

# Digital Terrain Analysis of Tapi River Basin in Gujarat, India

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**Abstract** With the new advancements in GIS techniques and better computer aid, the projects that require field exploration, can now be carried out digitally with ease. In the present paper a digital terrain analysis is performed using QGIS software with SAGA plugin. QGIS version 3.22.2 and SAGA 7.8.2 is utilized in present study. The study area is of Tapi river basin in Gujarat which is Surat district. The raw data is collected in the form of Cartosat-1 Digital elevation model (DEM) from Bhuvan web portal which is Indian geo platform of ISRO. The DEM tiles are first mosaicked and the study area is extracted using SAGA software. Morphometry algorithm available under terrain analysis package is used to determine thematic layers of slope, aspect, curvature, etc. Using TPI base terrain classification algorithm thematic layer of landform is prepared. Analytical hill shading and contour maps were prepared using QGIS.

**Keywords** —Geomorphology, GIS, Digital terrain analysis, DEM, QGIS, aspect, slope, hill shade, contour, thematic layers

## I. INTRODUCTION

Terrain analysis is the study of the nature, origin, morphological history, and composition of land forms. Terrain is very important aspect which modulates Earth surface and atmospheric processes.[5] Understanding of the nature of terrain can play vital role in understanding of the nature of these processes. Terrain analysis gives us various analytical maps which can be very useful in understanding nature of the terrain.[7] Thus, analysis and representations of terrain have proved exceptional for many activities in GIS and environmental modelling.

Using elevation data along with other geospatial information, terrain analysis describes the landscape, for basic visualization, modelling, or to support decision making.[4] Using terrain analysis one can create attribute tables, scatterplots, or histograms, but most widely used product is thematic maps.

With open data sources available in the form of Digital Elevation Model (DEM) and Geographic Information System (GIS) have gained popularity in the river basin analysis in recent decades. GIS is found to be an important tool for evaluating various terrain parameters like topography, slope, landforms, geology etc. GIS can also be used to manipulate spatial data related to river basins.[6] The increasing availability of DEM and open source software like QGIS one can perform hydrological, geomorphological and environmental investigations with ease.

DEM is a digital representation of a terrain in three dimensions and made the direct application in terrain analysis with the existing GIS tools. It is an effective way for obtaining accurate terrain information. Multiple approaches are used to create river morphology mapping and DEM is a common approach in generating river terrain models.

Present paper describes the results of the river profiles and lineaments of the Tapi river basin in order to understand the terrain characteristics using DEM, remote sensing and GIS tools. The objective of the study is to analyze the topography of Tapi River basin in Surat district in Gujarat State with respect to its slope, aspect and curvature etc., using Digital Elevation Models. The data can be used for basin management, its planning and other hydrological activities.

## II. METHODOLOGY

### A. Study Area

Tapi is one of the major rivers of central India with a length of around 724 km running from east to west. It outfalls into Arabian sea through the gulf of Cambay. The Tapi basin is located in the northern part of the Deccan plateau and covers drainage area of 65145 km<sup>2</sup>. Nearly 80% of the basin lies in the state of Maharashtra. In Gujarat its drainage area is 3837 km<sup>2</sup>, which covers Surat district. The basin consists of two well defined physical region namely hilly region and plains. The soil falls under the category of black cotton soil. The coastal plains of Gujarat are composed of alluvial clays and black soils.

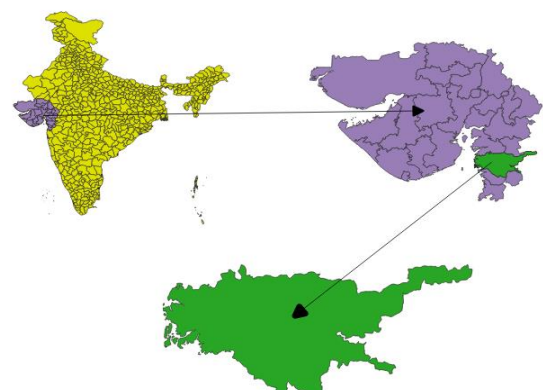


Fig. 1 Study area

**B. Data Acquisition**

The row data is collected in the form of Cartosat-1 Digital elevation model (DEM) from Bhuvan web portal. Bhuvan is an Indian web based utility which allows users to explore a set of map based content prepared by Indian Space Research Organization (ISRO). Data sets are usable, actionable, multi-layered. Terrain analysis is multi-resolution, multi-temporal and multi-sensor. The following figure shows five DEM tiles which covers the study area. The data sets are in Geographic coordinate system (CRS) with WGS84 as datum.



Fig. 2 DEM images overlapping Surat region

**C. Data Processing**

Mosaicking:

Since one single DEM image can't cover entire study area, we require a number of tiles that can be used for our study purposes. Hence it is necessary to combine all these DEM tiles into one single tile from which our study area can be extracted.

SAGA allows us to perform such kind of things. In the present study there were five DEM tiles covering Surat region. Using the geoprocessing tool, grid mosaicking one single tile can be generated.

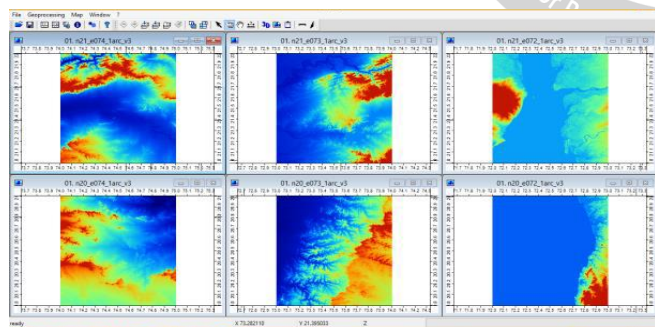


Fig. 3 Mosaicking DEM

Sub setting/ Extracting study area:

Performing analysis on combined mosaic tile can become very time consuming and may produce unwanted errors if the processor of computer is not fast enough. To avoid that we can extract our concerned region using clip grid algorithm. After extracting it becomes very easy to visualize and analyze the study area.

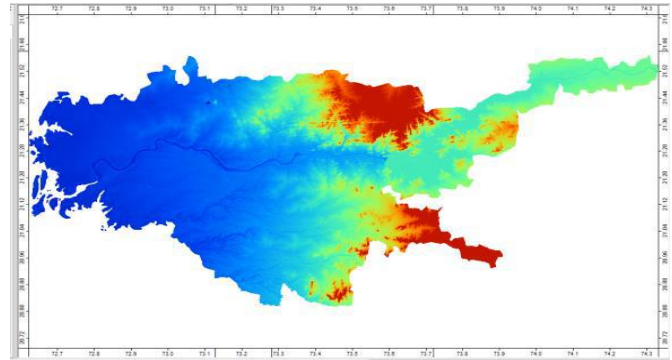


Fig. 4 Extracted study area

Terrain Analysis:

Using the morphometry tool available under the geoprocessing tab one can easily generate thematic layers of any region. It allows us to perform curvatures, slope, aspect etc. The output will be various thematic layers from which we can understand the topography of the region. We can also classify the landforms using TPI based classification tool. Using the histogram of this layer we can understand the data distribution under various landforms like streams, valleys, ridges, slopes etc.

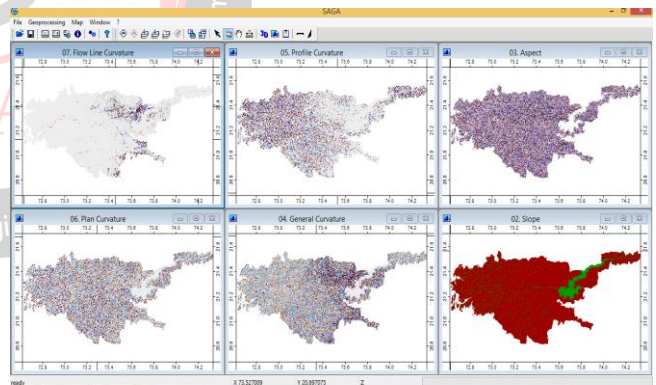


Fig. 5 Thematic layers of slope, aspect, curvature etc.

Analytical hill shade:

The 3D visualization of DEM is very effective in understanding the topography. Using the analytical hill shading algorithm, we can generate 3D map of the DEM image. Hill shade shows how the terrain looks with the interaction between sunlight and surface features. A mountain slope directly facing towards sunlight will be very bright and a slope opposite to the light will be dark.

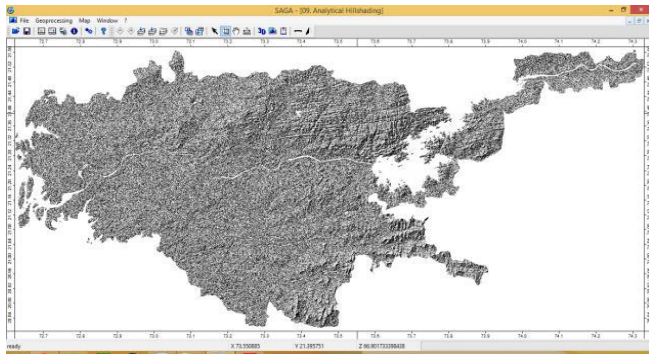


Fig. 6 Analytical hill shade of study area

**Contours:**

Contour map provides elevation details of the study area. Using QGIS raster analysis tool we can generate the contour map of the study area. From which we can determine maximum slopes, hills, valleys, accumulation of drainage etc.

**D. Data Postprocessing**

QGIS is used to prepare maps of different thematic layers generated in SAGA. The images were exported as Geo TIFF files and imported in QGIS.

**III. RESULTS AND DISCUSSION**

From the slope map we can see that maximum slope can be seen at northern part of the main catchment area of Ukai Dam in Surat district. So, we can say that maximum runoff received during rainy season will be from northern area which can be seen in Slope map with yellowish colour.

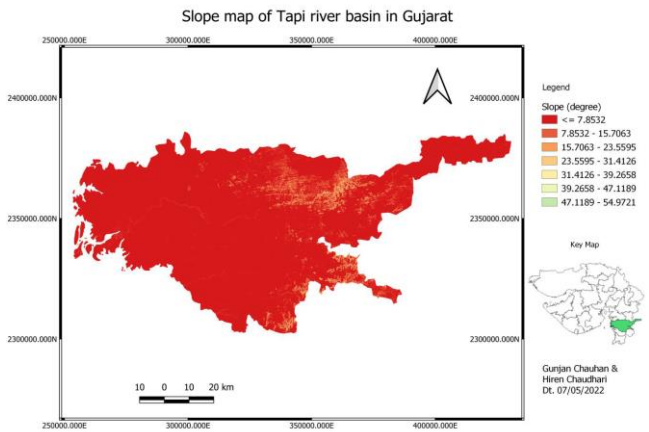


Fig. 7 Slope map of study area

Aspect map helps us understand the orientation of curvature and impact of sun on local climate. In present Aspect Map, the Tapi river basin showing maximum mountainous region is present northern side of the Ukai Dam and major slopes are Southern East Facing therefore, these slopes have higher vegetation compare to other parts of the region.

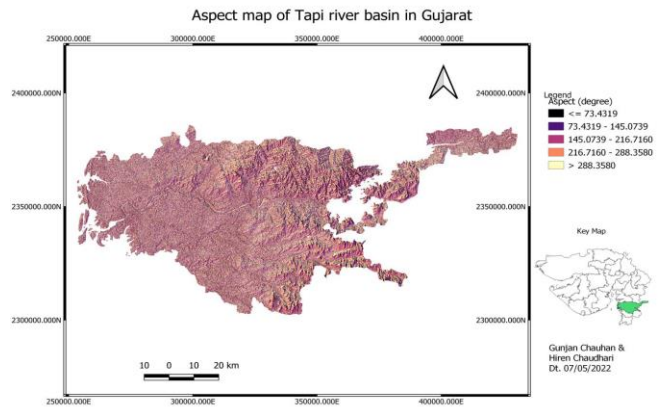


Fig. 8 Aspect map of study area

From Land form map we came to know the type of natural Features present in study area. From the present map we can see that maximum area is occupied by Plain following by Valleys, Slopes , Ridges and Streams. As shown in histogram, the highest bar denotes plain area hence conclusion can be made that majority regions in Surat district is having plain terrain. The ridges and valleys are mainly located at Eastern part of the district where Tapi river enters Gujarat state.

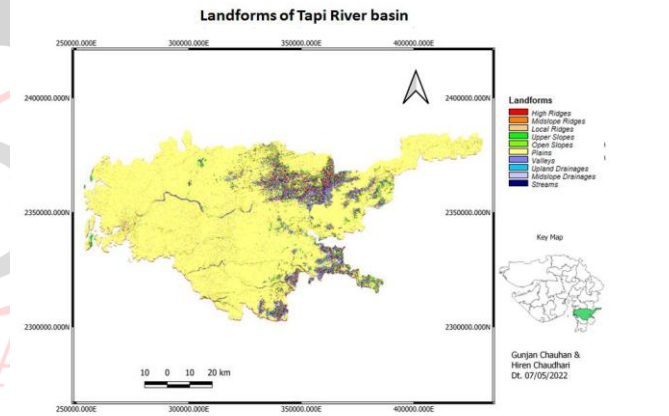


Fig. 9 Landform map of study area

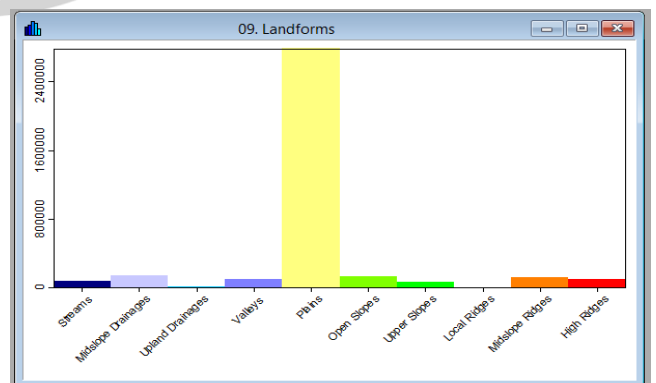


Fig. 10 Histogram of thematic layer- landform

The contour map shows that the elevation is ranged from - 250 meter to 500 meter in the study area. Negative values indicate the depression from mean sea level and positive values indicate the elevated areas and features in the Contour map. The map shows that 250 meter maximum depressed

area is present in Tapi river basin falls under Gujarat State and Maximum 500 meter highest elevation area is present in the study area.

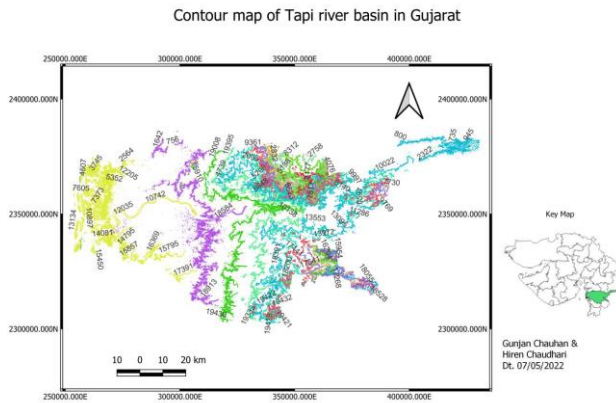


Fig. 11 Contour map of study area

#### IV. CONCLUSION

The purpose of the study was to use the approach to acquire geo information and to use GIS software to analyze the data obtained. From the study it is obvious that DEM images can be very helpful in carrying out the terrain analysis very effectively within a short period of time which was very difficult and time consuming in the past. From various maps prepared in the research, it is concluded that Surat district is having plain terrain in majority of its regions. Also contour lines indicate higher values in Eastern part where Tapi river enters Gujarat. As majority of ridges are facing east direction, they receive less direct solar radiation giving rise to greenery in this region. We can see that these products are very helpful in the present scenario when going for various projects, flood prone areas, mitigation plans, relief measures, precautionary measures, temporal pattern changes of land use etc.

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