REMOTE SENSING AND GIS APPLICATIONS IN DETERMINATION OF GEOMORPHOLOGICAL MAPPING OF ACHANAKMAR AMARKANTAK BIOSPHERE RESERVE USING MULTISPECTRAL SATELLITE DATA

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Abstract:

Geomorphological mapping and necessary supporting data are crucial to developing countries that are usually under severe environmental and demographic strains. Approaches and methods to map the variability of natural resources are important tools to properly guide spatial planning. In this paper a comprehensive and flexible new geomorphological combination legend that expands the possibilities of current geomorphological mapping concepts. The piece-by-piece legend forms a “geomorphological alphabet” that offers a high diversity of geomorphological information and a possibility for numerous combinations of information. This results in a scientific map that is rich in data and which is more informative than most previous maps but is based on a simple legend. The system is developed to also be used as a basis for applications in GIS. The symbol-based information in the geomorphological maps can be digitally stored as a powerful database with thematic layers and attribute tables. By combining and further developing aspects of different classical mapping systems and techniques into expanded data combinations, new possibilities of presentation and storage are developed and thus a strong scientific tool is provided for landscape configuration and the reconstruction of its development; in turn the combination paves the way for specific thematic applications. This paper demonstrates a systematic approach for the identification of landforms and structures in Achanakmar Amarkantak Biosphere Reserve where conventional field based methods are difficult to adopt due to terrain inaccessibility. The geomorphological parameters of the study area using Multispectral Satellite Data (LISS 3 and TM) and interpretation techniques were used by means of ARC-GIS 10.1 and ERDAS IMAGINE 10 Software which aided a better option for visualizing the terrain and mapping.

1. Introduction

“Geomorphology is the study of landscapes It entails the systematic description of landforms and the analysis of the processes that create them.”

Geomorphology is defined as the science of landforms with an emphasis on their origin, evolution, form, and distribution across the physical landscape. The science that deals with surface features of the earth, their forms, nature, their origin and development is termed as geomorphology. DAVIS (1912) first projected the concept of geomorphic cycle. According to bauling (1950), the role of factors that are important the geomorphology are lithology, stratigraphy, climatic variation and the regional basis for the development of landforms. The use of remote sensing technology for Geomorphological studies has definitely increased its Importance due to the establishment of its direct relationship with allied disciplines, such as geology, soils, vegetation/Land use & hydrology. Geomorphological mapping involves the identification and characterization of various landforms and structural features. The various landforms can influence a conservation area in many ways like slope gradient, elevation and aspect, affect the quantity of solar energy, water, nutrients and other materials, while the slope affect the flow of materials. Slope is also the deciding factors of intensity of disturbance, such as fire and wind, which are strongly influenced by the pressure of vegetation (Swanson et al 1988). The scope of geomorphology has further expanded with the landform maps widely used in various fields of resource surveys, environmental planning, hydrological studies, engineering application and geotechnical studies, mineral and oil explorations and also in hazard mitigation. Geomorphology has long been treated as a subject with landform identification by field investigation. Each of these investigations was focused on landform characterization leading to the process understanding. After more than a hundred years as a recognized discipline, landform characterization through field investigation remains central to many geomorphological studies until recent. Now, new trends have emerged that integrate field work with modern technologies such as GIS, GPS, remote sensing and elevation models, which further strengthens the study of relationship between the land-forms and the processes that created them. Over the years, scientists have conducted research and shown the usefulness of spatial technologies, remote sensing and field studies in landform mapping and understanding of geomorphic processes. Satellite imageries have been used for geomorphological mapping of large and remote areas along with field study and aerial photographs. However, while aerial photographs are of restricted nature in many countries, field investigations are labour intensive.

In this paper the geomorphological and Lineament map of the Achanakmar Amarkantak Biosphere Reserve (India) is presented. The map is the result of the interaction of different datasets, both traditional and innovative in geomorphology. Aerial photos and field survey are enhanced by satellite images to achieve a digital final product that is not only a simple thematic map, but also an interactive and upgradable Geographical Database. The geomorphological processes producing the present landscape are therefore better visible and understandable through the use of new tools to a certain detail level which is a basic requirement in understanding the processes that have acted or are acting in the evolution of the present day landscape. Special emphasis was given to bring out the morphological attributes and probable geomorphic evolution history which led to the development of the present morphography.

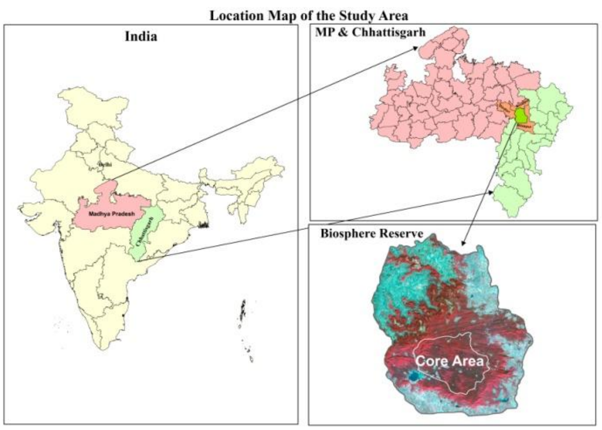


Figure: 1 Location Map of Study Area

2. Study Area

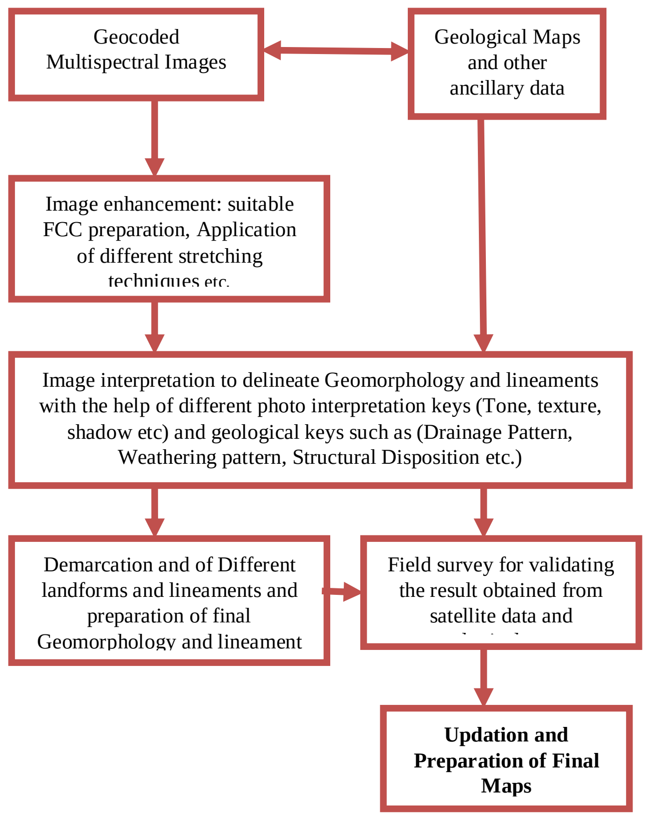
Achanakmar Amarkantak Biosphere Reserve located at the junction of hill ranges of Madhya Pradesh and Chhattisgarh state, India. (Fig.1) Occupying total area of 3835.51sq.km. With topography ranging from high mountains, shallow valleys and plains. The core region of Achanakmar Amarkantak Biosphere Reserve falls in Chhattisgarh state lies between 22015' to 22058'N and 81025' to 82050'E, falls under the survey of India Toposheet No.64 F5 to F15, 64J1,J3.The

Biosphere is bounded by Anuppur, Dindori and Bilaspur district.

3. Data Sources

Georectified Resourcesat-1 LISS 3 and Landsat TM data were used for the identification of landforms. LISS 3 has 23.5 spatial resolution and four bands such as green (0.52 - 0.59 µm: band 1), red (0.62 - 0.68 µm: band 2), NIR (0.77 - 0.86 µm: band 3) and SWIR (1.55 - 1.70 µm: band 4), Landsat TM 7 band data were used in this study. Apart from the space-based data, ancillary data such as Topographic map on 1:50,000 scale with a 20 m contour interval and District Resource Map (GSI) on 1:250,000 were also used in this study. Contours were also generated from Topographic sheets.

4. Methodology



Flowchart: Describing steps for preparation of Geomorphological Maps from satellite image

The study of geomorphological and environmental changes involved a series of different stages: study of bibliographical references, field-work, observation and direct digitizing on the basis of satellite images (Landsat, LISS 3), topographic Sheet (SOI scale 1:50,000) and geological map DRM (GSI. scale: 1:2, 50,000). All primary data were imported in a Geographical Information System in the Arc GIS environment. Thus a GIS database was developed and updated with data deriving from different sources. Data were analyzed quantitative and qualitative, while different aged thematic maps were created. The geomorphological alterations were studied through photo interpretation of satellite image. In order to increase the accuracy of photo interpretation, field work was done. These functions were supported by Image Processing and GIS software's, enabling the user to perform on screen Synoptic observation and instant on screen digitization to the GIS database. The geomorphologic map of entire project area has been prepared mainly through Landsat sensor TM and IRS LISS 3 satellite data on 1:50,000 scale. Some physiographic details were transferred from Toposheets to the base map along with the interpreted units through satellite data.

Several digital and analogical sources of data can be used to produce thematic maps both in the stage before the preparation of the map and in the successive stages. The interpretation of satellite data for geomorphological study is best accomplished by visual interpretation techniques with the understanding of spectral property of rock material and image characteristic of landforms. The criteria of interpretation may, however, change from region to region due to climatic influence on weathering, vegetation cover and mass movements. Interpretation of satellite images based on qualitative use of the following recognition key elements such as shape, size, tone or colour, pattern, shadow, association, texture and shadow.

Tone or colour is the brightness or the shade of gray or the colour of the detected element and depends on the amount of light that it reflects, constituting a sort of spectral signature of anthropogenic and natural objects in the area. Also, a transition between two different tones is relevant to detect a variation in some physical processes and useful to locate landform limits.

Texture can be defined as the arrangement of tone or colour structured in a well recognizable pattern and depends strongly on the scale of the photos. When features are too small on an image to be identified, their repetition can be a clear evidence of a specific feature. So, the smoothness (uniform and homogeneous texture) or the roughness (coarse and heterogeneous texture) of an image can identify a particular vegetation cover (e.g. tree as rough, grass as smooth). Pattern, or the spatial arrangement of a landform, is the last characteristic used in geomorphology, particularly useful in drainage network recognition (dendritic, rectangular, parallel and so on).

Different band combinations of satellite data were used to generate a false colour composite (FCC) for image interpretation and onscreen mapping. For example, while the use of SWIR in FCC highlighted the rocky outcrops, NIR band helped in the identification of vegetated scarp areas. The selection of optimum FCC for mapping geomorphic features was done interactively. Visualization of the terrain is an important component of the landform identification process in a hilly area. The resulting geomorphologic map has several advantages. The final document is upgradable and easily editable. The organization of data into layers lets the user to select, for viewing and printing operations, one or more layers simultaneously. The attribute tables associated with the themes contain alphanumeric data in unlimited quantities.

The geomorphological map was produced to a medium scale 1:50000, with ESRI's ArcGIS 10.1 with an equivalent project scale. The Spatial Reference is UTM (Universal Transverse Mercator) Zone 43N and WGS 84 N. The DRM and Toposheet scanned and is imported and then georeferenced. The following stage, the vectorization of each single group of landforms, is particularly important. The symbology associated with a geomorphological map is complex. Thus, it is not always possible to draw symbols identical to those proposed in the traditional and official legends. In the Attribute Tables several information are stored for each layer.) For each landform the data included in the attribute table are: i) the main geomorphologic process responsible for landform creation, ii) the state of activity, and iii) the area and the perimeter. Spatial analysis tools can calculate the statistical distribution of the landforms, starting from the topographic grids (Melelli & Taramelli, 2010; Taramelli & Melelli, 2009).

To better understand to what extent the topographic parameter influences the spatial distribution of a geomorphological process a quantitative analysis is required. Therefore, the digital map becomes an interactive document for further applications. Remotely sensed data also offer further enhancements to geomorphological mapping and landscape comprehension. Due to the aforementioned difficulties in interpreting the geomorphological symbolism, a backdrop layer resulting from remotely sensed images can aid in the comprehension of the landforms.

It is well known that particular RGB arrangements can highlight different natural aspects on the ground: 432 for vegetation, 741 for the moisture content in the soil coverage and so on. In the final layout, the part dedicated to the geomorphogical data and the section for the grids and satellite images have the same importance. So the remote sensing information is added to make the final product in keeping with the rest of the maps, becoming a source of Information for the knowledge of the territory. This helped in synergetic use of the various data sources in landform mapping.

5. Results

Landforms of structural origin were mapped in these areas which represent a typical Plateau and Hill-valley complex. Most of the landforms under this class have genesis related to underlying horizontally to sub-horizontally bedded sedimentary rocks of Chhattisgarh and Gondwana Super groups. Primary structures such as bedding play an important role for developing resistance of litho units, which manifested itself in different types of landform. Some of these variations are minor and some are in a mega scale. The mega scale structures have a dramatic effect on the genesis of landforms and hence mapping of such forms indirectly indicates the structural setup of the area. Landforms identified in this area using satellite image are explained below.

Landform of structural origin

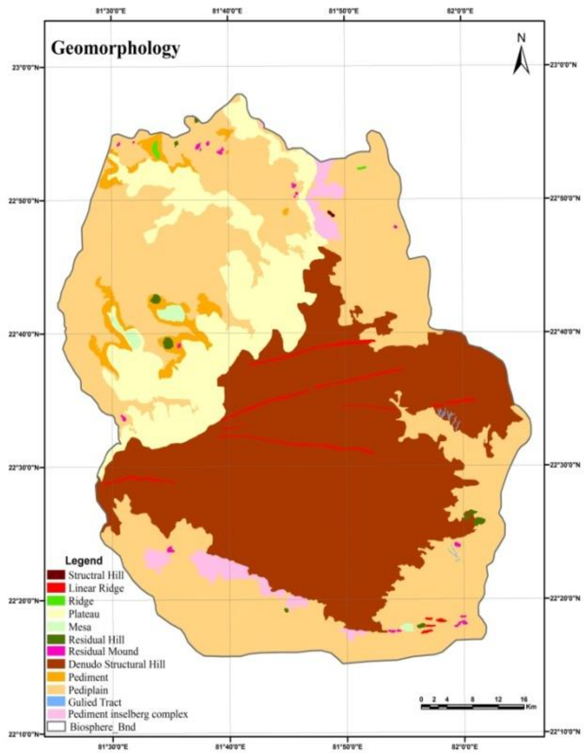


Figure: 2 Geomorphology Map of Study Area

Landform of structural origin is related to structural aspect of the area. Most of the landforms under this class has genesis related to underlying structure. Structure plays an important role for reducing the resistance of rock which manifests itself in different geomorphic forms. Some of the variation is minor and some are in mega scale. The mega scale forms have a dramatic effect on the genesis of landforms and hence mapping of such forms indirectly indicates the structural set up of the area. The mega scale structural features like fault and fold depending on its type plays an important role in genesis of structural landform. The influence of geologic structures on the development and appearance of landscapes is prominent. The influence of geologic structures ranges from large features, which exert a dominant influence on the form of an entire landscape, to small features, which affect an individual landform and the geomorphic processes operating on it. The structural control could be active structures whose form is directly impressed on the modern landscape or ancient structural features whose influence on a modern landscape is primarily due to differential erosion. Structural landforms which are mapped are explained below.

5.1 Structural Hill

Hills which are originated due to tectonic process and are highly dissected by the drainage lines. This can be further classified as highly, moderately and low dissection depending on the density of joints and drainage. Mostly this will be interpreted from a planimetric satellite data and the classification is highly subjective.

5.2 Ridge

A ridge is a geological feature consisting of a chain of mountains or hills that form a continuous elevated crest for some distance. Ridges are usually termed hills or mountains as well, depending on size there are several main types of ridges.

Landforms of Denudational origin

Landform of Denudational origin is formed where the denudation process dominates over the other process. Most of the landform resulting due to this process is the combined effect of mechanical and chemical weathering. Denudation is the process of Removal of material by erosion and weathering. This has direct influence on the relief of the area especially in the reduction of relief to the base level. The agents are mostly water, ice and wind. The major factors affecting denudation are geology, climate, tectonics and anthropogenic effects. All rocks and minerals at or near surface are attacked by physical and chemical process. The effect of this process is not same everywhere because of rocks varying resistance to change. As a result weathering and erosion Yield number of landforms, which have typical shape and forms. Weathering is an essential part of the rock cycle. The parent material, or rock weathered material is disaggregated to form smaller fragments and some of the minerals are dissolved and removed by the agent of water. This removal of material is erosion and is accomplished by running water, wind, glacier etc. The weathering provides a raw material for the sedimentary rock and soil. Denudational landforms which are mapped are explained below.

5.3 Plateau

Broadly, any comparatively flat area of great extent and elevation and extensive land region considerably elevated (more than 150-300m in altitude) above the adjacent country or above sea level and commonly limited on at least one side by and abrupt descent, having a flat or nearly smooth surface but often dissected by deep valleys or canyons and surmounted by ranges of high hills or mountains, and having a large part of its total surface at or near the summit level. A plateau is usually higher and has more noticeable relief than a plain (it often represents an elevated plain) and is usually higher and more extensive than a mesa.

5.4 Mesa

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 layers of resistant, nearly horizontal rocks (usually lavas). Less strictly, a very broad, flat-topped, usually isolated hill or mountain of moderate height bounded on at least one side by a steep cliff or slope and representing an erosion remnant.

5.5 Residual Hill

A small remnant hill, which has witnessed all forms of denudation.

5.6 Residual Mound

A small remnant hill, which has witnessed all forms of denudation and formed a rounded or a circular peak.

5.7 Pediment Inselberg Complex

The pediments dotted by numerous inselberg of small sizes, which makes it difficult to distinguish from the pediments. Hence it is called as a complex of pediment and inselberg.

5.8 Pediment

A broad, flat or gently sloping, rock floored erosion surface or plain of low relief, typically developed by sub aerial agents (including running water) in an arid or semiarid region at the base of an abrupt and receeding mountain front or plateau escarpment, and underlain by bedrock (occasionally by older alluvial deposits) that may be bare but more often partly mantled with a and discontinuous veneer of alluvium derived from the upland masses and in transit across the surface.

5.9 Pediplain

An extensive, multi-concave, rock cut erosion surface formed by the coalescence of two or more adjacent pediments and occasional desert domes, and representing the end result (the "peneplain") of the mature stage of the erosion cycle.

5.10 Gullied Tract

A deep ditch or channel cut in the earth by running water after a prolonged downpour. A gully is a landform created by running water, eroding sharply into soil, typically on a hillside. Gullies resemble large ditches or small valleys, but are meters to tens of meters in depth and width. When the gully formation is in process, the water flow rate can be substantial, which causes the significant deep cutting action into soil

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6. Conclusion

Cartography is experiencing an important change with the introduction of computer systems and digital images (GIS, satellite images). In particular in the Earth Sciences, Geomorphological mapping begins to benefit from the digitalization of information. From a graphical point of view, given the complexity of symbology, geomorphological maps interpretation is often difficult, especially for non-experts. The potential offered by GIS can solve this problem. In addition, the input of satellite data allows integrating additional information to better understand the mechanisms that regulate the morphogenetic processes. The remote spatial data acquisition techniques are also moving important steps. Therefore, the availability of data with high accuracy allows having progressively more accurate information on the topographic attributes evaluation of landforms. Statistical distribution of landforms, morphogenetic processes and numerical calculation of quantitative indices (Melelli & Floris, 2011; Serrano & Ruiz-Flaño 2007a,b) benefit significantly from these new techniques. Today is possible to merge the information collected by traditional techniques (aerial photo-interpretation or field survey) with numerical data, obtaining final documents completely different from traditional cartography. The data can be updated, queried and displayed in various ways. They can also, with the help of statistical analysis, offer new research methods to build advanced models for morphogenetic processes of landscape evolution.

Identification of landforms using key interpretation features such as image tone, texture, association and terrain shadow was demonstrated in this paper. Using these data and method, landforms such as Pedi plains, Pediment Inselberg Complex, Plateau, Pediment, Residual Hill, Residual Mound, Structural Hill, Linear Ridge, Mesa, Ridge, and Gullied Tract were identified. These landforms were developed mainly due to the control by the Structural and denudational origin.
This study highlighted that the Landsat TM and IRS LISS 3, for the mapping of geomorphic features at medium scale (1:100,000 or 1:50,000). The procedure for Systematic use of satellite image and ancillary data, demonstrated in this paper, can be adopted for landform mapping in any hilly terrain.

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