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# REVIEW ON HYDROLOGICAL APPLICATIONS OF GIS

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**Abstract**

***Geomorphometry is the science of quantitative land surface analysis. It gathers various mathematical, statistical and image processing techniques that can be used to quantify morphological, hydrological, ecological and other aspects of a land surface. Geomorphometry aims at extracting land surface parameters and objects using input digital land surface model and parameterization software. Extracted surface parameters and objects can then be used, for example, to improve mapping and modelling of soils, vegetation, land use, geomorphologic and geological features and similar. This paper discusses some of the applications of GIS in areas like geomorphologic studies, land use evaluation, watershed management and so on.***
***Keywords- DEM, GIS, geomorphology, landuse, watershed.***

## I. INTRODUCTION

For a scientific and rational approach to different river problems and proper planning and design of water resources projects, an understanding of the morphology and behaviour of the river is a pre-requisite. Geomorphometry is the science of quantitative land surface analysis. It gathers various mathematical, statistical and image processing techniques that can be used to quantify morphological, hydrological, ecological and other aspects of a land surface. In simple terms, geomorphometry aims at extracting land surface parameters (morphometric, hydrological, climatic etc.) and objects (watersheds, stream networks, landforms etc.) using input digital land surface model (DEM) and parameterization software. Using GIS, spatially varying parameters or characteristics can easily be computed, stored, retrieved and analysed and much derivative information can be generated. The GIS tool (both software and hardware) has made the data handling and analysis much easier with meaningful research outcomes. It has the advantage of handling attribute data in conjunction with spatial features, which was totally impossible with manual cartographic analysis. Geographic Information Systems are now-a-days indispensable in applications related to spatial analysis. GIS facilitates repetitive model application with considerable ease and accuracy. The cartographic and data overlaying capability of GIS coupled with its dynamic linking ability with models plays a vital role in water management decision making process. The model output can be displayed effectively and the information stored in a particular region will be handy for use. Thus geographic information system (GIS) is described in a nutshell as follows:

G-Geographical reference ⟶ Data of spatial coordinates on surface of earth-location data
+
IS-Information System ⟶ Database of attribute data corresponding to spatial location and procedures to provide information for decision making

## II. GIS IN GEOMORPHOLOGICAL ANALYSIS

Turoglu *et al.* conducted a study with the aim to analyse geomorphological units of Bartın territory (NW Turkey) by using Remote Sensing and Geographical Information System Technologies [1]. For this purpose, LANDSAT 5, Thematic Mapper (TM) scenes of the study area used to collect data based on spectral reflectance properties of land , 1/25000 scale topographic maps digitalized ,for Geographical Information Systems database for morphometric analysis and also ERDAS 8.5, ARCVIEW 8x software's were used. The basic geomorphological units such as mountainous areas, plateau, lowlands and metric properties of these units, etc. was not only dissected but also calculated and mapped in RS and GIS Technologies. The results of applying RS and GIS for Bartın were tested in field season. For instance, geomorphological data produced with unsupervised classifications based on spectral reflectance features and signatures checked and clearly named and collected new spatial data by using Global Positioning System (GPS) on field. Finally, Geomorphological features of Bartın and its territory explained as units and types, quantitative results and digital mapping.

Sarkar *et al.* initiated this study to determine the capacity of ungauged catchment to produce runoff through geomorphological study as prior investigation to install hydropower. An ungauged catchment of Solani River, a tributary of the Ganges from northern India hilly terrain, has been chosen for investigation. Further, the catchment has been divided in five sub catchments (sub catchments 1 to 5) to study the catchment capacity to produce runoff more precisely. Geographical Information System (GIS) has been used as a tool for geomorphological parameter estimation. The study reveals that the sub catchment 1 is of medium size among all five sub catchments but having maximum drainage density (1.11 $km/km^2$) and maximum available relief ratio (0.023), which demonstrates better capacity to produce runoff among all. Hence sub catchment 1 can be considered as a site of interest for hydropower installation on Solani River as prior survey basis. Further, the relief value and slope value within the sub catchment 1 measured on main stream which used to explore the hydropower site [2].

Sreenivasulu *et al*. made an attempt is made to evaluate the physical characteristics of the Devak catchment up to Gura Slathian in Jammu region of Jammu & Kashmir (J&K), India using remote sensing and GIS techniques. The results of the study are useful for further hydrological investigations and are the major inputs to various hydrological models [3].

Doad *et al*. conducted a study in Bordi river basin, Maharashtra. The river basin is mainly drained by dendritic drainage which indicates the homogeneity in texture and lack of structural control. The bifurcation ratio (Rb) value is 3.787 indicates that the geological structures are less disturbing the drainage pattern. The basin had medium drainage density (D) 2.627 km/sq. km indicating the moderately permeable subsoil and moderate vegetative cover. The stream frequency (Fs), 3.44 exhibit positive correlation with the drainage density value of the area indicating the increase in stream population with respect to increase in drainage density. The texture ratio (T) of the basin is moderate 3.430 while elongation ratio (Re) is 0.55 indicates that the low relief of the terrain and elongated shape. The circularity ratio (Rc) 0.463 of the basin also indicates that the basin is elongated in shape, have low discharge of runoff and highly permeability of the subsoil condition. The low form factor (Rf) value of the basin, 0.37 represents a flatter peak of flow for longer duration. Flood flows of such elongated basins are easier to manage than of the circular basin. Hence from the study it is clear that morphometric analysis based on GIS technique is a competent tool hydrological studies [4].

Ramaiah *et al.* carried out a morphometric analysis of Sub-basins in and aroundMalur Taluk, Kolar District, Karnataka [5]. The drainage network of Kanamanahalli and Devaraguttahalli sub-basins were delineated using false colour composite (FCC) of IRS-1C/1D merged satellite data on 1:50,000 scale. SOI toposheets were used as reference with limited field work. The study area falls in Ponnaiyar river basin covering an area of 686 sq. km comprising two sub-basins namely Kanamanahalli and Devaraguttahalli having an area of 439 sq.km and 247 sq.km respectively in and around Malur taluk of Kolar district. The morphometric analysis of these two sub-basins shows that the terrain exhibits dendritic to sub-dendritic drainage pattern. Stream order ranges from first to sixth order. Drainage density varies between 1.57 and 1.88 $km/km^2$ and has coarse to fine drainage texture. The relief ratio ranges from 0.0111 to 0.0117. The mean bifurcation ratio varies from 3.51 to 4.86 which fall under normal basin category. The elongation ratio shows that these sub-basins are associated with high relief and steep ground slopes.

 

Raj *et al.* carried out a study in one of the less studied Bharathapuzha river basin (BRB), the second longest river in the state of Kerala, India. The annual discharge of the river is 3.94 $km^3$. Nevertheless the basin, which receives about 1828 mm of annual rainfall, in recent years has been facing dearth of water. They used GIS and RS tools to study the morphometric characteristics of the basin. The seventh order main river is formed by several lower order streams forming a dendritic flow pattern. Basin geology, slope and rainfall pattern in the basin determine the morphometric characteristics of the basin. The linear aspects of the basin including stream length ratio and bifurcation ratio indicate the role of relief in the basin while the areal ratios indicate the elongate nature of the basin [6].

Paul *et al*.carried out this study in Hebbal valley, located in Bangalore district of Karnataka state. In this study, morphometric analysis and prioritization of nine sub-watersheds of this valley was done using Remote Sensing and GIS techniques. The morphometric parameters considered for analysis are stream order, stream length, bifurcation ratio, drainage density, stream frequency, texture ratio, form factor, circulatory ratio, elongation ratio, relief ratio, length of overland flow and basin shape. The watershed has a dendritic drainage pattern. The bifurcation ratio varies from 1.89 to 3.03 and all sub-watersheds fall under normal basin category. The circularity ratio ranges from 0.42 to 0.78 indicating that all the sub-watersheds except SWD9 are more or less circular. Elongation ration of all the water sheds except SWD3 and SWD9 is above 0.7 indicating that all the sub-watersheds except SWD3 and SWD9 are more or less circular. The compound parameter values are calculated and prioritization rating of nine sub-watersheds in Hebbal valley was carried out. The sub-watershed with lowest compound parameter value is given the highest priority. The sub-watershed SWD3 is likely to be subjected to maximum soil erosion hence it should be provided with immediate soil conservation measures [7]**.**

Magesh *et al*. developed an automatic extraction tool through the model builder technique in ArcGIS environment to delineate the basin morphometry. The basic requirements to run this tool are a SRTM data, and a pour point shape file. The developed model will create necessary data required for morphometric analysis after the processing of the input data. The output from this model will create a number of parameters such as, stream network , aspect, slope, DEM, drainage density, hill shade, and basin boundary in meter square. Before proceeding with the model, there is an option to the user to select the minimum upstream area to which a stream should be counted. This option helps the users to select the range of stream delineation. The slope generated will be in degrees and the drainage density in Sq.km. This technique is very useful for those who work in the field of terrain analysis, hydrology, and watershed analysis as it is easy to use with a single click for the generation of a reliable database for morphometric analysis [8].

John *et al.* conducted a study in the region around Wadakkancheri which has been a site of micro seismic activity since 1989 [9]. Studies, subsequent to 1994 M= 4.3 earthquake, had identified a prominent NW–SE structure overprinting the E–W trending lineaments associated with Palghat–Cauvery shear zone. The right angled turn of Bharathapuzha River at Desamangalam and a waterfall near this structure shows the influence of the structure to the drainage system which is identified as a south dipping reverse fault. The hanging wall side of the fault is characterized by abandoned river courses due to the river shift. The network of paleochannels was identified through SRTM data. Distance elevation profiles were also drawn from SRTM data to observe the influence of fault on the drainage system of the area. Near the coast both paleochannels and the river is flowing approximately at the same elevation. The data generated in the present study indicates, that a marked correlation between channel morphology and the proximity of the fault in the Bharathapuzha river basin.

Magesh *et al.* carried out a morphometric analysis of Bharathapuzha river basin using geoprocessing techniques in GIS [10]. This technique is found relevant for the extraction of river basin and its drainage networks. The extracted drainage network was classified according to Strahler's system of classification and it reveals that the terrain exhibits dendritic to sub-dendritic drainage pattern. The Bharathapuzha drainage basin is sprawled over an area of 5,988.56 $km^2$. The study area was designated as seventh- order basin and lower order streams mostly dominate the basin with the drainage density value of 1.07 km/ $km^2$. The slope of basin varied from $0^{\circ}$ to $70^{\circ}$and the slope variation is chiefly controlled by the local geology and erosion cycles. The elongation ratio of the basin is 0.57 indicating that the study area is elongated with moderate relief and steep slopes. The drainage texture of the basin is 7.78 which indicate an intermediate texture that exists over the region. Hence, from the study, it can be concluded that remote sensing data (SRTM–DEM) coupled with geoprocessing techniques prove to be a competent tool in morphometric analysis and the data can be used for basin management and other hydrological studies in future.

## III. GIS IN LAND USE EVALUATION

Lin *et al.* conducted study on evaluation of land use in a selected area in south of Guilin by using GIS .The system includes four functions :input, storage , analysis and output .While the map of land use is overlaid on the map of slope classification, the analysis of land potentialities can be made [11].

Dermet *et al.* conducted a GIS procedure for automatically calculating the USLE LS factor on topography complex landscapes units. A computer algorithm to calculate the USLE and RUSLE LS factor over a two dimensional landscape is presented. The computer procedure has the obvious advantage that it can easily be linked to GIS software. If data on landuse and soils were available, specific K, C and P values can be assigned to each land unit so that predicted spill losses can then be calculated using a simple overlay procedure [12].

Richard *et al.* made few studies on comparison of GIS verses manual techniques for land cover analysis in a Riparian restoration research projects were used to compare the cost involve in calculating land cover areas with a GIS and manually with a planimeter and dot grid. While estimates of land cover areas were similar for two methods, GIS cost were much higher than manual technical cost [13].

Wu *et al.* studied about evaluating soil properties of CRP land. Remote sensing and GIS Techniques are used to evaluate the present CRP in terms of its main goal and to give recommendations for the future of the program in Finney country, Kansas. With GIs technology, calculation of erosion index was more efficient and value was more accurate that calculated by hand [14].

Van *et al*. calculated the total water requirement for a common area with different crops and soils. The table map calculation features of ILWIS for Windows are used to combine different map layers and table attributes [15].

Van *et al*. conducted a study on methods of combining multiple maps for empirical modelling in a GIS [16]. Several approaches to annualize multiple maps (Boolean logic models. Binary evidence maps, Index overlay with multi class maps and Fussy logic method) are introduced by means of basic exercises.

Hoobler *et al*. conducted a study using the GIS combined with land evaluation and site assessment (LESA) which enhances land use planning by delivering a versatile and dynamic model to assist state policy and decision makers, country and local officials, landowners and interested citizens in making wasteland management decisions [17]. Objective of this study is to integrate LESA methods and GIS to assess their use for land use planning in East Park Country, Wyoming. Study results were fairly consistent with a park country land use plan, suggesting the combination of LESA and GIS is a rapid, versatile and up to date approach to assist in land management decisions.

Bathgate *et al*. studied about GIS based landscape classification model to enhance soil survey. The objective of the research was to develop a quantitative tool to model landscape elements using GIS and digital elevation model for application in soil survey [18]. The model was tested at a case study site in a quarter section of Massac Country, Illinois. Potential productive capabilities of the model are great and should be extended to heterogeneous landscape through further testing model for communities that contend with landslide risk.

 

## IV. GIS IN WATERSHED MANAGEMENT

Hamlet *et al*. studied about the state-wide GIS based ranking of watersheds of agricultural pollution prevention. GIS combined with a pollutant generation and transport model can be used to identify and rank critical pollutant source areas on a region basis. This model was used to rank the agricultural pollution potential of 104 watersheds in Pennsylvania. The ranking allowed identification of critical non-point source pollutant contributing watersheds in Pennsylvania and is useful for targeting further investigations and control Programs [19].

Kwong *et al*. conducted a study on erosion assessment of large watershed in Taiwan [20]. The objective of this study was to integrate the agricultural Non-point source pollution model and technology of GIS to quantify erosion problems at Bajun river basin and Tswengwen reservoir watershed in Taiwan. They found that the annual sedimentation depth for the Tswengwen reservoir is approximately 5.9 mm, which is not significantly different from the observed rate.

Sidhu *et al.* prioritized the upper Machukund watershed covering an area of 16111 ha by Remote Sensing and GIS Techniques. Based on secondary and tertiary drainage pattern, watershed areas were subdivided into 8 sub watersheds. By using GIS, land use, land cover and slope maps were combined to generate erosion intensity and composite maps. Watershed was prioritized by following sediment delivery index approach [21].

Roo *et al.* conducted a study on modelling runoff and sediment transport in catchments using GIS. Existing erosion models can be loosely coupled to a GIS, such as the ANSWERS model. More models can be fully integrated by embedded coupling, such as the LISEM model [22].

Tripathi *et al.* conducted a study using a calibrated Soil and Water Assessment Tool (SWAT). The model was verified for a small watershed (Nagvan) and used for identification and prioritization of critical sub-watersheds to develop an effective management plan. The study revealed that the SWAT model could successfully be used for identifying and prioritizing critical sub-watershed for management purposes [23].

Fernandez *et al.* studied about estimating water erosion and sediment yield with GIS and RUSLE [24]. The method was applied to a typical agricultural watershed in the state of Idaho, which is subjected to increasing soil erosion and flooding problems. The spatial pattern of annual soil erosion and sediment yield was obtained by integrating RUSLE and raster GIS. Required GIS data layers included precipitation, soil characteristics, elevation and landuse. Thus it provides a useful and efficient tool for predicting long term erosion impacts of various cropping systems and conservation support practices.

## V. GIS IN GENERAL PURPOSE

Noveline *et al.* conducted a study on wasteland development using GIS techniques. Soil $p^H$ ,soil texture, soil drainage and permeability conditions, rainfall, altitude , slope, water availability, water quality forms the layers which were analysed for land suitability. Favourable sites for conducting percolation ponds have been selected by adopting GIS techniques to augment the ground water potential. The same methodology can be extended to develop the cultivable wastelands elsewhere [25].

Joseph *et al.* conducted a study on the highway route production line using a GIS-based approach for economic road construction and maintenance costs. The generalized, probabilistic analysis methods are based on GIS concepts and applied to a test area in Nigeria. GIS concepts allow the creation of predictive cost models that can support road way planning. This numerical model defines road way cost factors by accessing database from Remote Sensing Image Interpretation [26].

Srivastava *et al*. conducted a study on RS and GIS for natural resource study. The effectiveness of this technique increases manifolds when it is integrated with other kinds of data sets. GIS permits integration of different sets specially referenced data of interrelated parameters or periodic data sets about a resource type for its better utilization and management [27].

Cheryl *et al.* conducted a study about GIS as a tool for sitting farm ponds. GIS was developed for identifying potential sites for a farm pond to serve as a permanent livestock [28].Watering system amenable to rotational grazing and independent of ephemeral streams. Using water balance calculations for 10 years of simulated climate data, the potential amount of water harvested at each site was determined using water harvesting potential. Location and negative impacts of a pond at a specific site as criteria, nine sites were ranked as most desirable.

Pascal *et al.* made a GIS based distributed hydrology model for prediction of forest harvest effects on peak stream flow in the Pacific Northwest. The model, known as Distributed Hydrology Soil Vegetation Model provides a dynamic representation of the spatial distribution of soil moisture, snow cover, and evapotranspiration and runoff prediction, at the scale of digital topographic data [29].

Zaitchik *et al.* studied about applying a GIS slope stability model to site specific and landslide prevention in Honduras. This model was applied to an agricultural region of Honduras that suffered extensive landslide damage during Hurricane milth. Zones of predicted instability were subsequently categorized according to local slope gradient and relative wetness (w) based on steady hydrology for Hurricane conditions [30]. Knowledge about, w in potentially unstable zones allows for informed stability, management practices, improving the utility of hazard.

## VI. CONCLUSION

Geographic Information Systems are now-a-days indispensable in applications related to spatial analysis. With GIS, one can generate information on the spatial and temporal patterns and processes on the earth surface. Potentiality of GIS is realized in the recent past and now it has popular among many users for variety of uses. Recently commercial organizations in India have realized the importance of GIS for many applications like natural resource management, infrastructure development, facility management, business / market application etc. and many GIS based projects according to the user organization requirements.

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