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Geo-morphological mapping for land resource assessment study of north western part of Bhopal using remote sensing and GIS technique

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Abstract
Geomorphological mapping, was carried out using IRS-P6 LISS III data of about 713 sq. km area of north western part of Bhopal district, Madhya Pradesh. Present study attempts to identify and delineate geomorphic features based on visual image interpretation technique from digital data. Geomorphic Landforms are interpreted on the basis of interpretation elements like tone, texture, size, shape, color etc. and extract the specific information from the false color composition LISS III sensor images. Geomorphological units are classified on the basis of differential erosion processes. Geomorphic unit namely pediplains, pediments, butte, mesa, cuesta, hogback, plateau, plateau remnant and residual hills mapped using IRS P6 LISS III satellite imagery using visual interpretation technique along with selected field checks. Remote Sensing and GIS offers detecting and analyzing time and cost effective way to fulfill the goal. Limited field transverses were undertaken to verify the interpretation.

Keywords: Vindhyan basin, geomorphic mapping, geomorphology, GIS & remote sensing

1. Introduction

Remote sensing and GIS tools and techniques are used to identify geomorphic units present in an area and used in mapping because geomorphology is the base of land use planning. Remote Sensing and GIS techniques are very useful for the study of geomorphology. Evaluation of the types of landforms is understand through the preparation of geomorphological map. Bhopal the capital city of Madhya Pradesh is the part of Malwa plateau with an undulating topography. The Vindhyan hills covered a major part of the present area along with the Deccan basaltic rocks. The highest elevation of these hills is about 628m above mean sea level lies at Singar Choli – a hillock near Bhopal airport. The lowest elevation is situated near Phanda block.

There are several lakes known to occur in Bhopal area of these two famous lakes are Upper and Lower lakes give a beautiful panoramic view to the city. The lake level is at around 500 m while the hills rise up to 604 m above the mean sea level. The Upper Lake is fed through Kolans river flowing through the western side of the city. The Lower Lake is fed by Banganganala from the southeastern side and the outlet is on the northwestern side from below the Pulpukhta and this outlet is fed to the Patranadi which later joins the Halalinadi.

Geologically, the Bhopal region consists of the rocks of Vindhyan Supergroup of Late Proterozoic age and Deccan Traps of Cretaceous to Eocene age and Recent Alluvium. The rock formations of Vindhyan Super group comprise of sandstone and shale. The basaltic rock present in the area are the basic volcanics of the Deccan trap volcanic activity and some part is occupied by alluvium and laterite of the recent age. A thick succession of sandstone in Bhopal of Malwa and Bundelkhand region was first named as Vindhyan by Medlicott (1859) [30].

Present area is drained by external drainage. Upper Lake is the major water body of the area. Drainage in the area is controlled mainly by the lithology and structures resulting in the development of two contrasting type of drainages, the Upper Vindhyan sandstone, in general shows coarse textured sub dendritic to sub parallel joint controlled drainage. Deccan Traps show medium textured, well developed dendritic drainage pattern. In the present study satellite remote sensing data has been used to interpret the geomorphic landforms and their characteristics have been discussed.

Many workers have done pioneer works in the field of remote sensing with geomorphological application are considered such as Mishra and Choubey (1999) [16],

Roy (2000) [18], Bhan (2000) [3], Kalluri *et al.* (2003) [7], Mishra (2003) [14] Reddy and Maji (2003) [17], Jaiswal *et al.* (2005) [6], Mishra (2010) [15], Katla and Saxena (2015) etc.

Remote sensing application

Remote sensing as describe earlier is sensing from a distance. The electromagnetic energy after interaction with matter can be recorded by a sensor and the recorded data can be seen as an image or photo depending upon the sensor. The electromagnetic spectrum is a continuum of energy that ranges from meter to nanometers in wavelength and travels at the speed of light. The spectrum has several windows through which reflected or emitted radiation is recorded in sensor (Sabins 1997) [20].

2. Aim and Objectives

The present paper aims to 1. Identify and delineate the geomorphic features based on detailed examinations of satellite image after considering local geology, topography, structures and field visits; and 2. Assess the relationship between the existing geomorphic features and the local land use pattern. Finally this study will provide a very good asset to the people and to the developers who are engaged in this region for landuse planning and developmental purpose.

3. Study area

The present study area of Bhopal lieson the Survey of India Toposheets no. 55 E/7 and 55E/8. It is bounded by 23˚15' to 23˚30' North latitude and 77˚15' to 77˚30' East longitude covering an area of approximately 522sq. km. the area is the North – Western part of the Bhopal district (Fig. 1). The district is bounded by Guna district on the north, Vidisha district on the northeast, Raisen district on the east, Sehore and Rajgarh districts on the southwest and west respectively.

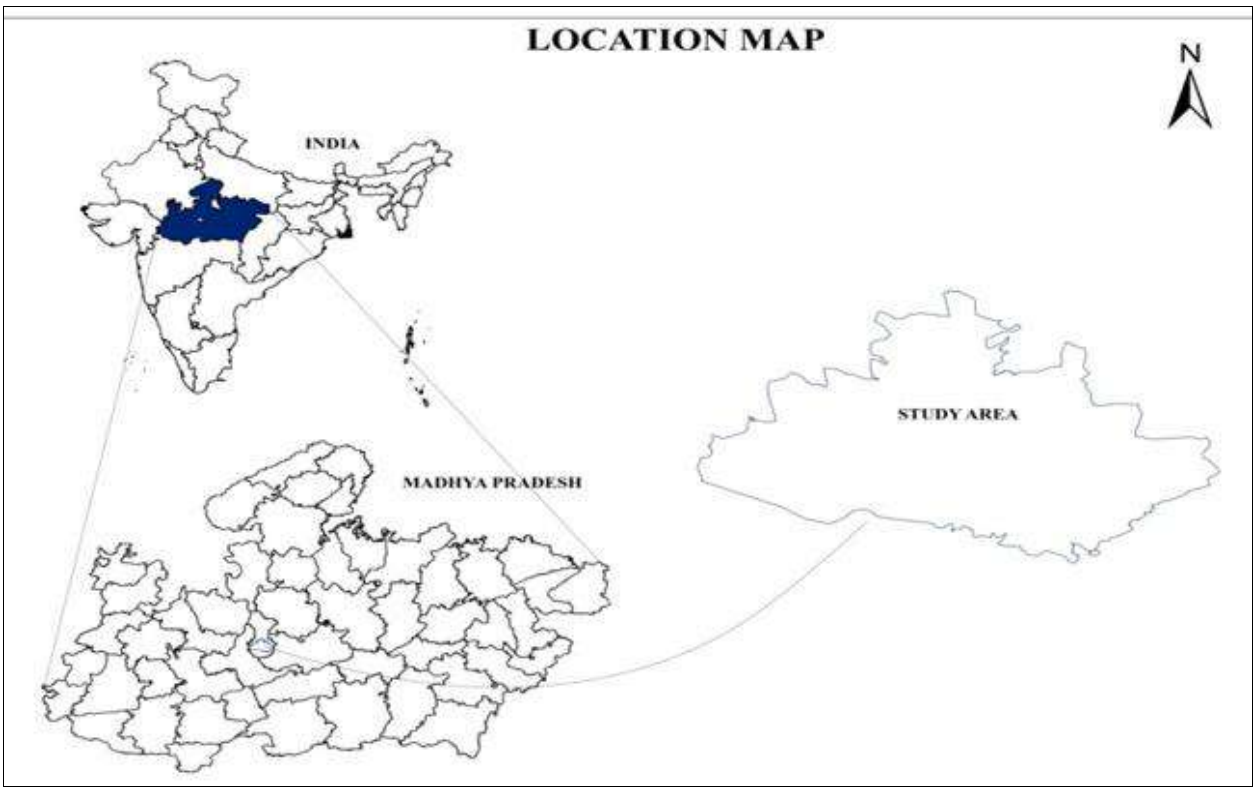

Fig 1: Location map of the study area

4. Data used

SOI toposheets and IRS P6 LISS III data was used for the generation of Geomorphological map with the help of GIS software 10.3 verson. LISS III imageries were acquired for the year 2019 from the USGS Global Visualization Viewer. These data were used for the generation of geomorphological map (Table 1). The resolution satellite imagery is 23.5mtrs. and swath is 141km. this data used for mapping on 1:50,000 scale was for the preparation of geomorphology map with the help of GIS software.

Table 1: Data used for the geomorphological mapping

Serial No.	Toposheets No. / Sattelite data	Scale	Source	Year of Publication
1.	55E/3, 55E/4, 55E/7, 55E/8, 55E/11, 55E/12	1:50,000	Survey of India	1974
2.	IRS_LISS III	Geocoded	Bhuvan	18 arch 2019

5. Database and Methodology

The geomorphic features were mapped by the visual interpretation technique on the IRS P6 (Resource sat) LISS III image, followed by ground truth verification. The geomorphic features present were interpreted using standard visual interpretation elements, *viz.* colour, tone, texture, pattern, shape, association etc. The methodology of geomorphic map is shown in Fig. 2. The area was calculated th rough Arc GIS software show in Table 4.

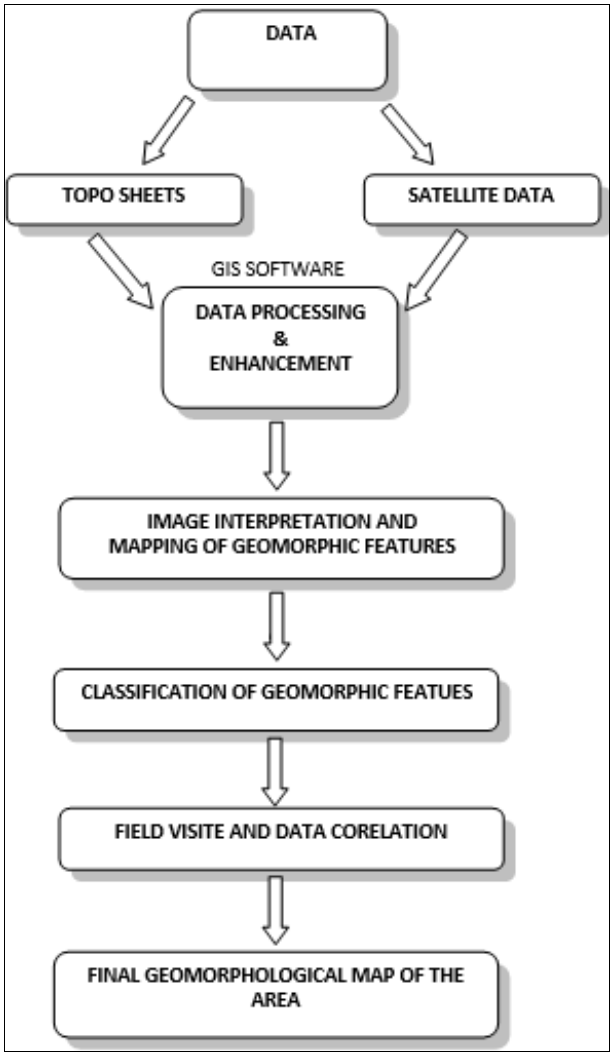

Fig 2: Flow chart for Geomorphology map

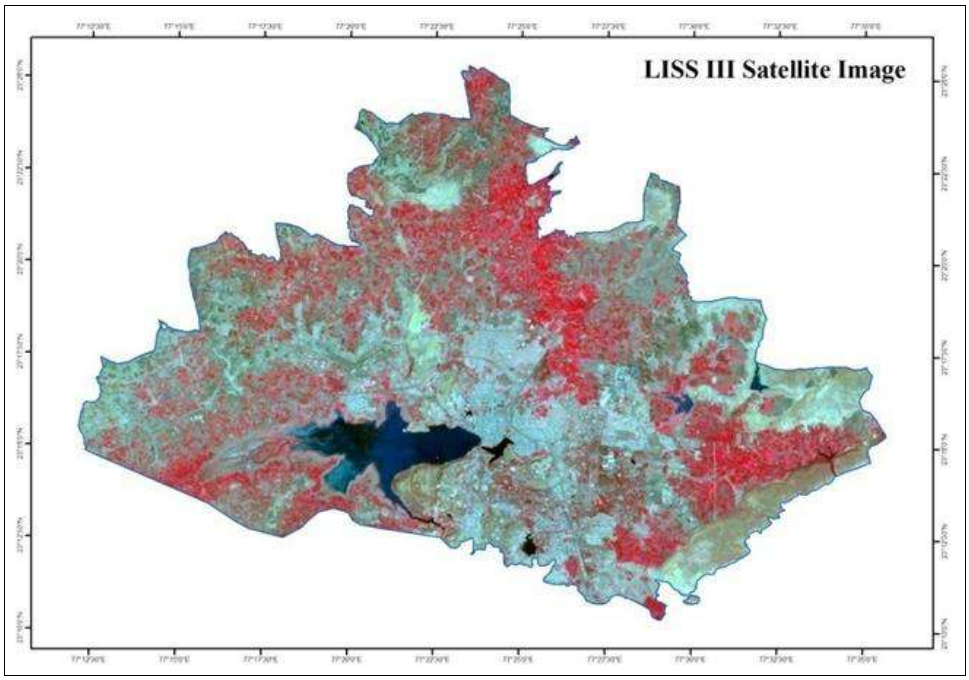

Fig 3: Satellite image of the study area

Geomorphological Analysis

The geomorphic units are classified into two broad categories i. e., Denudational and Structural units identified through visual interpretation. The results of the geomorphological mapping have been brought out the presence of different type of geomorphic units and

landforms in the area, which have been classified as per their origin and shown in a 3D mosaic (Fig. 3) and listed in table 2.

Characteristics of Geomorphic features

In the present study following geomorphic units were identified from the satellite imagery with the help of Survey of India toposheets (Table 1). The Geomorphological units are interpreted from the LISS III imagery with the help of the image interpretation keys like tone, texture, pattern, association after processing the imagery in Erdas Imagine (Table 3).

Geomorphological mapping the first geomorphological map prepared in 1914 but the main demand for the maps came cover form planner after World War II. A geomorphological map must give information about morphology, morphometry, morphogen (origin) morphochronology (the age) of each form. Representation of these details is an involved matter on a single map.

Table 2: Geomorphic units identify in the study area

Geomorphic units	Geomorphic features
Anthropogenic	Active Quary
Denudational unit	Butte
	Mesa
	Pediments
	Pediplains
Structural unit	Cuesta
	Hogback
	Plateau
	Plateau Remnant
	Residual Mound
	Escarpment

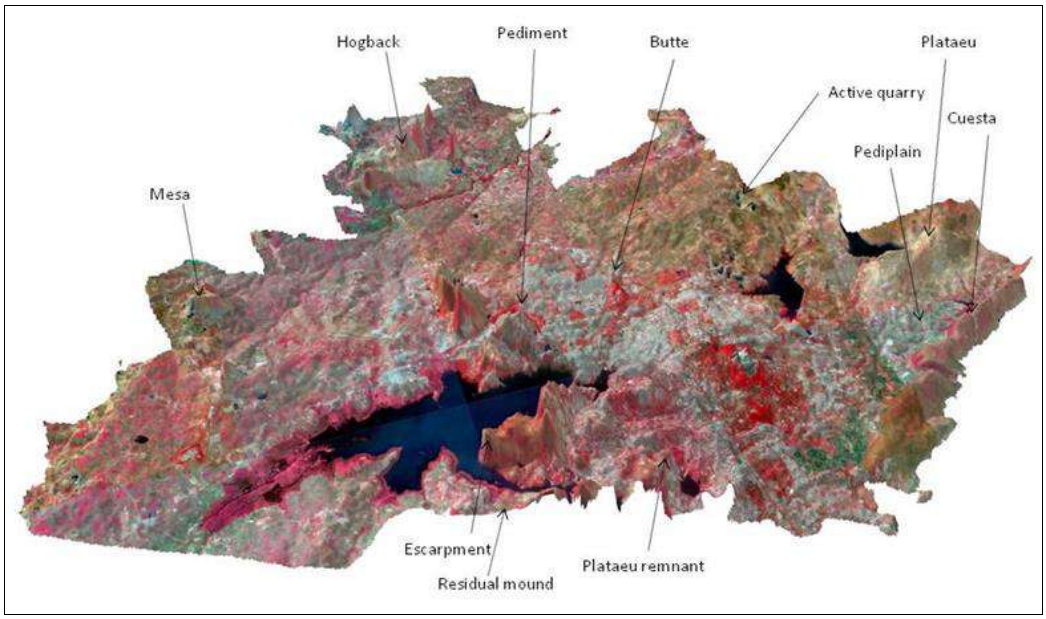

Fig 4: 3-D Visuallization of Geomorphic features

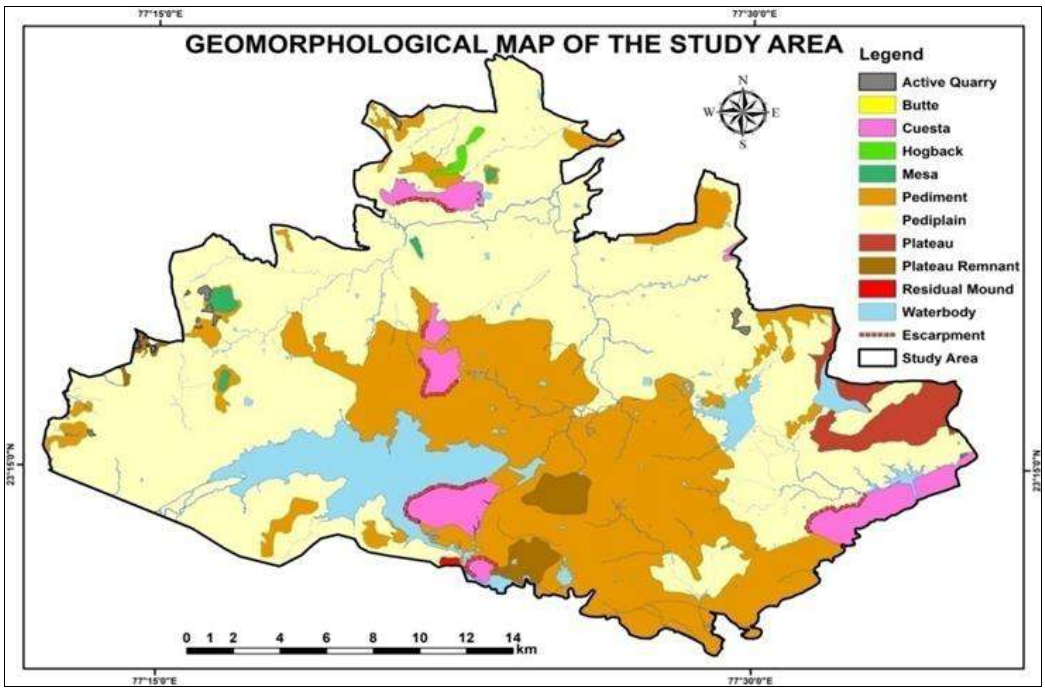

Fig 5: Geomorphology of the study area

Denudational units

Denudational landforms present mainly in the sedimentary rocks. This type of units form by the combined affect of weathering, erosion and transportation. Units contain mainly pediment, pediplain, mesa and butte. They are identified by the relatively high terrain and further confirmed by the SOI toposheets and field check. Denudational landforms occupying eastern and western portion of the study area cover about 456.6 sq. km. (Fig. 5 and Table 4).

The denudational units may be categorized as follows:

Table 2: Identification of Geomorphic units in Image Interpretation

Geomorphic Landforms	Tone	Texture	Patterns	Land use/ Land Cover	Relief	Association
Butte	Light yellowish	Smooth due to flat top	Nearly circular but sometimes elliptical	Sparse bushes	High	Plateaus
Cuesta	Brown to light brown	Moderate to finr	Irregular	Waste land	High	Structural plateaus and homocline
Hogback	Light brown	Sharp summit	Linear pattern	Shrubs	High	Structural plateaus and homocline
Plateau	Light brown to light green	Moderate	Irregular	Agriculture, forest, waste lands	Moderate	Plateaus
Mesa	Light red	Smooth	Regular and circular with table top	Scrub, shrubs and forest	Moderate	Plateaus
Pediments	Light brown	Coarse and uneven	Often to gentle slop	Dry cultivation at lower part	Low	Plateaus and pediments
Pediplains	Reddish due to cultivation grey without cultivation	Fine and uneven	Rectangular & field patterns	Intensive cultivation	Low	Residual hills, butte, pediments
Plateau Remnants	Dark red	Smooth	Regular	Scrub and herbs	Moderate	Plateaus
Residual Mound	Light brown	Coarse	Irregular	Scrub	Low	Pediplain
Active Quarry	Brighter tone due to fresh cut of rock	Rough	Irregular	Minning	Low	Minning
Escarpment	Dark red	Rough	Regular	Scrub	Moderate	Plateaus

Butte is isolated generally flat- topped hill or small mountain with relatively steep slope or precipitous cliffs, often capped with a resistant layer of rock and bordered by talus, and representing an erosion remnant carved from flat-lying rocks. Butte shows smooth texture and light brown and green tone on the satellite image. One such Butte is observable in the north of study area (Fig. 4).

Mesa is also an isolated nearly level land mass standing distinctly above the surrounding country bounded by abrupt or steeply sloping erosion scarps on all sides, and capped by the layers of resistant, nearly horizontal rocks. Mesa shows smooth texture and light brown and green tone on the satellite image (Fig. 4). The characteristics of landforms are given in Table 4. This landform is visible on the north western part of the area.

Pediments are the gentle sloping erosional surfaces developed at the foot of a receding hill or mountain slope, commonly with a slightly concave- upward profile that cross-cuts rock or sediment strata that extend beneath adjacent uplands. About 28% of the area is occupied by the pediments of such pediment is noticeable in the central part

The term pediplaines was first proposed by Anderson *et al.* (1976) [2] and used to describe a series of coalescing pediments. The pediplaines covered with a thick over burden are referred to as buried plain. Pediplaines are extensively developed in low lying areas associated with hills and pediments. It is identified on image on the basis of its smooth texture, thick vegetation, square shape because of agriculture activity, large aerial extent and also on the basis of thickness of weathered zones. Total area covered by this landform is 34% and is confined to basaltic rocks.

Structural Landforms

These landforms are developed due to effect of tectonic movements and later on modified by erosion. The landforms of this category are observed in the region where Vindhyan sediments are present. They are located in the eastern part of the study area having greenish and reddish tone with rough texture on the satellite image (Fig. 4). Approximately, the area covered is by the 69.5 sq. km. (Table 4). The structural hills representing the geomorphic landform of structural origin present in the southern part of the area.

Some of the structural landforms observed in the area are as under:-

Hogbacks constituted of long narrow ridges of hills, structurally controlled by the presence of homoclinal sedimentary strata that slopes steeply. Hogbacks are the sharp crested ridges which develop where rock slopes are steep. Hogbacks were identified by the parallel to sub parallel drainage pattern at steep slopes. It stands as prominent ridges and identified by light pink colour (Fig. 4). Hogbacks are present in the northern part of the study area and best seen near Khajuri and Binapur (Fig. 4).

Cuesta is an asymmetric ridge capped by resistant rock layers of slight to moderate dip, commonly less than 10˚ (approximately 15%). It is a homocline type produced by differential erosion of interbedded resistant and weak rocks. It has a long, gentle slope on one side that roughly parallels to the inclined beds, and on the opposite side has a relatively short, steep or cliff like slope that cuts the tilted rocks. It is covering the northern and eastern part of the study area near Manikherikat, Acharpura and Gandhi nagar (Fig. 4).

Escarpments are relatively continuous steep or cliff

produced by erosion or faulting, which topographically interrupts or breaks the general continuity of more gently sloping land surfaces. The term is most commonly applied to cliffs produced by differential erosion. Escarpments are generally present along fault scarp in the study area and are observed near T. T. Nagar, Bada talab (Bhopal Lake, Upper Lake) and eastern part of the area. On the FCC image it is seen in dark blue tone and course texture (Fig 4).

Plateau is a comparatively flat area of great extent and elevation; specifically an extensive land region considerably elevated (more than 100 meters) above adjacent lower lying terrain, and is commonly limited on at least one side by an abrupt descent has a flat or nearly level surface. A comparatively large part of a plateau surface is near summit level. In the study area, a large part of the eastern area is covered with this landform (Fig. 4).

Plateau Remnant

A topographic feature that remains or is left standing above the general land surface after erosion has reduced the surrounding area; eg. A monadnock or a butte. Remnants are observable as a landform in eastern part of the area (Fig. 4).

Active Quary is manmade feature it is a shallow mining structures it shown in northern part of the area (Fig. 4).

6. Result and discussion

Geomorphology is the science and study of landforms on the earth. Both the disciplines are exhaustively covered in literature (Blaschke, T., 2010). Today all land use planning processes in most of the countries are based on geomorphological units (Dragut, L., Blaschke, T., 2006). The detailed geomorphological mapping of the area has revealed the presence of various landforms. They are mostly formed due to denudational, depositional and also the structural processes. Active quarry, Butte, Cuesta, Hogback, Mesa, Pediments, Pedi plains, Plateau, Plateau Remnant, Residual Mound and Escarpment present in the study area are shown in (Fig. 4) and Table 2.

Table 4: Area of Geomorphic features covered (in %)

S.N.	Origin	Geomorphic features	Area (in sq. km.)	Area (in %)	Total area
1	Manmade	Active Quary	22.8	3.2	22.8
2	Danudational	Butte	8.6	1.20	454.6 sq. km.
3		Mesa	1.9	0.26	
4		Pediments	200.1	28.1	
5		Pediplains	244	34.2	
6	Structural	Cuesta	25.6	3.5	69.5 sq. km.
7		Hogback	9.0	1.2	
8		Plateau	9.7	1.2	
9		Plateau Remnant	10.6	1.4	
10		Residual Mound	3.3	0.46	
11		Escarpment	11.3	1.58	
12		Water body	166.3	23.6	166.3
Total Area			713	100%	713 sq. km

This area will be useful for various applications such as groundwater exploration, land use planning, disaster management, geoengineering and so on. In addition this study will geomorphological mapping in near future. According to (Fig. 4 and 5) all features of the study area are Active quarry is covered 22.8 sq. km area in our study area it is useful for mining. Butte is present in 8.6 sq. km., Mesa is covered 1.9 sq. km., Cuesta covered 25.6 sq. km, Plateau present in 7.7 sq. km., Plateau Remnant covered area 10.6. sq. km., Residual Mound present in 3.3 sq. km., Hogback is present in 9.0 sq. km., Escarpment covered area 11.3 sq. km. and the water bodies coverd a large area approximate 166.3 sq. kms. They are also useful for plantation, forestration and forder also. Pediments present in 200.1 sq. km. area this feature is important for plantation, industrialization, built-up, forestration and forder. Pediplains covered 244 sq. km. it is important feature for agriculture, horticulture any type of built-ups, lakes, ponds, canal, railway lines, roads and forestration also etc. because it it covered with thick soil. It is also useful for natural hazard assessment.

These geomorphic units shown in Pie diagram

1. Active quary
2. Butte
3. Mesa
4. Pediments
5. Pediplains
6. Cuesta
7. Hogback
8. Plateau
9. Plateau Remnant
10. Residual Mound
11. Escarpment
12. Water body

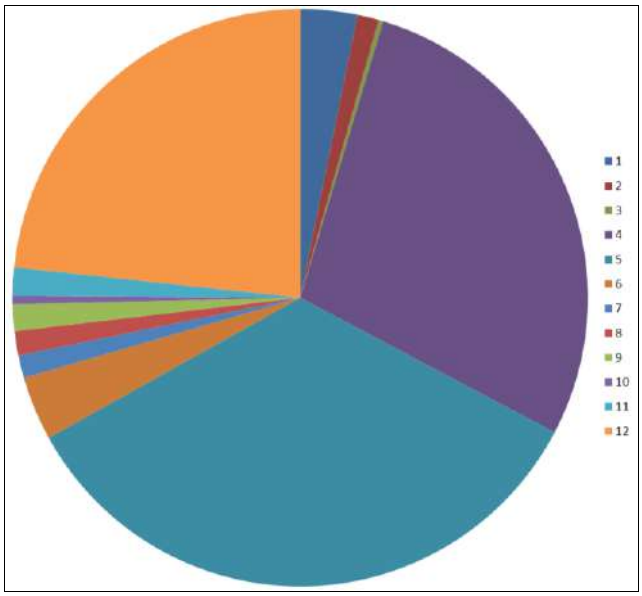

Fig 4: Pei chart for Area in sq. km

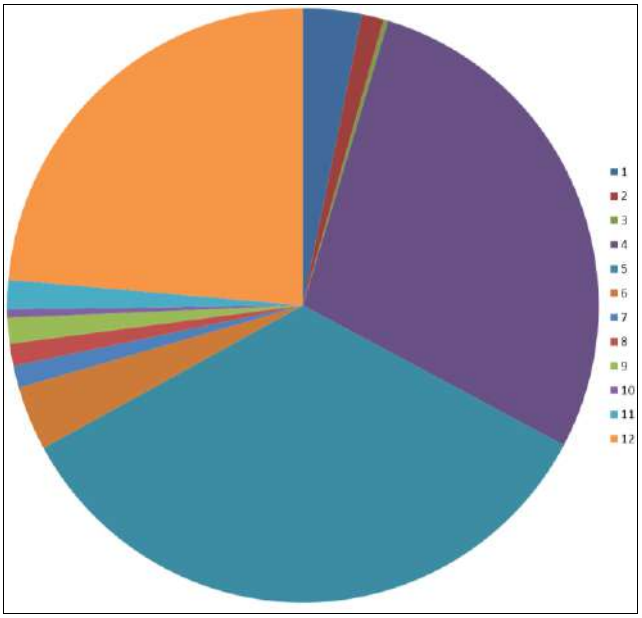

Fig 5: Pei chart for Area in percent

7. Conclusion

The geomorphological units interpreted from the LISS III imagery with the help of the image interpretation keys like tone, texture, pattern, association after processing the imagery in Erdas Imagine. For future land use planning, it is necessary to understand the existing geomorphic units and extents. Remote Sensing and GIS have capability to mapping geomorphic units (G. P. Obi Reddy, A. K. Maji., 2003) [17]. The geomorphic units mapped from satellite image as structural hills eastern parts, residual hills western and south western portions, pediments eastern margin and in the southern portion, Pedi plain western and north eastern, alluvial plain central and western portions of the map. Now based on mapped geomorphic units local and government authority can make decision to land use planning for human activities.

According to (Fig. 4 and 5) all features of the study area include Active quary covers 22.8 sq. km. where mining on local scale is being practiced. Butte is present is present in 8.6 sq. km. Mesa 1.9 sq. km., Cuesta 25.6 sq. km., Plateu present in 7.7 sq. km. Plateau Remnant covered area 10.6 sq. km., Residual Mound present in 3.3 sq. km., Hogback is present in 9.0 sq. km., Escarpment covered area 11.3 sq. km. and the water bodies cover a large area approximate 166.3 sq. kms. They are also useful for plantation, forestration and forder also. Pediments present in 200.1 sq. km. area this feature is important for plantation, industrialization, built-up, forestration and forder. Pedi plains covered 244sq. km. it is important feature for agriculture, horticulture any type of built-ups, lakes, ponds, canal, railway lines, roads and forestration also etc. because it is covered with thick soil. It is also useful for natural hazard assessment.

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