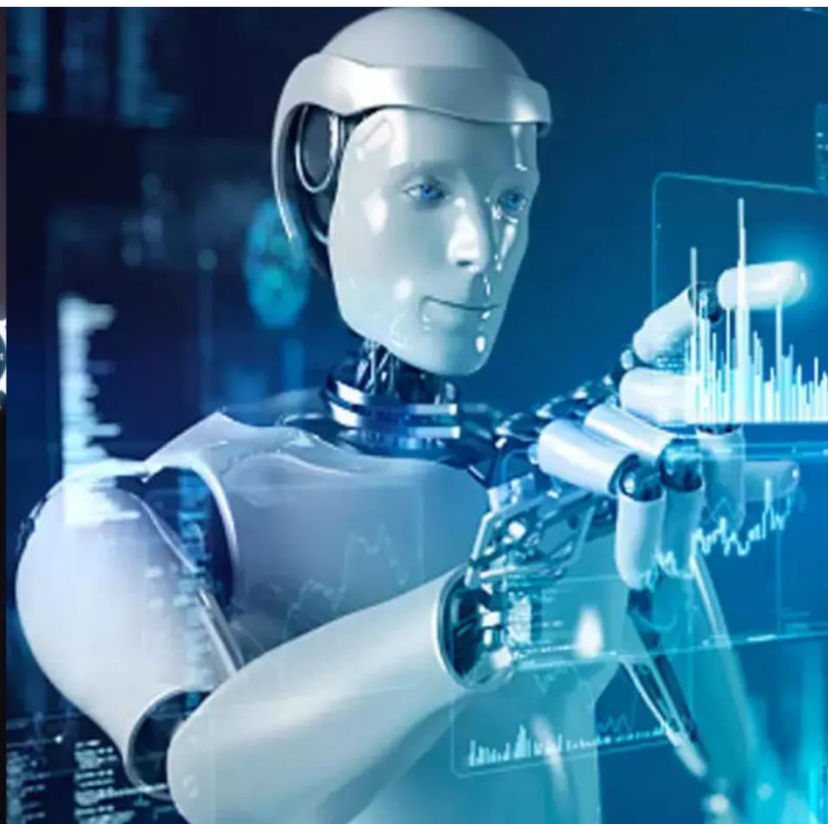




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Watershed Delineation and Stream Pattern Analysis using GIS and DEM

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ABSTRACT: Watershed mapping and stream flow analysis play a key role in understanding water behavior and land surface features. With the help of geospatial technologies, especially GIS and DEM, it has become easier to study watersheds, drainage patterns, and stream networks. This study aims to use GIS and DEM data to identify watershed boundaries and analyze stream patterns for better water and land management. DEM provides detailed elevation data that helps determine flow direction, flow accumulation, and stream orders using GIS tools. Combining spatial data with terrain analysis reveals how topography influences drainage formation and flow. These GIS-based methods are faster, more accurate, and reduce human errors compared to traditional manual techniques. Stream pattern analysis also helps relate drainage characteristics with soil, slope, and land-use conditions. The results from GIS-based watershed mapping are precise and support identifying flood-prone zones. Such studies are essential for sustainable watershed management and effective resource planning. They provide valuable insights for water conservation, soil erosion control, and regional development. Overall, integrating GIS and DEM offers a reliable scientific platform for mapping watersheds and analyzing stream networks, helping researchers and planners manage water resources efficiently and promote environmental sustainability.

KEYWORDS: Watershed Delineation, Stream Pattern Analysis, Geographic Information System (GIS), Digital Elevation Model (DEM), Drainage Network, Hydrological Analysis, Flow Accumulation, Water Resource Management, Terrain Analysis, Sustainable Development.

I. INTRODUCTION

One of the most important natural resources for the survival of all living things is water, which is also crucial for the socioeconomic advancement of any given area. Planning, environmental protection, and efficient management of water resources all depend on an understanding of how water moves across the landscape. A watershed is a naturally occurring hydrological unit that gathers rainfall and directs it into a shared outlet, such as a river, lake, or ocean. It is also referred to as a drainage basin or catchment area. The availability, distribution, and quality of water resources within a specific geographic area can be evaluated with the aid of watershed studies. In hydrological analysis, watershed delineation is a crucial step because it enables researchers to identify the borders and flow paths that characterize a drainage system. The field of hydrology and watershed management has undergone a revolution in recent years due to the utilization of Geographic Information System (GIS) and Digital Elevation Model (DEM) data. The manual contour mapping, field surveys, and topographic maps used in traditional watershed delineation techniques were labor-intensive and inaccurate. As geospatial technology has developed, GIS has become a potent instrument that enables accurate spatial data analysis and visualization. The primary input for watershed and stream network analysis is a digital elevation model (DEM), which is a representation of the Earth's surface elevation. Based on the features of the terrain, DEM assists in precisely determining stream patterns, accumulation areas, and flow directions when combined with GIS. Preprocessing DEM data, filling sinks, determining pour points, calculating flow direction and accumulation, and defining watershed boundaries are some of the analytical steps involved in watershed delineation using GIS and DEM. These procedures enable researchers to produce precise and repeatable results, which are crucial for resource management, flood risk assessment, and hydrological modeling. The arrangement and geometry of river networks

within the watershed are examined by stream pattern analysis, which offers important information about the area's geological structure, slope, soil properties, and drainage development. Dendritic, trellis, radial, and parallel drainage patterns are common, and each one reflects distinct geomorphological conditions. In addition to increasing the precision of watershed boundary identification, the integration of GIS and DEM improves multi-layer spatial analysis capabilities, including soil classification, slope evaluation, and land use mapping. These analyses assist engineers and planners in creating plans for soil conservation, flood mitigation, and sustainable watershed management. A useful platform for decision-making and raising public awareness of the sustainability of water resources is also provided by the ability to model and visualize hydrological processes in GIS. To gain a thorough grasp of the hydrological behavior of the region being studied, watershed delineation and stream pattern analysis are carried out using GIS and DEM. It aids in determining the general drainage network, surface runoff patterns, and possible areas for water accumulation. Applications for the analysis's findings include infrastructure development, agricultural planning, and groundwater recharge studies. The use of GIS-based methods will enable effective data processing, visualization, and interpretation as our project develops, guaranteeing a more scientific approach to watershed management. Watershed delineation using GIS and DEM is therefore a contemporary, precise, and effective way to comprehend and manage water resources in any geographic area.

II. LITERATURE SURVEY

Qiu yang Chen, et al., (2024) proposed a novel approach to extract accurate global river networks by combining radar and multispectral satellite data. The research focused on improving the precision of river mapping, especially in areas where traditional DEM-based methods struggle due to vegetation cover, terrain complexity, or low resolution. By integrating data from sensors like Sentinel-1 (radar) and Sentinel-2 (multispectral), the authors developed a method that overcomes the limitations of using only elevation data. Their results showed significant improvements in identifying small streams and river channels, which are often missed in standard global datasets. This advancement is crucial for hydrological modelling, flood prediction, and water resource management, particularly in data-scarce or remote regions. The paper shows how combining remote sensing technologies can enhance global-scale environmental analysis, which is highly relevant for current and future studies in hydrology and geomorphology.

B Dileep Kumar Reddy (2024) conducted a comprehensive analysis of morphometric characteristics of watersheds in India using Digital Elevation Model (DEM) data and QGIS software. The study focused on extracting important morphometric parameters such as drainage density, stream order, bifurcation ratio, and elongation ratio to better understand the hydrological behaviour and geomorphological features of the selected watersheds. By utilizing QGIS, the author demonstrated an efficient and user-friendly approach to watershed analysis, highlighting the advantages of open-source GIS tools in environmental studies. The findings revealed significant variations in drainage patterns and watershed shapes, which are essential for effective water resource management, flood prediction, and soil conservation. This study emphasizes the growing role of GIS and remote sensing technologies in watershed characterization, especially in the context of sustainable development in India.

Luca Carraro (2023) introduces rivnet, an R package designed to facilitate river-network extraction and analysis directly from digital elevation models (DEMs) without reliance on traditional GIS interfaces. Using TauDEM's D8 flow-direction algorithm under the hood, rivnet allows users to delineate drainage networks, compute flow paths, assign hydraulic variables, and attach covariates across network nodes in a largely automated and scriptable workflow. Carraro, (2023) One of the key strengths of this approach is that it promotes reproducibility by avoiding back-and-forth file transfers between GIS and modeling environments, allowing hydrologists, ecologists or modelers with limited GIS expertise to work within the R environment. The package supports flexibility: although it works with minimal input (e.g. outlet coordinates and DEM extent), it also permits customization for more experienced users. Carraro demonstrates the utility of rivnet via two case studies: one analyzing scaling laws (e.g. Hack's law) of river networks extracted from DEMs in Swiss catchments, and another coupling the river network output with a phosphorus transport model at catchment scale. He also discusses limitations of the D8 method (e.g. difficulty handling flat terrain or braided channels) and suggests practical workarounds. Overall, the contribution of this work lies in lowering the technical barrier for integrating geomorphological network information into ecohydrological or biogeochemical modeling workflows, making spatially explicit river modelling more accessible.

Kaliappan S and Venkatraman (2023) conducted a detailed study on watershed delineation and the accuracy assessment of various Digital Elevation Models (DEMs) in the Vaigai River Basin, located in Tamil Nadu, India. The researchers compared the performance of commonly used DEMs, including SRTM, ASTER, and ALOS, for their suitability in hydrological modeling and watershed boundary delineation. Using ArcGIS and HEC-HMS tools, they evaluated how differences in DEM resolution and quality impact the delineation process and hydrological outputs. Their findings highlighted that higher-resolution DEMs, particularly ALOS, provided better accuracy in capturing terrain features and drainage patterns. The study emphasized the critical role of DEM selection in achieving reliable watershed modeling, which is essential for effective water resource management and planning. This paper is particularly relevant for hydrological studies in Indian river basins and demonstrates the importance of integrating GIS-based techniques for improved watershed analysis.

Lijie Lu, Lihui Wang, et al., (2023) presented an improved method for extracting river networks from Digital Elevation Models (DEMs) by integrating surface water occurrence data and Sentinel-2 satellite imagery, specifically focusing on the Danjiangkou Reservoir Area in China. Traditional DEM-based methods often fail to detect small or seasonal streams, especially in flat or vegetated regions. To address this issue, the authors enhanced the extraction process by combining multi-source remote sensing data, which significantly increased the accuracy of river network detection. The use of long-term surface water occurrence maps helped identify persistent water bodies, while high-resolution Sentinel-2 imagery allowed for better visualization of river channels. Their results showed that this hybrid approach performed better than conventional DEM-only methods, especially in detecting minor tributaries. This study is valuable for improving hydrological modeling and water resource management, and it demonstrates how integrating optical and elevation data can enhance river network mapping in complex terrains.

Rahitya ragi, Mallikarjuna. V (2023) carried out watershed delineation and morphometric analysis in the Chittoor district of Andhra Pradesh using GIS and remote sensing techniques. The main objective of their study was to understand the drainage characteristics and terrain features of the region to support better watershed management. They used DEM data along with tools in ArcGIS to delineate the watershed boundaries and extract drainage networks. Various morphometric parameters such as stream order, drainage density, bifurcation ratio, and form factor were calculated to assess the hydrological behavior and geomorphology of the watershed. The study found that the area has a dendritic drainage pattern, which indicates homogeneous rock formations. Their work highlights the usefulness of GIS and remote sensing in analyzing watershed characteristics, especially in semi-arid regions like Chittoor. This kind of study is important for planning soil and water conservation measures and sustainable land use practices.

Desalew Meseret Moges, et al., (2023) investigated how the choice of Digital Elevation Model (DEM) affects the accuracy and performance of hydrological modelling. The study compared different DEM datasets, including SRTM, ASTER, and LiDAR, to evaluate their influence on watershed delineation, flow direction, and runoff prediction. Using hydrological models, the authors demonstrated that DEM resolution and quality significantly impact the simulation of hydrological processes, such as surface runoff and streamflow. Their findings showed that higher-resolution DEMs, like LiDAR, produced more detailed and accurate hydrological outputs, while lower-resolution models sometimes missed smaller streams or drainage features. This study highlights the importance of selecting appropriate DEM data for hydrological studies to improve water resource management and flood forecasting, especially in regions with complex terrain.

Md. Sharafat Chowdhury (2023) provided a comprehensive review of hydrological modelling techniques that use GIS and Digital Elevation Model (DEM) data. The paper discussed various methods for watershed delineation, flow direction analysis, and runoff estimation by integrating GIS tools with DEMs of different resolutions. It emphasized how GIS-based hydrological models have become essential for effective water resource management, flood prediction, and environmental planning. The review also highlighted challenges such as data accuracy, DEM resolution, and computational limitations that affect model performance. Chowdhury stressed the importance of combining remote sensing data with advanced GIS techniques to improve the precision of hydrological simulations. This study is useful for researchers and engineers aiming to apply GIS and DEM data in watershed analysis and hydrological modelling.

Padala Raja Shekar (2022) conducted a morphometric and land use/land cover (LULC) analysis of the Murredu watershed in Telangana State using remote sensing and GIS techniques. The study aimed to understand the watershed's drainage characteristics along with how land use patterns have changed over time. Various morphometric parameters

such as stream order, drainage density, form factor, and bifurcation ratio were calculated using DEM data to assess the basin's hydrological behaviour. Additionally, satellite imagery was used to classify LULC into categories like agricultural land, forest, built-up areas, and water bodies. The results showed that the watershed has a dendritic drainage pattern and moderate drainage density, indicating a relatively uniform geologic structure. The LULC analysis revealed significant changes due to urbanization and agricultural expansion. This study is important because it combines both morphometric and land use analysis, providing valuable insights for watershed management, soil conservation, and sustainable land development planning.

Anushaa et al. (2022) analysed water resources in the semi-arid Anantapur district of South India using the Modified Normalized Difference Water Index (MNDWI) along with remote sensing data. The study aimed to monitor surface water bodies and assess their spatial and temporal variations in a region facing water scarcity. By processing satellite images from multiple years, the authors were able to detect changes in water extent and identify areas vulnerable to drought. The use of MNDWI proved effective in distinguishing water features from built-up and vegetation areas, improving the accuracy of water resource mapping. This research highlights the importance of remote sensing techniques for sustainable water management in semi-arid regions, where traditional ground-based data collection is challenging. The study provides valuable insights for policymakers to plan water conservation and resource allocation in drought-prone zones.

Aseel A Alkatib, et al., (2021) performed watershed delineation and morphometric analysis of the Karbala–AlNajaf plateau in Iraq using Digital Elevation Model (DEM) data and remote sensing techniques. The study aimed to identify the watershed boundaries and evaluate the drainage characteristics of the plateau, which is important for water resource planning in arid and semi-arid environments. Using GIS tools, the researchers extracted various morphometric parameters such as stream order, drainage density, bifurcation ratio, and basin shape. These parameters helped in understanding the surface runoff behaviour and erosion potential of the region. The results showed that the area has a dendritic drainage pattern and moderate to low drainage density, indicating less structural control and moderate infiltration capacity. This study highlights the usefulness of integrating DEM and remote sensing data for effective watershed management, especially in regions facing water scarcity and irregular rainfall patterns.

W. R. Singh, et al., (2021) carried out a detailed morphometric analysis of the Dudhna River Basin located in Assam, India, using Digital Elevation Models (DEM) and ArcGIS tools. The main objective of the study was to understand the drainage characteristics and geomorphological behaviour of the basin, which is important for watershed management and flood risk assessment. Using GIS-based techniques, the authors extracted and analysed linear, areal, and relief aspects of the drainage basin, including parameters like stream order, drainage density, bifurcation ratio, elongation ratio, and basin relief. The study revealed that the basin exhibits a dendritic drainage pattern, suggesting homogeneous lithology and structural stability. The morphometric values indicated moderate relief and slope, which can influence runoff and erosion processes. This research is significant as it demonstrates how geospatial tools can be effectively applied for basin characterization, especially in flood-prone regions like northeast India.

Mohamed ElKashouty (2020) conducted a detailed hydrogeological and morphometric analysis of the Qena-Safaga-Bir Queh area in Egypt to enhance the understanding and management of drainage basins in arid environments. The study aimed to evaluate groundwater potential and drainage characteristics by integrating geological, hydrogeological, and morphometric data using remote sensing and GIS techniques. Various morphometric parameters such as drainage density, stream frequency, bifurcation ratio, and elongation ratio were analyzed to assess surface runoff behavior and watershed response. The findings showed that certain sub-basins in the region have favorable conditions for groundwater recharge and development. This study is significant as it links surface morphology with subsurface hydrogeology, which is essential for water resource planning in dry regions. It also demonstrates how the combination of remote sensing, GIS, and hydrogeological data can be effectively used for basin management and water conservation strategies.

Thangaperumal et al., (2020) carried out a study on watershed basin determination in the Karaikal area using remote sensing data from Bhuvan (ISRO's geo-platform) and USGS sources. The main objective of the study was to accurately delineate watershed boundaries and analyze drainage patterns in the region using GIS techniques. The authors used satellite imagery and DEM data to identify streams, flow directions, and watershed extents. Their methodology included the use of tools like ArcGIS to process and analyze spatial data for hydrological modeling. The results showed

that combining Bhuvan and USGS data provided reliable outcomes for watershed delineation and supported better understanding of the area's terrain and water flow. This study is especially relevant for regions like Karaikal that are prone to both drought and flooding, as it helps in planning proper water resource management and flood control measures. It also highlights the importance of using freely available geospatial data for environmental and hydrological studies in developing regions.

Sowmya D R, et al., (2020) performed watershed delineation of the Bangalore South region using Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data combined with GIS techniques. Their study focused on accurately identifying watershed boundaries and drainage networks to support water resource management in this rapidly urbanizing area. By processing the SRTM DEM in GIS software, they extracted morphometric parameters such as stream order, drainage density, and bifurcation ratio to understand the drainage behavior of the region. The results revealed that the watershed has a dendritic drainage pattern, indicating uniform geological formations. The authors emphasized the usefulness of freely available SRTM data in generating reliable hydrological models, especially in areas with limited ground data. This research is significant for urban planning and flood control, highlighting the importance of remote sensing and GIS in watershed management.

III. SUMMARY OF THE REVIEW

In order to effectively manage natural water resources and comprehend hydrological processes, watershed delineation and stream pattern analysis using Geographic Information Systems (GIS) and Digital Elevation Models (DEM) have become essential tools. In comparison to conventional manual methods, the review emphasizes how GIS-based approaches streamline the difficult task of accurately and efficiently identifying drainage networks, stream patterns, and watershed boundaries. As the foundation for hydrological modeling, DEM data offers crucial elevation information that aids in stream network extraction, flow direction determination, and flow accumulation. Even in areas with little ground data, combining GIS and DEM enhances the accuracy of watershed delineation, as shown by a number of studies examined here. Researchers have examined the effects of aspect, slope, and terrain features on the drainage system using DEMs with varying resolutions. The review also highlights that stream patterns are better represented, and delineation results are more accurate with high-resolution DEMs. Additionally, the use of GIS makes it possible to overlay various datasets, including rainfall, soil type, and land use, which improves our comprehension of watershed dynamics and their effects on the environment. The review goes on to explain how stream pattern analysis aids in the classification of drainage types, such as dendritic, parallel, radial, and trellis patterns, which provide insight into the geological and geomorphological conditions of a region. Planning for flood prevention, water conservation, and sustainable watershed management techniques can benefit from these insights. Thus, the combination of GIS and DEM offers a hydrological analysis method that is effective, economical, and time efficient. The review concludes that stream pattern analysis and watershed delineation based on GIS and DEM are effective methods that improve decision-making in environmental management and water resource planning. They greatly aid in the comprehension of topographic variances, enhance the precision of hydrological modeling, and facilitate further studies in sustainable watershed development.

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