WATERSHED DELINEATION AND MORPHOMETRIC ANALYSIS USING GIS AND REMOTE SENSING

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ABSTRACT. A watershed is a territory from which many rivers and streams drain into a common reservoir. The first step in reaping the benefits of watersheds is identifying them and determining how much water they supply. Important watershed parameters may be defined and calculated using a Geographic Information System (GIS). The city of Chittoor in the Indian state of Andhra Pradesh is being investigated here. The Google Earth engine is used to create a LULC map (land use land cover), and USGS Earth Explorer is used to gather DEM data to define watersheds to better understand the study area's landscape. Watershed boundaries and morphometric parameters are presented in the current study.

1 INTRODUCTION

One well-known definition of a watershed is the area that drains into a major body of water, such as a lake, the ocean, or a much bigger river than others. The process of identifying the limits of a watershed, also known as a catchment, drainage basin, or river basin, is referred to as watershed delineation. Users are able to recognize surface water characteristics within a watershed and grasp the downstream implications when a watershed is delineated, which assists in the planning and execution of protection and mitigation activities connected with water quality and quantity. By using morphometric analysis, landforms are quantified and mathematically quantified. This is crucial for deducing the topographical feature's flow patterns and, in turn, the drainage basin's geohydrological features.

2 OBJECTIVES

1. A watershed delineation can be used to develop water resource management plans, including flood control and water supply strategies.
2. The features of a drainage system can be quantified with the use of morphometric analysis. Using this data, we can pinpoint problem regions prone to erosion and floods.
3. Watershed delineation may be used to locate highly ecologically significant areas that should be preserved from unfavorable development.

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3 LITERATURE REVIEW

3.1 Umang S. Visharolia et al., (2017)

In this work, researchers utilised the Purna River basin data to test out an ArcHydro model constructed using digital elevation models. Several intermediate findings were produced as the model ran. Following the completion of the model, the catchment area and primary parameters of the Purna River were determined. This study's results will be useful for future studies of runoff analysis and catchment area studies. It would also help with ground and surface water resource management, distribution, and decision-making. With this information, hydrologic and topographical characteristics of the watershed may be calculated in HEC-HMS, where a Rainfall-Runoff model is currently under development.[1]


The research area for watershed delineation in this investigation is the Cauvery Basin that includes the Selaigur region. Hydrologic, hydraulic, and water resource management have all benefited enormously from the availability and improved quality of DEMs made possible by GIS technology. The standard hydrographical study was conducted using both GIS and conventional methods, however, with GIS Arc Hydro, efficiency was much improved. These findings have significant use in hydrological modeling, watershed research, land use planning, and reservoir management and design.[2]


This research involved the development of a DEM and the subsequent extraction of geomorphological properties through the use of GIS. Despite the fact that the results reported in this work might be different depending on the watershed under consideration, the study illustrates clearly that GIS can be used for the extraction of geo-morphological properties of a watershed. Each feature's spatial distribution is mapped over the basins of all watersheds upstream of hydrometric stations in Madhya Pradesh as a case study to illustrate the efficacy of this technique. The results may be used to studies of regional flood frequency, in which watersheds are aggregated into hydrologically similar regions.[3]

3.4 Mohamed ElKashouty (2020)

The principal goal of Qena-Safaga-Bir Queh is likely the enhancement of drainage basins to increase aquifer potential. Hydrogeological and morphometric data are used to create the drainage development plan and strategy. In order to characterise the watershed and describe its hydrological features, DEM, ETM+8, a geology map, and SPSS were used. The morphometric study began with the extraction and characterization of ten drainage basins. Using geological and remote sensing data, digital geological distribution was derived for each basin. Basins with medium surface rock permeability are shown by morphometric characteristics. Seventeen morphometric descriptors were employed in a study of multivariate statistical techniques.[4]
3.5 S. Thangaperumal et al., (2020)

The purpose of this research is to determine the watershed basin in the Karaikal area by combining information from Bhuvan with that found on the USGS website. ArcGIS relies heavily on the digital elevation model to glean its hydrological information. The ArcGIS surface tool was utilised to get the contour, pour point, and stream segment ready. Developing the flow accumulation required using Model Builder. A watershed demarcation map is generated by combining data on flow accumulation, stream segment, and pour point. Watershed analysis not only identifies the borders of a catchment but also provides hydrological characteristics that may be used in management plans.[5]

3.6 Aseel A Alkatib, et al., (2021)

In this effort, a Digital Elevation Model (DEM) of the satellite picture of the Karbala–Al-Najaf plateau was uploaded. A topographic map of the area is extracted, and the areas of the watersheds and their perimeters are calculated in order to plan the water networks of the geographical plateau NI-38-14 in Iraq. This plateau is between the provincial boundaries of Al-Najaf and Karbala. The topographic chart clearly displayed considerable fluctuations in earth's elevation as the region's heights ranged from 20 to 120 metres. From the Karbala-Al-Najaf plateau, watersheds comprising 150 individual regions have been culled. The greatest watershed has an extracted area of 4882 km², while the lowest has an extracted area of only 1 km².[6]


Using a toposheet remotely sensed digital elevation model and morphometric ArcGIS toolbox, this study determines morphometric parameters in the Dudhnai river basin, a sub-basin of the river Brahmaputra that is susceptible to erosion and sedimentation. The seven Dudhnai sub-watersheds were evaluated for their susceptibility to soil erosion using morphometric criteria. According to measurements of bifurcation ratio, drainage density, drainage intensity, and continuous channel maintenance, the Dudhnai watershed is not in high danger of floods or soil erosion.[7]

3.8 Padala Raja Shekar(2022)

The Murredu watershed in Telangana State was the focus of the morphometric and land use/land cover (LULC) analysis described in this article. Using remote sensing (RS) and geographic information system (GIS) techniques, it is possible to estimate the morphometric properties of a watershed and conduct LULC analysis. Utilising morphometric and LULC characteristics, the fourteen sub-watersheds of the watershed were ranked. On the basis of morphometric and LULC analyses, the sub-watersheds were divided into low, medium, and high-priority categories for soil and water conservation. In high-priority sub-watersheds, soil and water conservation strategies can be implemented.[8]
4 Methodology

Fig 1. Watershed delineation process
4.1 AREA OF STUDY

The investigation will concentrate on the area surrounding Chittoor. Eight different districts make up the Rayalaseema region of Andhra Pradesh, India. Named Chittoor is one of them. 6703 square kilometres make up the whole surface. Fig 2 represents the study area and its DEM.

Fig 2. Study area

4.2 LAND USE LAND COVER

Using conventional scientific and statistical techniques of research, the phrases "land cover" and "land use" are used to describe the effects of human activity on landscapes and the classification of natural features during a certain time period. A watershed's annual mean discharge, frequency of floods, groundwater recharge, and stream flow are all significantly impacted by changes in land use. Extreme land usage reduces the amount of vegetation in the watershed, reducing humidity and increasing dryness. Land cover with little vegetation has high surface runoff and little water retention, while land cover with plenty of plants has higher evapotranspiration and lower annual river flow. The LULC map was made with Google Earth Engine. Flow chart 3 represents the methodology of LULC generation and Fig 4 represents LULC map.

Fig 3. The methodology employed for LULC map
4.3 FILL

Fill can be used to fix mistakes in the DEM data. There are no valleys in a complete DEM or elevation raster. Internal drainage is shown by a raster of elevation values where one or more cells have higher values than their neighbours. The tool can remove inaccurate peaks or cells with elevations higher than the surface trend. The spatial analysis fill function produces fill. This function generates fill when a layer is selected for corrected DEM. Fig 5 represents fill dem.

4.4 FLOW DIRECTION

Understanding the hydrologic characteristics of a surface requires knowing the flow direction from each raster pixel. With a surface as its input, this application generates a raster with the flow directions for each individual cell. A cell in an elevation raster will get the flow if it is lower than its neighbours. When many of a cell's neighbours have the lowest values,
the flow is estimated in an elevation raster by eliminating the cell's sink. Hydrology in ArcGIS will soon have access to this tool, which creates an output raster from a filled DEM. Fig 6 represents flow direction.

![Flow Direction](image)

**Fig 6.** Layout of flow direction

### 4.5 FLOW ACCUMULATION

Each pixel in a DEM is assigned its natural drainage direction via the flow direction procedure. All the pixels that will flow into outlets are counted by the Flow accumulation procedure based on the Flow direction map that is generated. With the use of error-free elevation raster data, flow accumulation is produced. Only the accumulation of flow will be used for cells that have uncertain flow directions. In the raster output, the total flow is calculated by adding together the number of cells moving in the direction of each cell. High flow zones in the output raster are essential for locating possible stream routes. Fig 7 represents flow accumulation.

![Flow Accumulation](image)

**Fig 7.** Layout of flow accumulation
4.6 POUR POINT

At the pour point, water can be seen exiting. In close proximity to the watershed base. After generating a new file of the point-type vector, changing to the editing mode and entering the basin drainage point or outflow on the water networks, save the file. Fig 8 represents pour point.

![Fig 8. Layout of pour point](image)

4.7 WATERSHED

A watershed is the term used to describe the upslope area that feeds water flow to the common outflow. It might be part of a larger watershed or include smaller subbasins. We use the watershed tool, which creates a watershed based on a flow direction raster and a pour point feature, to draw its boundaries. After the watershed raster has been generated, it is transformed into a polygon using a raster-to-polygon converter. Fig 9 represents watershed polygon.

![Fig 9. The layout of watershed polygon](image)
4.8 STREAM ORDER

Stream order refers to a system for ranking the importance of nodes in a stream network. Streams may be identified and categorised using this list based on the number of streams that feed into it. Knowing the order of events in a stream might help reveal some of its properties. A programme called "stream order" is used to create this map. Fig 10 represents stream order.

![Stream Order Map](image)

**Fig 10.** Layout of stream order

4.9 MORPHOMETRIC ANALYSIS

In order to quantify and mathematically quantify landforms, morphometric analysis is used. Understanding the topographical feature and the flow patterns within it is essential for appreciating the geohydrological features of a drainage basin.

In this analysis, we compute the following variables:

1. Area
2. Perimeter
3. Stream order
4. Stream number
5. Mean stream length
6. Stream frequency
7. Stream density
8. Basin length
9. Bifurcation ratio
10. Length of overland flow
11. Circulatory ratio
12. Texture ratio
13. Stream length ratio
5 RESULTS

To get dimensions like area and perimeter, utilise the attribute table's Calculate Geometry tool. The remaining perimeters are computed using methods similar to calculate field and calculate geometry, as well as statistics from the attribute table. Excel was also utilised to determine circumferences such as bifurcation ratios, stream length ratios, and circulatory ratios.

Table 1. Results

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>1633</td>
</tr>
<tr>
<td>Perimeter</td>
<td>246</td>
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<tr>
<td>Stream order</td>
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</tr>
<tr>
<td>Stream number</td>
<td>157</td>
</tr>
<tr>
<td>Mean stream length</td>
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<tr>
<td>Stream frequency</td>
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<tr>
<td>Stream density</td>
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<td>Basin length</td>
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<tr>
<td>Bifurcation ratio</td>
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<tr>
<td>Length of overland flow</td>
<td>0.12</td>
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<tr>
<td>Circulatory ratio</td>
<td>0.33</td>
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<tr>
<td>Texture ratio</td>
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</tr>
<tr>
<td>Stream length ratio</td>
<td>1.61</td>
</tr>
</tbody>
</table>

6 CONCLUSIONS

1. Using a method that is based on GIS makes it simpler to study the link between drainage morphometry and landform characteristics and to evaluate the various morphometric parameters.
2. Data from the SRTM Digital Elevation Model and ArcGIS were utilised in order to figure out the various landforms contained within the watershed.
3. The use of ArcGIS is incorporated into this study as part of an effort to speed up the process of computing morphometric parameters.
4. Parameters like the bifurcation ratio help us understand the geometry of the basin, the behaviour of runoff in the watershed, and the extent to which some places are prone to flooding. Stream density is a useful metric for comparing the recreational and water-supply possibilities of different watersheds.
5. The estimated study parameters will be utilised to learn how a drainage basin's topographical feature and flow patterns affect the basin's geohydrological features.

REFERENCE