ISSN NO: 9726-001X
Volume 07 Issue1 January 2019

JOURNAL OF CURRENT SCIENCE

Case study of the Kakrorasa sub-watershed's natural resource inventory using remote sensing and geographic information systems

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Abstract

Sustainable use of land resources and the development of effective management/conservation programs need the collection and analysis of spatial data on natural resources and the severity of their impacts. New methods for taking an inventory of degraded/eroded lands have become available because to the fast development of satellite Remote sensing and Geographical Information System (GIS). This research uses Remote Sensing and Geographic Information System (GIS) tools to evaluate the land use/land cover, slope, drainage order, geomorphology, and road network connectivity in the Kakrorasa Sub-watershed in the Ranchi district of Jharkhand. According to the results of the land use/land cover study, there are ten distinct types of land use up to level II. These include 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 Drainage systems are located and sorted into six distinct groups. The slope map was created using SRTM data and the contour lines found on the 1:50,000 scale Survey of India Toposheet. Nearly flat areas (1% or less), gently sloping areas (3% or less), moderately sloping areas (5% to 10%), strongly sloping areas (10% to 15%), fairly steep or severe sloping areas (15% to 35%), and extremely steep or sharp slope areas (>35%) were all detected. Hill top weathered, inselberg, plateau moderately dissected, plateau slightly dissected, plateau weathered shallow, residual hill, structural valley, structural hill, valley fill shallow, and valley gullied are the eleven primary geomorphic units that make up the region.

Geospatial information system, remote sensing, low-impact land-use (LULC), sub-watershed, drainage order, slope, geomorphology, natural resources inventory are all terms that have been used to describe this topic.

1. Introduction

The two most fundamental natural resources, land and water, are being used in a wide range of progressive endeavors. Stress on these resources is rising due to rising demand as the world's population rises (Panda, et al., 2014). The land, with its soil, water, drainage, slope, geomorphology, transportation, and related flora and fauna, is the most important and fundamental natural resource. Sustainable development, which is all the rage these days, is concerned with the long-term wise use and management of land. Kakrorasa Sub-watershed, the focus of this investigation, is a very beautiful and ecologically significant region, making conservation efforts all the more urgent there. Here, resource managers are challenged with striking a balance between environmental considerations and human demands. In order to properly plan for, make use of, and manage land resources, it is now essential to have accurate data on the geographical distribution of Land use/land cover (LULC) categories and to track the pattern of change over time. Over time, the relationship between land use/land cover and resources like slope, etc., changes. The slope also controls the region's overall drainage/river patterns and drainage, both of which exhibit some unique features (Nag, et al., 2003).Information is being extracted with the aid of the rapidly developing fields of satellite remote sensing and Geographical Information Systems (GIS). In light of this, a study was designed to assess the natural resources of the Kakrorasa Sub-watershed in the Ranchi district of Jharkhand using remote sensing and GIS.

Objectives

In order to compile a comprehensive land cover and land use map of the region.

To compile a comprehensive inventory of the area's slopes.

The goal is to identify and categorize the various Sub-watershed units' drainage patterns.

The goal of this research is to identify, categorize, and map the various geomorphic characteristics present in the region under investigation.

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Study area

Located in Ranchi district, Jharkhand, the research area spans 354.4 square kilometers and is largely covered by three Survey of India (SOI) Toposheets: 73E/7, 73E/11, and 73E/15. The coordinates 23°15′–23°25′ N and 85°30′–85°50′ E define the geographical limits of the Kakrorasa Sub-watershed, which is a portion of the Subernrekha Sub-catchment. The region under investigation is located on the Chotanagpur plateau, which is the peninsular table land's northern and eastern projection that is still a part of Gondwanaland. As a result, it is made up of geological and structural features from ancient times right up to the present day. However, more than 90% of its rocks are Archean in age and composed mostly of granite and gneisses. The region has been rather stable, although it has seen minor structural changes such faulting, warping, tilting, igneous intrusions, etc. Recent geologic time periods have also seen contributions to the area's geology from erosional forces. The Archeans are the foundation upon which subsequent geological layers have been built.

The cropping pattern and crop yields are substantially determined by the soil and climatic conditions of a location. The environment is conducive to study. Rainfall occurs almost every month of the year, with the monsoon season (June–September) being the heaviest. About 82% of the yearly rainfall occurs during the monsoon months. It rains the most in July and August. Kakrorasa Sub- watershed receives an average of 1293 mm of precipitation each year. (Table 1). The winter season lasts from November to February, the summer season runs from March to May, and the rainy season lasts from June to October.

Two main types of forest may be distinguished in the research area's woods: tropical moist deciduous and dry. The tropical evergreen forest is represented in certain places by Mango, Mahua, Bamboo, etc. There are three distinct types of forest vegetation. This vegetation, which consists of towering trees, thick shrubs, and grasses, seems to have three distinct levels. In this research region, the sal tree (Shoria robusta) is the most common kind of forest tree. Tendu (Diospyrus melanoxylon), Kusum (Schleichera oleosa), Pyar (Buchanania lanzan), Sidha (Anogeissus pendula), and Palas (Butea monosperma) are some significant examples of flora found in nature.

2. Methodology

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

2.1. Remote Sensing and Collateral Data Used

In this analysis, we employed IRS P6 LISS-IV satellite data with geo-coding (Table 2). Three different bands of spectrum, including green, blue, and infrared, are used to acquire satellite data. Band 5 is at 0.52 to 0.59 microns, Band 6 is at 0.77 to 0.86 microns, and Band 7 is at 1.55 microns. ERDAS IMAGEN 8.7 was used to create the industry-standard false color composites (FCCs) for bands 1, 2, and 3.

The 1:50,000 scale Survey of India (SOI) Toposheets 73E/7, 73E/11, and 73E/15 were used to gather topographic and ancillary data for locating purposes. The toposheet was also utilized to generate slope and drainage maps, as well as create a base map and locate sample regions.

3.2 Data preparation

After collecting the data; the images are registered with respect to toposheet. Next, identify or delineate theboundary 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 satelliteimage by visual interpretation.

3.3 Satellite Data Interpretation and data base generation

Kakrorasa Sub- watershed region land use/land cover mapping using IRS-P6 LISS-IV satellite data. We utilized the land use/land cover mapping picture interpretation key (Interpretation key Sources: Joseph G., 2005, Fundamental of Remote Sensing) to decipher the satellite data. Land use/land cover groups were distinguished from one another primarily by tonal changes, texture, and association (Lillesand et al., 2000). Finally, the total area that fell into each land use and land cover category was tallied. National Remote Sensing Agency, Department of Space (DOS), Government of India, Hyderabad (NRSA, 1995) developed the categorization system used.

Slope percentage data was driven by SRTM data and 1:50,000 scale Survey of India topomaps. With 1:50,000 scale topographical maps that feature contours spaced at 20 meter intervals (or its multiples, 40m, 60m, etc.), one can calculate the vertical drop simply by reading off the intervals between the contours, while the horizontal distance between the contours can be calculated by multiplying the map's distance by the scale factor. The percentage slope of a map with closely spaced contours is greater than that of a map with sparsely scattered contours (Table 3). Therefore, the slope map may be made

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using the map's contour density to show different types of slopes and their appropriate contour spacing at a 1:50,000 scale.
How the slope % was calculated:
% Slope = (Vertex Increment multiplied by 100 inverse Height Increment) (1)
Inclination (horizontal) = HI, and Inclination (vertical) = VI. The scanned information was vectorized in Arc GIS. Each stream was given an order using the method described by Strahler (1952). The research area was divided into 33 micro-Sub-watersheds and 3 mini-Sub-watersheds.
In order to define the geomorphic units, we used counter drainage and subtle data from SOI sheets. By superimposing these visually interpreted sheets on top of IRS P6 LISS- IV satellite data, we were able to improve and modify borders according to picture features (NRIS, 1995). Image features such as brightness, contrast, texture, form, color, association, backdrop, and so on must be used to define geomorphologic units (Rao et al., 2003).
The road system of the research area was developed using 1:50,000 scale topographical maps from the Survey of India. Using information gathered by the IRS P6 LISS-IV satellite, this road map has been revised and labeled.

3. 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 withor 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

Most farmable terrain is found on relatively mildly sloping plateau, pediment, and valley surfaces. Based on picture features and subsequent ground truth verification, agricultural lands are separated into several classifications, such as crop land, fallow land, poor cultivated land, paddy field, scrub with plant cover, cultivated land, single crop, double crop, and paddy single crop land.
Using satellite imagery, we can see that single crop land is a pale bluish green with gray patches, has diffuse parceling, and a medium texture, whereas double crop land is a more complex pink and blue coloration with the same characteristics. The double crop field has a striking checkerboard pattern, with a color palette that ranges from medium red to dark gray. About 0.93 percent, or 3.32 square kilometers, of the land in the Sub-watershed is dedicated to single crops or double crops. There is a dark, smooth texture along the stream line, a fine white texture in the valleys, a medium dark tone with a fine stream-side texture, a light pinkish and yellow tone with a small texture indicating poorly cultivated land, and a reddish and yellow color with a medium texture indicating crop land with trees. In addition, it has been shown that valley terrain is where double crops are most common, whereas extremely gently sloping plateau and pediment area is where single crops are grown. Cropland in the region under investigation extends over 91 square kilometers, or around 25.9 percent of the entire area of the Sub-watershed. The golden blue paddy, pinkish tone with clear and blue checker board, and light pinkish hue extremely dispersed checker board of farmed agricultural area. Sub-watershed covers 1.42 percent of the overall study area, or 5.06 square kilometers. The entire area of farmland in the Sub- watershed is 162.88 square kilometers, however only

The region that makes up 46.96% of the Sub- watershed as a whole.

Agricultural land that is cleared and prepared for planting is considered fallow. They are easily distinguished by their characteristic form and symmetry. Land that has been left fallow for one or more growing seasons accounts for 1.4% of the total land area. Agricultural land is defined as territory that has been cleared for agricultural use but that will remain fallow, or uncropped, for a period of time that is longer than one growing season but less than one full year. Particularly noticeable in images shot in both summer and winter are fields that seem to be completely barren.

Scrubs with vegetative cover occupy 14.26 square kilometers (4.31% of the entire area under investigation), revealing a yellowish, dark, and checkerboard-free coloration. Plantations refer to the land where trees are grown for agricultural purposes using a certain set of agricultural management practices. Plantations are only mapped in 3.2 square kilometers of the research region.

Just 0.91 percent of the whole area was analyzed.

4.1.2. Built up land

Land that has been developed encompasses both urban and rural regions, as well as places where some activities are prohibited or restricted. The built-up area of the Kakrorasa Sub-watershed was a total of 25.4%, or 7.2 square kilometers. Everything that has been built on the ground is included here. These are the infrastructures of human habitation, including homes, roads, utilities, services, businesses, and other commercial establishments. Places where people live fall under this umbrella term. They stood out from the rest of the pack because of their unusual form and great reflectivity. Image enhancement methods and bending combinations facilitate the separation of individual parcels from one another.

4.1.3. Forest area

From the 1:50,000 scale Survey of India (SOI) toposheet, we were able to extract the borders of the classified forest holdings. The Sub-watershed's forests cover 122.42 square kilometers, or 34.54 percent of the total area, and are concentrated in the western portion of the watershed. Images are further classified into six groups based on their visual characteristics: crop land in the forest, forest blank, forest blank/rock out in the forest, crop land in the forest, and thick forest. It has a dark tone texture on forest land with a checkerboard pattern, a pinkish reddish tone in dense forest, a light pinkish tone in wide forest, a pinkish tone in scrub forest, and a light pinkish tone in forest blank. About 4.66 square kilometers of woodland cover the farmland. That's just 1.31 percent of the whole forest, and the lack of checkerboard patterns and blue tones there suggests that the forest floor is smooth. There are 7.12 square kilometers (or 2.01%) of blank or rock out in the forest.

4.1.4. Wastelands

Lands with and without scrub, gullied/ravenous lands, barren rocky/stony waste, and mining/industrial wastelands are all well delineated in the region. Scrubland and non-scrubland land are equally common at relatively higher topography, with the exception of hilly and mountainous regions. Erosion is a constant threat in areas like this. The 34.24 sq. km of surveyed land includes both cleared and uncleared areas. Where just 9.66% is classified as usable terrain. Degraded terrain that cannot be used for anything at the moment, other than fallow, is referred to as wasteland. It has a medium texture and a mild blue green coloration with pinkish white areas.

4.1.5. Water body

4.2. 1.26 percent of the entire area of the Sub-watershed is made up of rivers and water bodies including reservoirs, tanks, streams, lakes, canals, and even an abandoned quarry filled with water. The satellite picture shows a mostly black or very dark blue sky.

The remaining 4.99 square kilometers (1.48 percent) are made up of things like quarries, quartzite rock, and rock out crops. The area of 2.19 square kilometers that is occupied by rocks outcrops is 0.61 percent of the whole area under investigation.

4.3. 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 gentlysloping (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 moderatelysloping (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.

4.4. Drainage

The drainage order map of the Sub-watershed was preparedbased 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 characteristicsand 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.

4.5. Geomorphology

Geomorphic units were defined with the use of information and counter-drainage techniques. Overlaying IRS P6 LISS-IV satellite data with these visually interpreted sheets allowed us to improve and modify boundaries based on picture features. Arc GIS was used to scan in these visually interpreted maps, georeference them, and turn them into vector graphics. Table 7 provides the distribution pattern of physiographic units and their corresponding picture attributes, and Fig. 5 depicts the physiography map. Weathered hilltops make for 1.6% of the entire study area (5.8 sq. km.), whereas inselbergs account for 1.7% (1.7 sq. km.). Area covered: 46 square kilometers, plateau, moderate dissection. Plateau weathered moderate (5-20M) occupied 6.5 percent area, which is 23 sq. km., accounting for 13 percent of the entire area; plateau slight dissected cover area of 16 sq. km. Four square kilometers of weathered shallow (5M) cover area, three and a half square kilometers of residual hill cover area, eight and a half square kilometers of structural valley cover area, and 151 square kilometers of structural hill cover the highest area of the Sub-watershed, or 42.6% of the entire geographical area. The Sub-watershed is made up of a total of 97 square kilometers of valley fill shallow (5M) area and a little amount of valley gulled land.

4.6. Road network

The road system of the research area was created using 1:50,000 scale topography maps from the Survey of India. Satellite information from the IRS P6 LISS-IV was used to update this route map. A national highway runs the length of the sub-watershed at 36.5 kilometers; a district road runs 8.6 kilometers (1.8 percent of the total road length); a state highway covers the area at 2.3% and runs 10 kilometers. The satellite picture has been updated, although only a small number of new roads have been added, increasing the total road length by 294.3 kilometers (62.4 percent). There are also footpaths, pack tracks, and wagon tracks in the hills and plains, respectively. There are a total of 120.8 kilometers of "other road" in the Sub-watershed, or around 25.5% of the overall road length.

4. CONCLUTION

The land, with its water, soil, slope, geomorphology, road network, and related flora and fauna, is the most important and fundamental natural resource there is. Therefore, land use/ land cover planning and management has emerged as a pressing concern for the efficient use, administration, and protection of land. This study used IRS P6 LISS-IV data to describe the natural resources in the Kakrorasa Sub-watershed in Jharkhand, including land use/land cover, slope, drainage, geomorphology, and the road network. Land capacity, irrigability, and suitability for cultivating cultivated land, agricultural land, built-up land, etc. were used to assess the land use/land cover. The following is a summary of the findings from the current study.

Cropland, 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/rock, paddy crops/cube, and paddy fields/fellow/scrub, forest blank/rock, paddy crops/cube were the twenty-Based on my visual analysis of the SOI toposheet, I've identified seven distinct types of slope: gentle, moderate, steep, extremely steep, almost level, strong, and very gentle. Units of topography include weathered hills, inselbergs, moderately dissected plateaus, slightly dissected plateaus, moderately weathered plateaus (5-20 m), moderately weathered shallow plateaus (5 m), residual hills, structural valleys, structural hills, shallow valley fill (5 m), and valley gullies.

Using a GIS (Geographic Information System) environment, including Arc GIS and ERDAS IMAGIN, the existing land use/land cover, slope, drainage, geomorphology, and road networking maps were integrated to create a recommended land use map for managing thematic (natural resources) mapping in the Sub-watershed. Afforestation, intensive cultivation, double cropping, single crop, agro-horticulture, and silvi-pasture development opportunities are all shown on the map. The research shows that accurate mapping of thematic natural resources of Sub-watershed is made possible by the use of false-color composites created from merged data from IRS P6 and LISS-IV, with the use of a reference map. For more efficient mapping, monitoring, and assessment of spatial data for generating usable information for agricultural planning, an integrated strategy of remote sensing and Geographical Information System (GIS) is recommended.

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

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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
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 7Geomorphology 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

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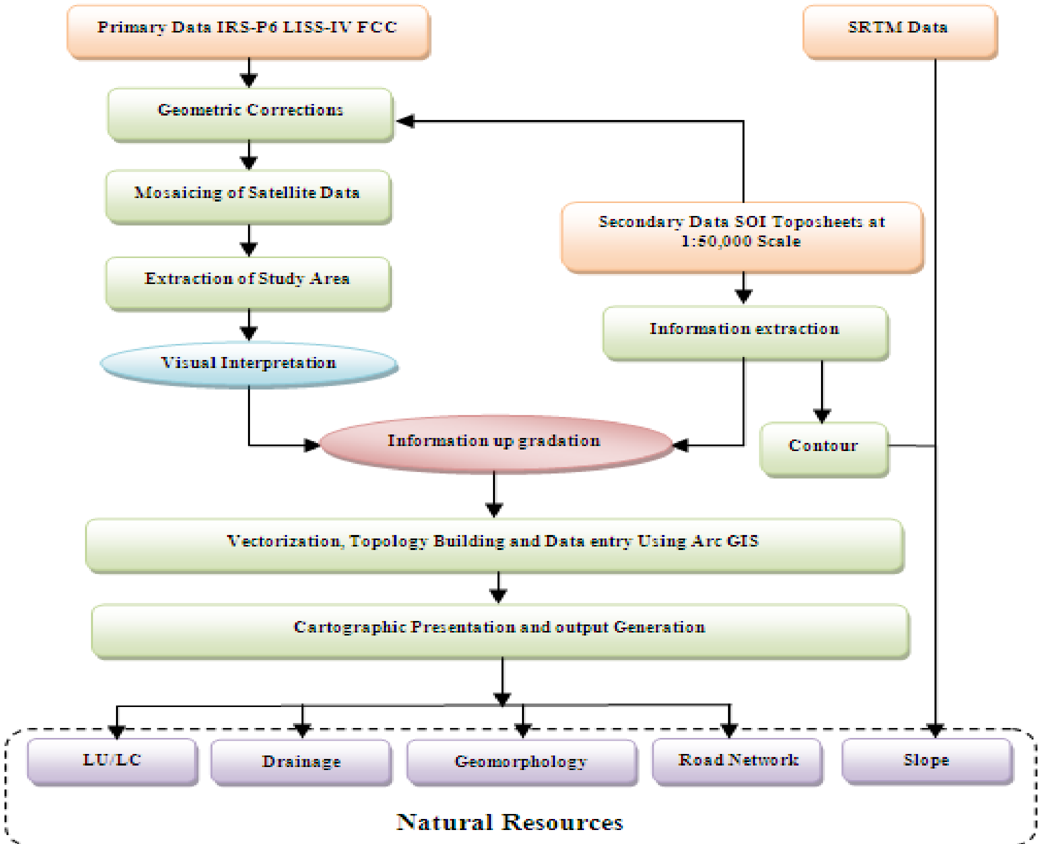

Fig 1. Flow chart of the methodology.

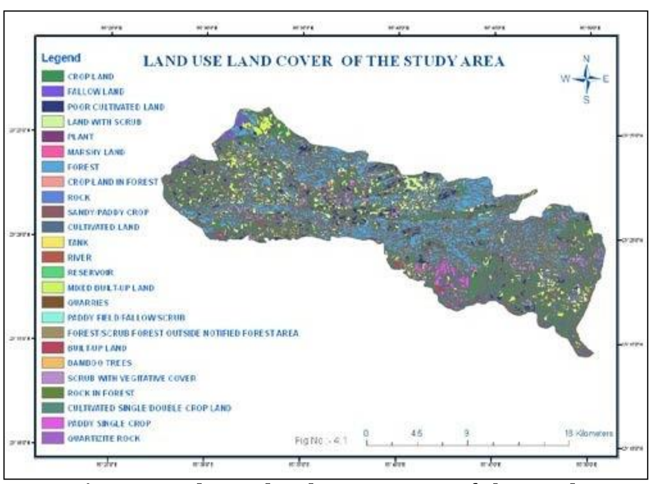

Fig 2. Land use/ land cover map of the study area

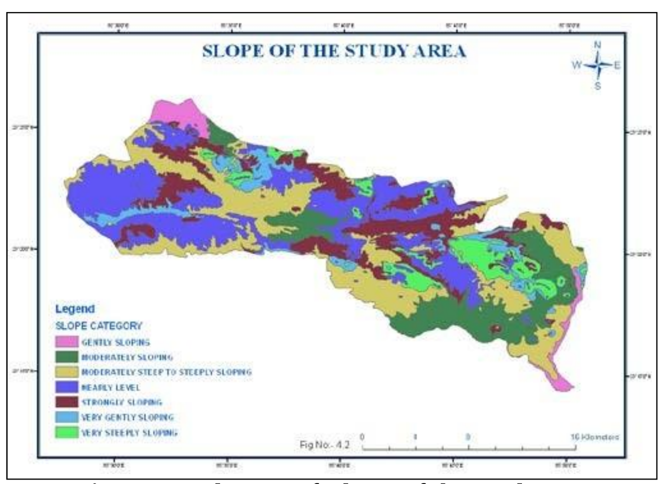

Fig 3. Aerial view of Slope of the study area

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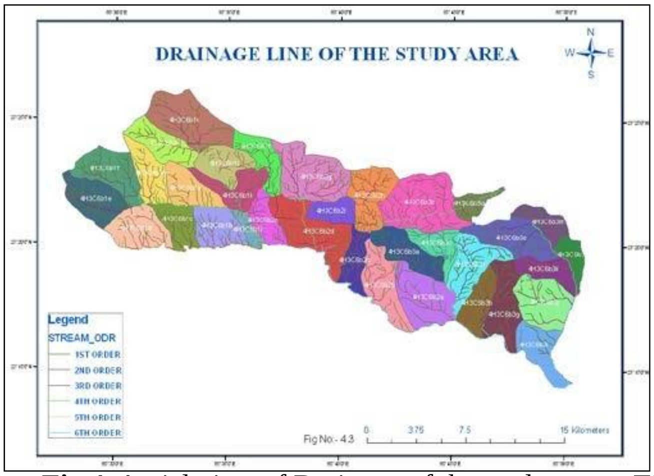

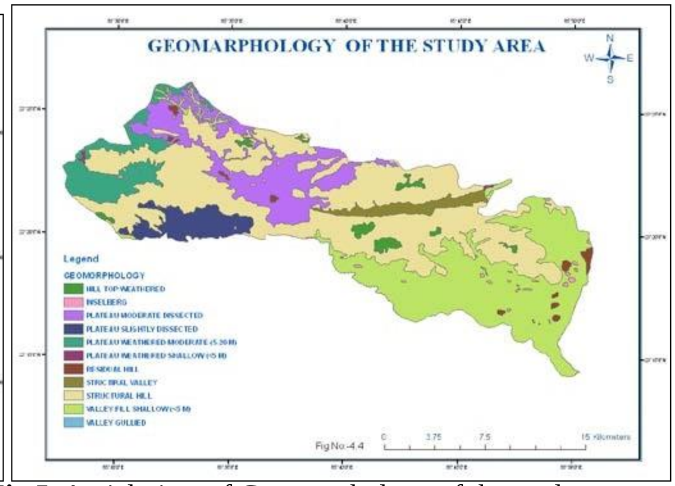

Fig 4. Aerial view of Drainage of the study area **Fig 5**. Aerial view of Geomorphology of the study area

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