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Integration of Remotely Sensed and Geophysical Data Sets in Engineering Mobile Site Characterization in a Basement Complex Area of Udupi District.

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Abstract: Remote Sensing and geophysical techniques have been used for investigation in the environmental sciences with remarkable success. Remote sensing techniques are used because of their cost effectiveness, their ability to access areas that are difficult to access and because the data can be collected frequently and rapidly on large scale. Geophysical techniques, on the other hand, are non-invasive, and can furnish broad, composite images of subsurface over large areas at relatively low cost and high speed. In the extent age of Geo-Information technology, it is almost becoming the norm to combine both remote sensing and geophysics in environmental studies. Satellite data have been in use for many applications such as urban planning, disaster management, agricultural monitoring and mapping of natural resources. With the availability of high-resolution images and stereo capabilities sensors, 3-D visualization has become easy. The current study evaluates the capabilities of satellite remote sensing technology for planning the locations of mobile communication infrastructure, which comprises mainly of towers i.e. Base Transceiver Station (BTS) with suitable antennae. The methodology also comprises of developing suitable spatial modelling in Geographic Information System (GIS) environment. GIS in the context of this study means medium scale map generation using satellite remote sensing data. The position of the BTS is kept in such a way that the strength of the signal remains good at the caller/receiver end. However, in engineering site investigations remote sensing and geophysics are rarely integrated and the present study aims to outline a methodology for the integration of these genetically related data sets with geological/geomorphologic data serving as ancillary information, in engineering mobile site characterization was carried out. The results of remote sensing and geophysical surveys were integrated to GIS environment so that accurate and realistic site placement can be achieved.

Keywords: *Remote Sensing, Geographical Information System, Geophysical data sets, engineering mobile site Characteristics.*

Introduction:

India is a vibrant market from communications point of view. The subscriber base in the wireless market in India, the world's fastest growing telecom market reached another milestone when it surpassed 200 million subscribers in Aug 2007. The country's mobile services market is forecast to grow by a compound annual rate of 28.3% in next five years. At present there are around 54000 cell sites operated by different GSM/CDMA operators. This number would further go up to 80,000 in next couple of years. A cell site is a term used primarily for a site where antennas and electronic communications equipment are placed to create a cell in a mobile phone network (cellular network). A cell site is composed of a tower or other elevated structure regular and backup electrical power sources, and sheltering. Cellular tower locations are the result of an engineering field called Radio Frequency Engineering or RF, for short. RF engineers work closely with the marketing departments to determine areas where the placement of a new tower will accomplish one (or more) of three goals:

Expansion:

The tower site provides coverage over areas that do not currently have coverage.

Capacity:

The tower site provides additional capacity for the carrier to handle more calls in areas where existing towers are overloaded.

Quality:

The tower fills in a hole or an area where customer calls are frequently dropped or call service is poor.

Remote sensing and geophysical techniques have been used for investigation in the environmental sciences with remarkable success. Remote sensing techniques are used because of their cost effectiveness, their ability to access areas that are difficult to access and because the data can be collected frequently and rapidly on a large scale. Geophysical techniques, on the other hand, are non-invasive and can furnish broad, composite images of the subsurface over large areas at relatively lower cost and higher speed. In the extant age of geoinformation technology, it is almost becoming the norm to combine remote sensing and geophysics in environmental studies. This is usually done with a view to harnessing the advantages inherent in both techniques. However, in engineering site investigations, remote sensing and geophysical techniques are rarely integrated despite the obvious fact that, like in other investigations in which they are integrated, so much could be gained by so doing. This study aims to outline a methodology for the integration of these genetically related disciplines in site testing undertakings. This would be done with a case study example after taking a look at the so-called environmental inventory' and the suitability of remote sensing and geophysical techniques for the environmental studies. In general parlance, the word 'site', derived from the Latin word situs (meaning position), denotes the position on which an entity is has been or is to be situated, especially as to its environment. In geographical space, such an entity could be a building, undeveloped land, a settlement, etc. in which case the environment would be composed of natural and/or man-made features. There are various discipline-specific definitions of site characterization. So, in the geotechnical and engineering sciences, site characterization is a location- or area-specific survey conducted to characterize (describe) the physical, chemical and/or biological attributes of that area, presumably intended for some engineering purpose, e.g., infrastructural development. The amenability of different engineering site characterization problems to remote sensing and geophysical methods is considered in the following sections. Airborne remote sensing techniques yield aerial photographs (panchromatic or multispectral) and other aerial sensor image products (e.g. SLAR and thermal infrared line scanner images), whereas the space-borne techniques generate mainly multispectral image products. As a rule, the target spatio-temporal phenomena determine the most appropriate image product to be used for a given application. However, in practical terms the availability and cost of data are the cardinal factors in making the choice of the Image data to be used On this premise, it may be noted that, although airborne image products (especially aerial photography) have been used extensively for the production of detailed thematic maps (geologic, pedologic, etc.) and provided much information that was not apparent on satellite images, it has become the standard practice in environmental investigations to use satellite imagery to tackle problems that were hitherto handled with aerial images. This trend has occurred because satellite imageries provide synoptic views, have uniform illumination and tonal quality, are acquired in multispectral bands, have repetitive coverage, are readily available and are cost effective. The problem of poor spatial resolution images of late seventies were providing little information. The current high resolution satellite images (e.g. Ikonos with 1 m resolution) now exist that compete favorably with image products from airborne sensors on this point. Nevertheless, when a given investigation requires multistage approach, data from both techniques are integrated. Geophysical methods encompass a wide spectrum of surface and down-hole measurement techniques, which provide means of investigating subsurface geologic and engineering conditions. The techniques that have been devised for use detect discontinuity in some physical property. In order to be able to countercheck result and provide basis for investing some reasonable degree of confidence in the interpretation results, the use of complementary techniques is always preferred by using only one technique. The factors that determine the suitability of a particular technique or a combination of techniques include the dependent physical property contrast between the target and the surrounding, depth extent of the target, nature and thickness of the overburden and cost. In view of the inherent ambiguities or non-uniqueness in their interpretations, geophysical results and their interpretations are usually controlled by selective drilling information. Remote sensing and geophysics are genetically related. The scope of geophysics, however, is mainly devoted to the investigation of the interior of the solid Earth, whereas remote sensing studies the natural and man-made environmental factors, in so far as these lie on the surface of the Earth or in the atmosphere. Thus, if it is desired to characterize the environment comprehensively (i.e. from the air, the ground surface and below the ground surface), so much is to be gained by a close integration of remote sensing and geophysical techniques. Proposed order of activities in engineering site characterization using a combination of remote sensing and geophysical techniques are discussed.

On the basis of the foregoing, the following four-stage order of activities is proposed for routine engineering site characterization investigations:

Stage 1:

Use of remote sensing techniques for the generation of regional environmental parameters (e.g. floral distribution and density, soil types, geology, etc.) that may help to provide a framework for further investigation at the next two stages.

Stage 2:

Generation of information on the lithology, tectonics, geomorphology, drainage character, etc. of the area of interest from surface investigations. This would also serve the purpose of ground-truthing the remote sensing deductions obtained from the activities in Stage 1.

Stage 3:

Subsurface mapping regarding the nature of the Earth materials making up the subsurface, soil testing, structural design and layout of ground based sites

Stage 4:

Integration of the results realized from the use of the expert knowledge involved in the first three stages. Spatial data analysis tools involving measurement, spatial query and classification functions, overlay operations, neighborhood functions and network functions have been used in a Geographic Information System (GIS) environment.

Materials and Methods:

The coastal district of Udupi of Karnataka state falls along the west coast of peninsular India and Western Ghats lies in the east and Arabian sea in the west. The district lies between 13° 04′ and 13° 59′ North latitude and 74° 35′ and 75° 12′ East longitude covering an area of 3575 sq km (Fig.1).

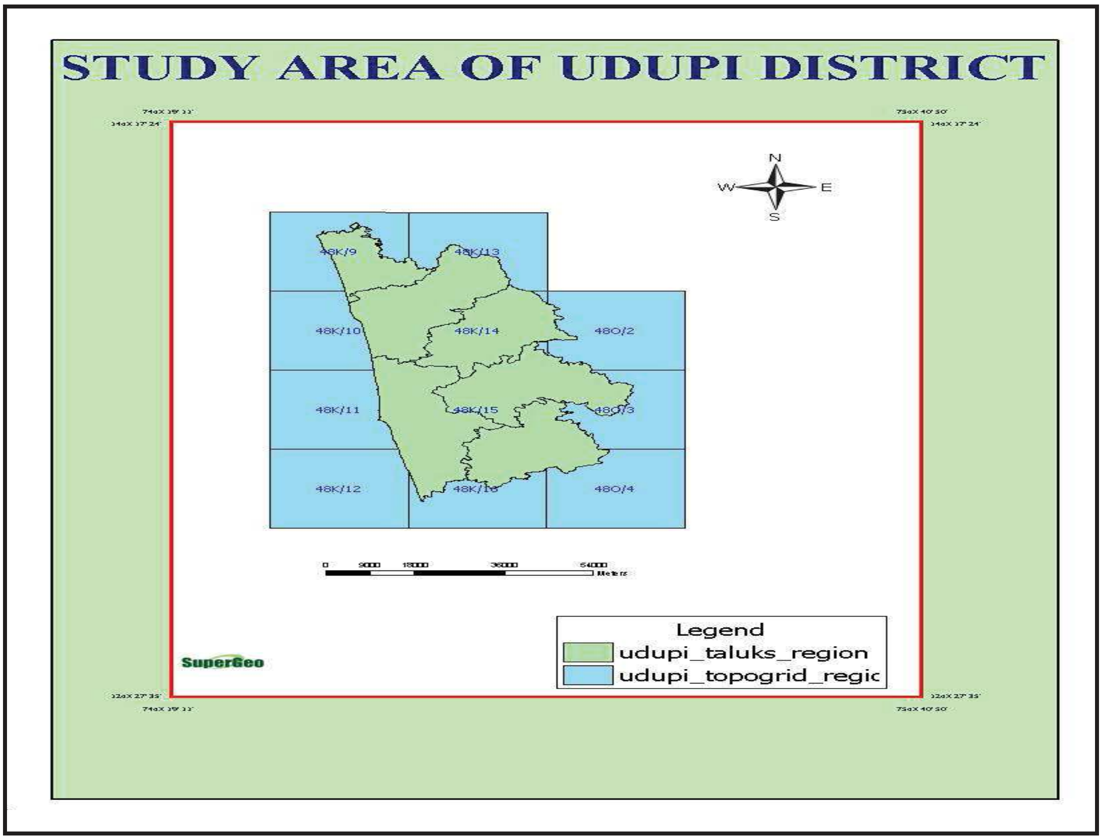

Figure 1: *Study Area of Udupi District, Karnataka State.*

The study mainly involves the integration of Remote Sensing and GIS techniques. A major part of the work has been carried out by making use of the satellite data (both hard copies and digital data), SOI topographical maps, Google maps and other maps. The satellite data taken for this study are the multispectral Linear Imaging Self Scanning-3 (LISS-III) sensor data of the Indian Remote Sensing satellite IRS-1C acquired on 1^{st} March 2000 (Table 1). These data primarily has been used for clutter analysis and for data integration with PAN, and for the extraction of road networks. In the present study, a planning strategy for establishing a network of towers for the purpose of mobile communications using remote sensing and GIS is demonstrated. In particular, this study addresses how to develop a surface model using IRS-1C LISS III. This information derived from the satellite data was integrated with raster GIS modeling. The study clearly demonstrates that the satellite data could be utilized for planning a suitable network of towers for telecom applications.

Table 1: *IRS-IC PAN and LISS – III Specifications. (Based on IRS-IC Data Users Handbook)*

Serial No.	Parameter	Specification PAN	LISS-III
1	Spatial resolution (m) (at nadir)	5.8	B2,B3,B4: 23.5 SWIR B5: 70.5
2	a) Swath (km)	70	B2,B3,B4: 141 SWIR B5: 148
	b) Swath steering range (degrees)	±26	–
3	Spectral band (micron)	0.5–0.75	B2: 0.52–0.59 B3: 0.62–0.68 B4: 0.77–0.86 B5: 1.55–1.70
4	Camera square wave response (SWR) (at Nyquist frequency)	>0.20	B2 > 40; B3 > 40; B4 > 35; B5 > 30
5	Quantisation (bits)	6	7
6	Signal to noise ratio (SNR) (at saturation radiance)	>64	>128
7	Saturation radiance (mw/cm^2-str-micron)	47	B2: 29 ± 1.5; B3: 28 ± 1.5; B4: 28 ± 1.5; B5: 3.25 ± 0.25
8	Integration time (ms)	0.8836	B2, B3 and B4: 3.5528; B5: 10.6584
9	Data rate (Mbps)	84.903	B2, B3 and B4: 35.7904; B5: 1.3906

The aim of the work was to derive height information from satellite data; clutter analysis and extraction of road network using multispectral data, and integrate this information using GIS techniques. There are some areas, such as parks and monuments protected under government law. Those areas were marked as protected and not included in GIS modeling (Figure 2).

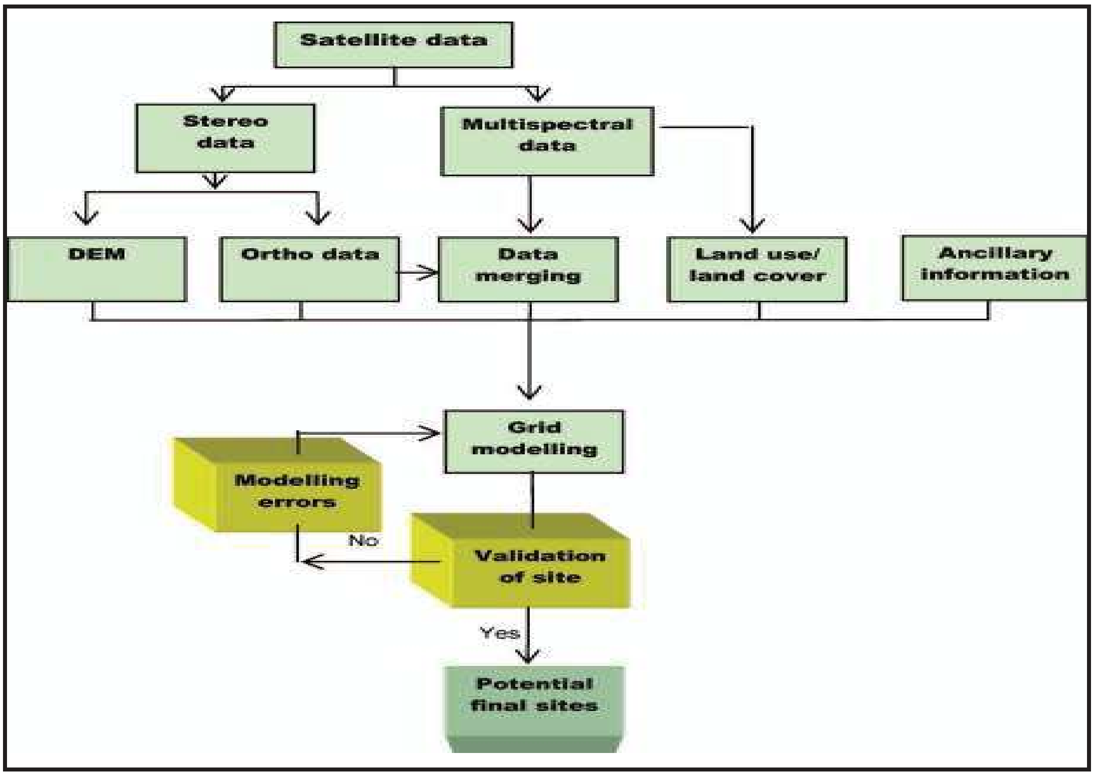

Figure 2: *Methodology for Mobile Site Deployment using RS/GIS*

Results and Discussions:

Remote Sensing Investigation:

IRS satellite images covering an area measuring 23.5 ×23.5 km centered on Udupi District were acquired for the study. After the necessary geometric and radiometric correction of the image data, they were enhanced using techniques such as edge enhancement, colour composites formation and band rationing, using ERDAS Imagine software. The resultant data sets were then interpreted together with a suite of ancillary data (geological, soil, topographic and drainage maps of the area). The interpretation results were verified during a ground-truthing exercise in the area and then used to construct regional thematic maps (Fig. 3, 4, 5 & 6).

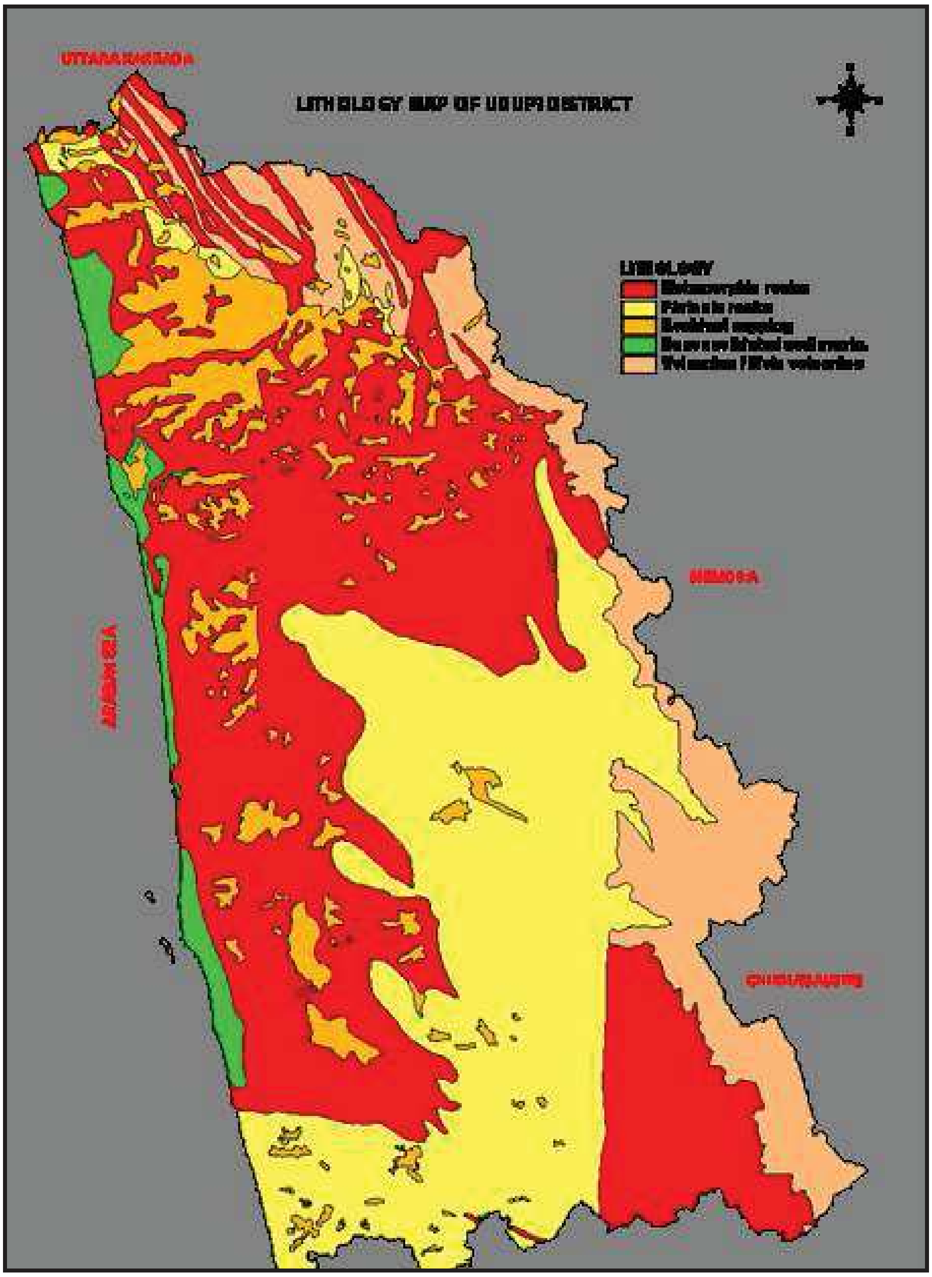

Figure 3: *Geological Map (Source: GSI, Bangalore)*

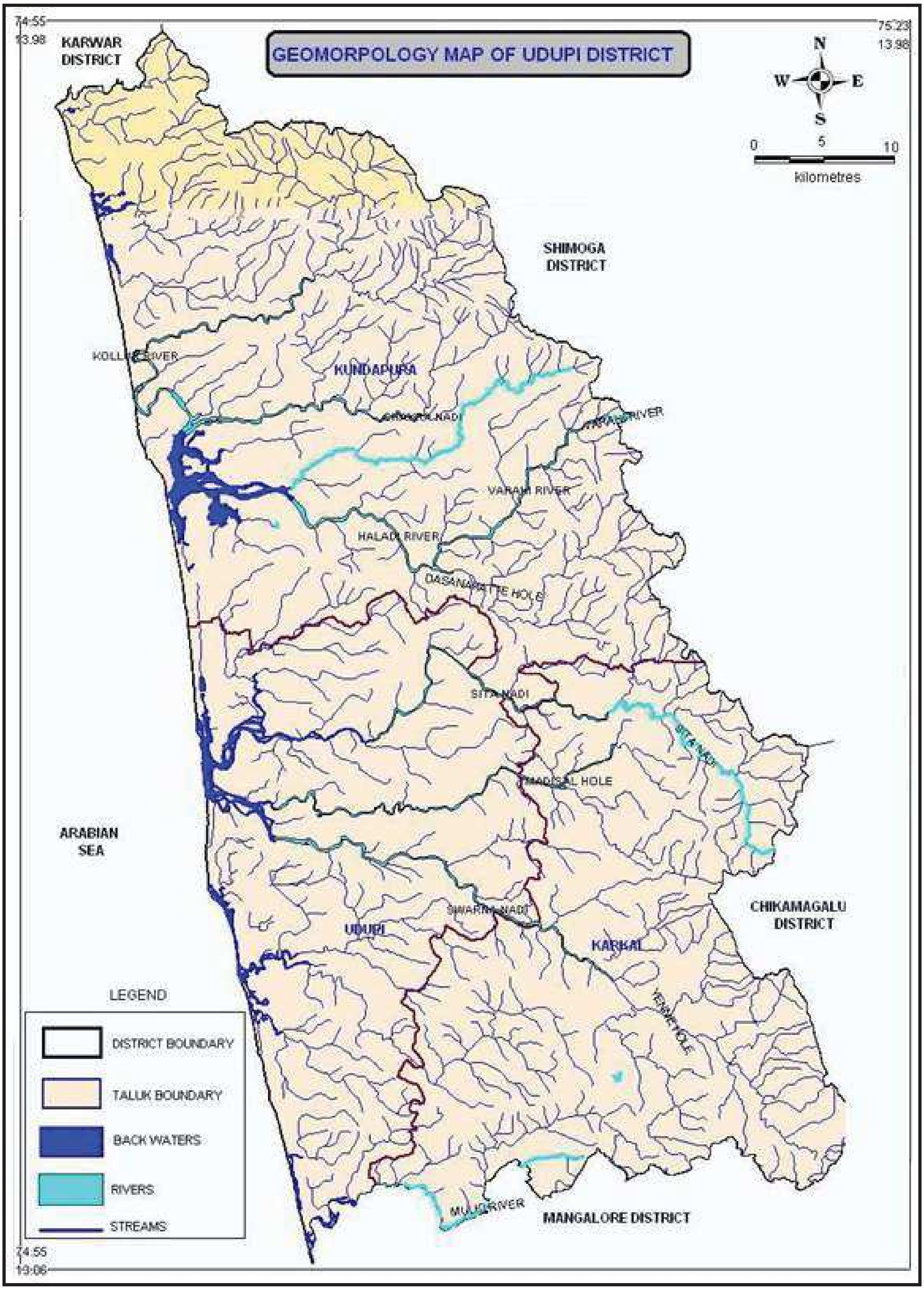

Figure 4: Geomorphological Map

Geological and Geomorphologic Investigations:

During the ground-truthing of the remote sensing interpretation results, detailed geological investigation of the site was also carried out. Geomorphologic study based on the existing topographic maps and satellite images of the site was also carried out. Slope and slope aspect map of the site were also generated from the topographical maps.

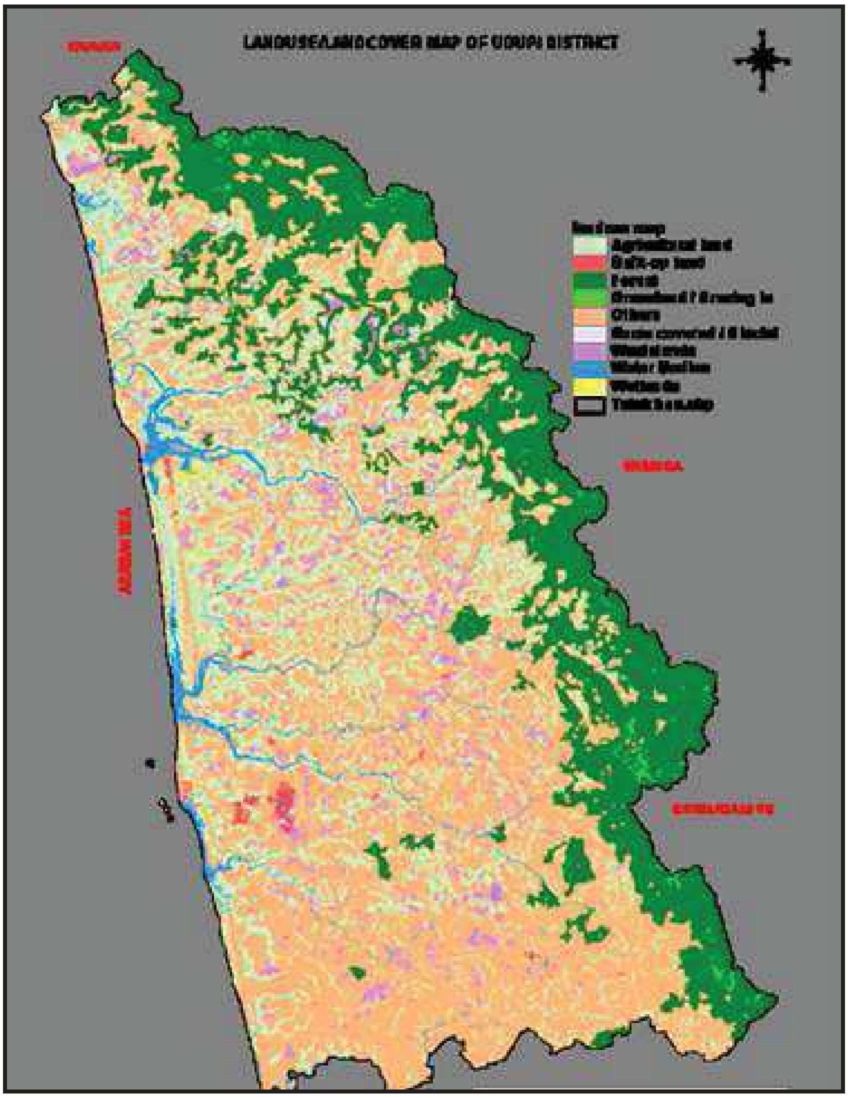

Figure 5: *Land Use/Land Cover Map*

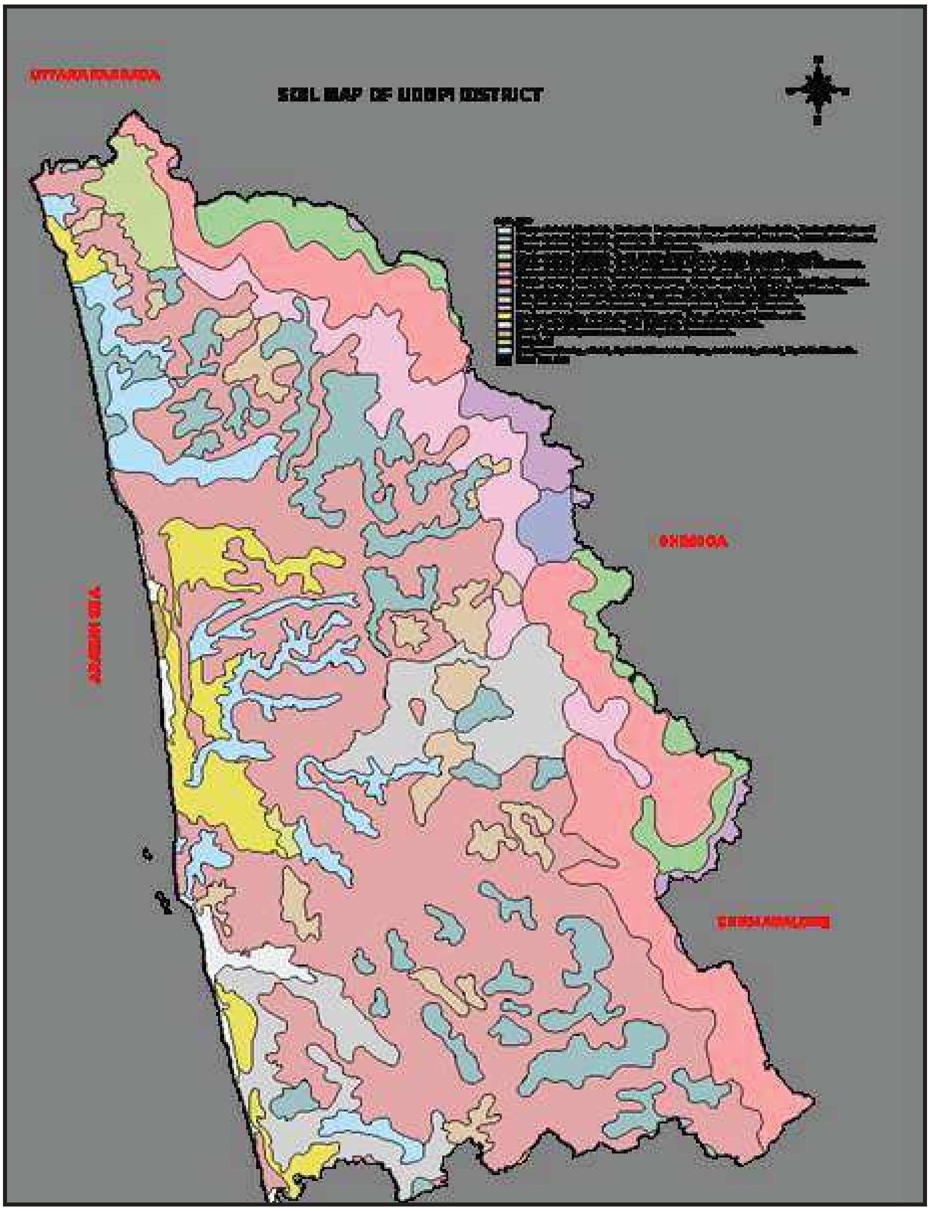

Figure 6: *Soil Map*

Geophysical Investigations:

The geophysical investigations of the site involved the electrical resistivity and magnetic methods. The 54 electrical resistivity measurements taken at 50 m interval were, using the vertical electrical sounding technique (VES). The VES curves were quantitatively interpreted by partial curve matching method and computer iteration with the RESIST program. The interpretation results were correlated with the available lithologic logs (Table 2). After the necessary diurnal and offset corrections were effected, the residual magnetic values were used to produce a magnetic map for visual (qualitative) analysis. Magnetic profiles for semi quantitative analysis were also generated.

Table 2: *Resistivity Ranges of Various Litho-Units of Udupi Area.*

Litho-Units	Resitivity Ranges in Ohm-m
Soil	30 – 3100
Laterite	120 – 3500
Lithomargic clay	10 – 48
Fractured gneiss	90 -200
Semifractured gneiss	400 – 600
Sand	705
Saturated sand	160
Gneiss	300 - α

Integration of Data Sets:

This involved the combined analysis of the remote sensing, geological, geomorphologic and geophysical data sets using the GIS vector data overlay approach in the Super GIS program environment. In this way the required engineering site characteristics were deduced.

Results and Discussions:

Satellite data have been in use for many applications such as urban planning, disaster management, agricultural monitoring and mapping of natural resources. With the availability of high-resolution imageries and stereo capabilities sensors, 3-D visualization has become easy. At present space borne satellites are providing approximately 2–30 m height information digital elevation model (DEM) data. The current study evaluates the capabilities of satellite remote sensing technology for planning the locations of mobile communication infrastructure, which comprises mainly of towers i.e. Base Transceiver Station (BTS) with suitable antennae. The methodology also comprises of developing suitable spatial modeling using satellite remote sensing data. There are three important stations in the operation of mobile communications: 1) mobile services switching centre (MSC), 2) base station controller (BSC), and 3) base transceiver station (BTS). Both MSC and BSC are intelligent units and communicate with each other. These two stations can be stationed anywhere inside the rooms or buildings, whereas the BTS have to be kept in high, elevated places like high rise building tops, mountain tops or tower with a height greater than 40 m. The installation of BTS is a critical component in the operation of mobile communications. The function of the BTS is to receive and transmit the signal from the cell/hand phone to the BSC and MSC. These signals are processed by the BSC and MSC, and in turn, identify the position of the caller/receiver. In case the caller/receiver goes outside the limit of the one BTS, the BSC/MSC would identify the nearest BTS and connects to the caller/receiver. These two stations can be stationed anywhere inside the rooms or buildings, whereas the BTS have to be kept in high, elevated places like high rise building tops, mountain tops or tower with a height greater than 40 m. The installation of BTS is a critical component in the operation of mobile communications in Geographic Information System (GIS) environment. From this model, fifty-six sites were selected for the tower placement within the study area of 3575 sq.km. These results were compared with the existing Bharat Sanchar Nigam Limited's (BSNL) network, which was prepared using ground survey methods. On comparison, it was observed that some of the sites were very close to BSNL sites and distances between the sites proposed by the study and existing sites in the study area were very close and only varied from 60–40 m (planimetric distance). One could see a good fit if compared with it sized area (Figure.7). It appears that existing sites have a similar geographic placement to proposed sites as well as similar elevations, implying that the spatial analysis was reasonable. Based upon analysis, we proposed sites are as shown in figure 8. It was observed that if the density of mobile phone users is high, then a single BTS would not be sufficient to cater for all because of signal strength, and hence a greater number of BTSs are to be planned based purely on this factor. Generally, telecom companies use a propagation model to study the signal attenuation in their study area. Cell phone companies have used a mix of field surveys called drive tests in the study area for estimating signal attenuation and their statistical information on number of subscribers for site plan. This is a field survey based method utilizing empirical models, which are dependent on the internal technical experience of the telephone companies. The propagation model thus generated is integrated with the clutter to study the overall impact of the signal strength originating from a particular location of the tower (BTS). This information i.e. signal strength from the drive test is confidential in nature and was not given for this study. In spatial data integration, the signal strength of the transmission tower was not taken into consideration.

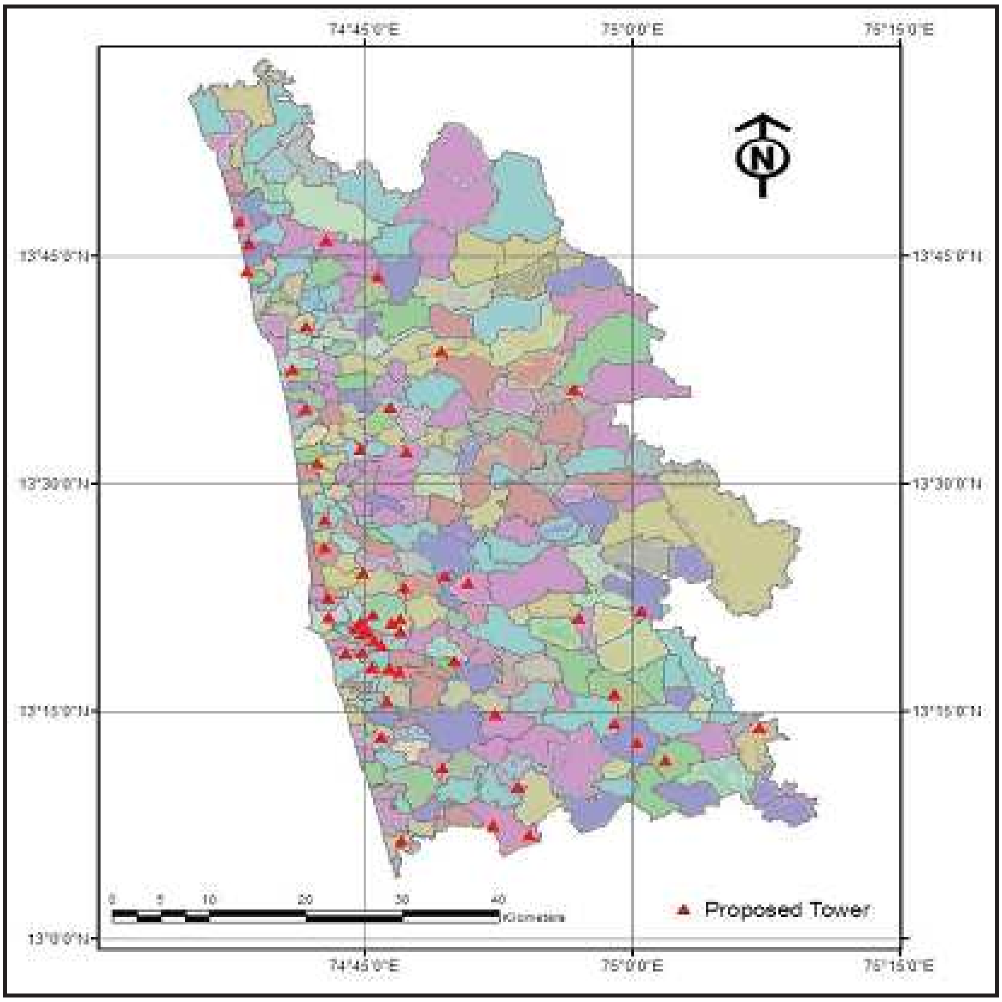

Figure 7: *Proposed Mobile Tower Sites of Udupi District*

Therefore, the number of towers as estimated by this study is less compared to the actual number of towers positioned by BSNL in the field. Since the present study goes by elevation, clutter information etc., without considering the cell users density, those sites were identified. As the competition among mobile service providers is very high, getting this information from cell companies was difficult and for this study the number of cell users was not included, but population density of the study area is very high. Hence for future planning, these towers would be definitely helpful for the telecom companies. Using four basic parameters, the present study was able to select sites for fifty-six cell towers within the study region. As it stands, it is felt that this study did a fair job in proposing sites, which will reduce cost and environmental impacts, although it does not take into account the aesthetic impacts of large tower placement. On verification it was found that ideally, existing elevated structures should be included in the analysis, as due to cost reasons these elevated sites would clearly be ideal. It was also clear that for accurate and realistic site placement, it is better to conduct a site-by-site analysis to interpret unnecessary overlap.

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