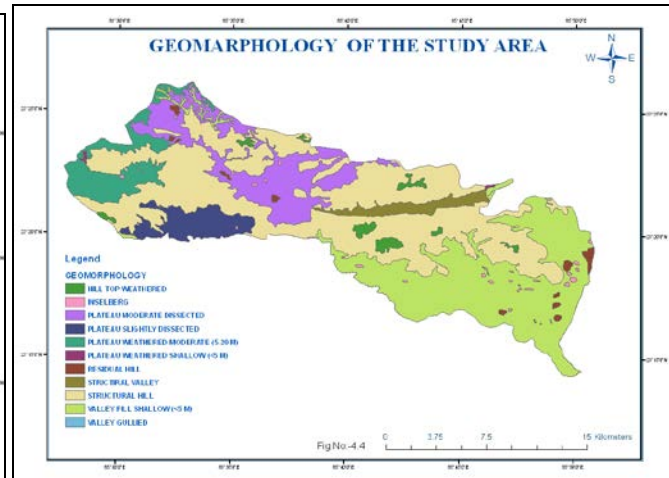
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