Hydro -Morphological Study of Subansiri Watershed of Brahmaputra River

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***Abstract*— For water resource development of any watershed, basic watershed properties such as area, slope, stream network, flow length are required. Traditionally this was being done manually by using topographic/contour maps. Topographic information is often out dated and costly to obtain using traditional survey. In this paper watershed of Subansiri River and its drainage paths have been delineated using Spatial Analyst Hydrology tools in ArcGIS software. Advanced Space-born Thermal Radiometer (ASTER) data, available at a resolution of about 30 m, has been used to generate digital elevation model (DEM) of the study area. Delineated Subansiri River watershed at the gauging station Gerukamukh is sub Basin of Brahmaputra River. Drainage network, so obtained, has been utilized to calculate various hydro-morphological parameters of the watershed. The delineated watershed and associated data can be used to better utilization of water resource, precipitation-runoff modeling and watershed management.**

***Keywords—* ASTER, DEM, Watershed.**

I. INTRODUCTION

Hydromorphology is that subfield of hydrology that deals with the structure and evolution of Earth's water resources. It deals with the origins and dynamic morphology of those water resources. Hydromorphology addresses the dynamic morphology of water resource systems caused by both natural and anthropogenic influences [17]. It describes the geomorphology and hydrology of a river system, their interactions, their arrangement and variability in space and time [16]. Morphometric studies in the field of hydrology were first intended by hortan [4] Many projects in geomorphology, hydrology, and related disciplines require delineation of the stream channel and divided networks [1]. Geomorphology is the science of evolution of landforms in terms of its lithology, structures, basin geometry and other morphometric factors.

Drainage network and its geometry is important feature within hydromorphology. Drainage lines are the lines along which fluvial processes act to transport water, sediment, and mineral material out of a local region, allowing gravity processes on slopes to continue to lower landscapes. [9]. Drainage networks an essential component in hydrologic models and resource management plans. Drainage network studies are based on digital elevation model (DEM). DEM may be defined as any numeric or digital representation of the elevations of all or part of a planetary surface, given as a function of geographic location [9].

Watershed properties can be extracted by using automated procedures from the DEM and GIS tools. Correct delineation of a watershed boundary also plays a great important role in the management of the watershed because most of hydrological calculations use watershed area and its characteristics as primary parameters. Watersheds and Drainage paths are closely related to slope, aspect. It is also generated from DEM using GIS spatial analyst tools.

II. REVIEW AND LITERATURE

O'Callaghan and Mark [9] used a method for extracting drainage networks from gridded elevation data. The method handles artificial pits introduced by data collection systems and extracts only the major drainage paths. Its performance appears to be consistent with the visual interpretation of drainage patterns from elevation contours.

Band [1] used digital elevation models to automatically map the stream channel and divide networks of a watershed. These topographic skeletons are used to partition the watershed to a set of fundamental, runoff producing sub regions each of which drains into one stream link.

Goovaerts [3] presented three multivariate geostatistical algorithms for incorporating a digital elevation model into the spatial prediction of rainfall: simple kriging with varying local means; kriging with an external drift; and colocated cokriging. The techniques are illustrated using annual and monthly rainfall observations measured at 36 climatic stations in a 5000 km2 region of Portugal. He used cross validation to compare the prediction performances of the three geostatistical interpolation algorithms with the straight forward linear regression of rainfall against elevation and three univariate techniques: the Thiessen polygon; inverse square distance; and ordinary kriging. He conclude Larger prediction errors are obtained for the two algorithms (inverse square distance, Thiessen polygon) that ignore both the elevation and rainfall records at surrounding stations. ordinary kriging yields more accurate predictions than linear regression when the correlation between rainfall and elevation is moderate (less than 0.75 in the case study)

Savant et al. [11] discussed about the advantages of applying remote sensing technologies and GIS application for the delineation of a gauged watershed. Specifically, they evaluated the watershed of a section of the Upper Pearl River in Mississippi using DEM data. They found that the delineated area from the use of software compares well with the areas determined by USGS. The delineated watershed and associated data can then be exported to other modeling software for watershed management.

Vogel et al. [18] introduce a generalized multivariate approach for exploring hydro morphological problems that involves estimation of the multivariate sensitivity or elasticity of stream flow to changes in climate, water use and land use. The method does not require a model assumption, yet it provides confidence intervals and hypothesis tests for resulting elasticity. This case study highlights the influence of urbanization on the complete range of stream flow and shows that accounting for the simultaneous interactions among land use, climate and water use is a necessary component for understanding the influence of urbanization on stream flow regimes.

Elmahdy [2] used Advanced Space-born Thermal Radiometer (ASTER), the Shuttle Radar Topography Mission (SRTM ~90 m) DEMs and Quick- bird images to corroborate the presence of surface and near surface paleodrainage network in the north-western part of Sudan. He found that the new unnamed depression which recharges by a longitudinal paleodrainage network may receive vast amount of groundwater during humid phases. The results also demonstrate that the D8 and curvature algorithms are very efficient tools for revealing and characterizing hydrological elements in arid and semi-arid regions

Lewandowski, P., [6] developed research methods for the hydrological valuation of watercourses The Water Framework Directive (WFD) introduced the obligation to monitor hydromorphological elements of rivers, including hydrological regime, river continuity, and riverbed morphology. It was estimated that by the year 2015 all uniform water bodies in the EU will be ensured at least very good (class I) or good (class H) ecological status plus good ecological potential.

Toroimaca et al. [15] developed a hydromorphological typology, oriented toward the stability of river channels. Based on recent topographic profiles and on the maps drawn in the late 1970s, several parameters of the bankfull stage are computed: the ratio between the maximum depth and the height of the lower bank, the ratio between the channel width and its mean depth, the river competence, and the specific stream power. This methodology is applied for 34 cross profile in perimeter

Singhal & Goyal [12] developed a GIS based methodology based on spatial distribution of parameters for understanding affect of rainfall and vegetation density on groundwater recharge. Singhal et al. [14] used geospatial tools for the study area around Bandi River, Pali to estimate the annual recharge and draft over a four year period. They concluded that recharge would be different for different land use covers and therefore, further research could be carried out to correlate recharge to land use cover as well. Singhal & Goyal [13] carried out groundwater modeling of Pali district of Rajasthan to understand impact on groundwater regime due to increase or decrease in rainfall due to climate change.

Meier et al. [8] describe the German field survey method for hydromorphological assessment of streams and points at its potential as a tool for river basin management. They give examples for the application of the method at different management scales: analyzing the overall hydromorphological state at the river basin scale, describing specific hydromorphological characteristics at the river reach scale and monitoring the success of restoration projects at the river segment scale. They found that that the German field survey method an easy-to-apply and efficient tool for river basin management since its introduction in the year 2000. And also several drawbacks have to be considered regarding its application in other regions of the world.

Wiejaczka et al. [19] evaluate in there study the hydromorphological state (the degree of naturalness and anthropogenic transformation) of Himalayan Rivers in the study and to determine the role of human activity in shaping their hydromorphology. The study was conducted in the valley of the Tista River in Darjeeling Himalaya. The assessment of the hydromorphological state was conducted on the basis of the river habitat survey method. The analysis of research results shows that the habitat quality of the river sections with noticeable human interference is not significantly different from that in the sections without noticeable anthropogenic pressure.

III. METHODOLOGY

A. Study Area

The Brahmaputra River is one of the largest systems, with a length of about 2900 km and a total drainage area of 580,000 km2, of which 194,000 km2 is in India. The system is crucial for the socio-economic status as well as the hydrology of the region. The flow dynamics of the Brahmaputra River can have a significant impact on the hydropower, irrigation and transportation sectors in the region.

Subansiri River has three gauging sites where discharge and sedimentation data is measured. These sites are located at the lower Subansiri (Gerukamukh), the middle Subansiri (Tamen Bridge) and the upper Subansiri (Menga) as shown in Fig. 1. Watershed study Area is selected at the gauge point lower Subansiri (Gerukamukh). It lies between latitude 27°25'56"N to 28°55'25"N and longitude 91°33'25"E to 94°48'45"E. Also various districts of Arunachal Pradesh and International Boundary are shown in Fig. 1.

Subansiri River has its origin in the Central Himalayas in Tibet. It is a left tributary of the Brahmaputra. The river enters India in its North-East corner in Arunachal Pradesh. The contribution of the Subansiri River is estimated to be about 10.66 % of the total discharge of Brahmaputra River at Pandu near Guwahati. The total catchment area of the Subansiri basin up to the Chouldughat gauging site is 26419 sq. km, out of which 16182 sq.km (61.25% of total) lies in India and 10237 sq.km (38.75% of total) lies in Tibet [9].

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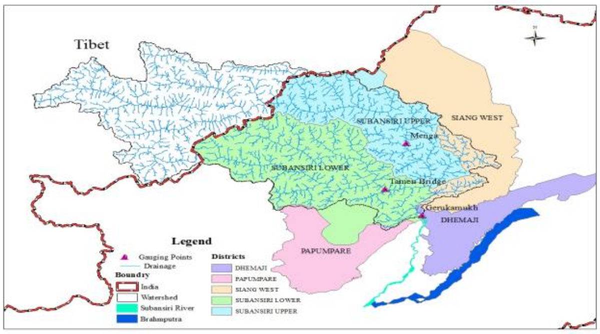


Fig.1: Study area watershed boundary

B. Data Used

Digital Elevation Data can be acquired from different sources such as Satellite data toposheet, Google earth image and GPS Survey with different spatial resolutions. In present study high-resolution digital elevation data of advanced space borne thermal emission and reflection radiometer (ASTER) has been used to generate DEM. The ASTER DEM data has been downloaded from the Ministry of Economy, Trade and Industry of Japan (METI) and the National Aeronautics and Space Administration (NASA) project, [5] with spatial resolution of 30 meter in 1o x 1o size tile. Table 1 gives the details of different tiles downloaded.

Table 1: Details of ASTER tiles downloaded

S. No.	Tile Name	Longitude	Latitude
1	ASTGTM2_N27E09	91° to 92°	27° to 28°
2	ASTGTM2_N28E091	91° to 92°	28° to 29°
3	ASTGTM2_N27E092	92° to 93°	27° to 28°
4	ASTGTM2_N28E092	92° to 93°	28° to 29°
5	ASTGTM2_N27E093	93° to 94°	27° to 28°
6	ASTGTM2_N28E093	93° to 94°	28° to 29°
7	ASTGTM2_N27E094	94° to 95°	27° to 28°
8	ASTGTM2_N28E094	94° to 95°	28° to 29°

C. GIS Processing

Fig.2 shows the flowchart of methodology used to delineate the drainage network and demarcate the watershed for pour points. Pour points are points on drainage network on which we want to demarcate the watershed. They are points typically at the outlet or at a point where flow discharge and/or sediment flux is measured. After accruing the ASTER DEM individual tiles, they were all mosaiced as a single image. The DEM's projection system is simultaneously transformed from Geographic Coordinate System-WGS 84 into Universe Transverse Mercator (UTM) Zone 46 projection. Algorithm of delineating drainage network is dependent on determining movement of water from each individual cell to one of the networking cell, for which down gradient is steepest. It is therefore very important to fill the depressions in the DEM, else the drainage network would be broken and not continuous. Using spatial hydrology tools of Arc GIS an artificially modified DEM with filled sinks is obtained as shown in Fig. 3. From filled DEM, flow direction is determined as shown in Fig. 4. Flow direction raster indicates the direction of one of the adjacent eight cell in which water would flow from that cell. Next flow accumulation is determined for each cell and the flow accumulation raster is shown in Fig. 5. Flow accumulation is number of all higher elevation cells, which are draining into the current cell. So a flow accumulation raster value of 1350 in a particular cell "A" means that there are 1350 higher elevation cells than "A", the water of which is passing through the cell "A". Now if this cell is draining to south-west cell (Say "B" Cell), that would mean that "B" cell is receiving water from minimum 1351 cells (1350 + 1 for "A" cell) through the "A" cell. "B" cell may also be receiving water from its other adjacent cells and so its value may be much higher than 1351. Next drainage network could be delineating with the help of flow accumulation and flow direction raster. Drainage network is shown in Fig. 6. Finally watershed boundary is demarcated for Gerukamukh gauge point by taking nearest point on drainage network as a pour point.

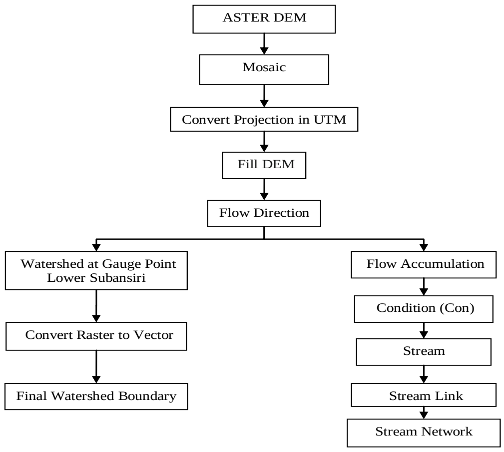
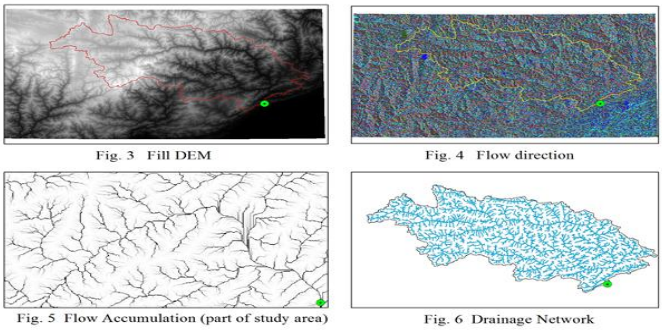


Fig. 2: Flow Chart of Watershed and drainage network delineation



IV. RESULTS

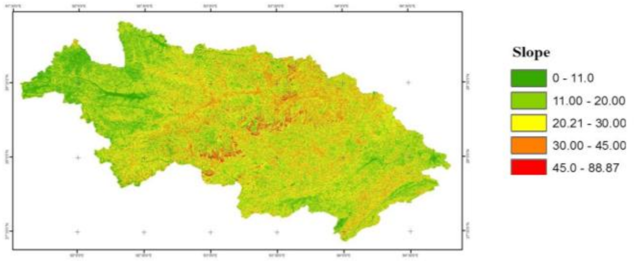
Aim of the present study is to understand advantages of remote sensing technologies and GIS application with current software for the delineation of a watershed and drainage network. Demarcation of drainage network using GIS tools has been found to be very helpful for rapid collection of study area data.

Parameter	Measurement
Area	26171.0 km2
Perimeter	1263 km
Longest Flow Path	432 km
Min. Elevation	44 m
Max. Elevation	7174m
Longitudinal difference	325 km
Latitudinal difference	130km
Min. Slope	0°
Max. Slope	88°

Table 2: Watershed parameters of Subansiri basin

Watershed boundary of Subansiri River is delineated at the gauge point using ASTER elevation data. Watershed area could now be used to limit further data collection in the study area and for study of important hydromorphological parameters.

Total calculated watershed area is 26171 Km^2 and elevation range varies from minimum of 44 to maximum of 7174 meter above mean sea level. Slope lie in between 0^o to 88^o as shown in Fig. 7. Highly sloping terrain accelerate the runoff process and the slope map could be used to demarcate different zones with different slopes.



As can be seen from the Fig. 7, elevation range has great variation in Subansiri basin and the study area has huge water potential which remains mostly untapped. This sub-basin has high hydropower possibility and therefore a number of hydropower and irrigation projects are under implementation/active consideration. It would be useful to determine hydromorphic information of the basin to develop a hydrological model capable of describing the basin's hydrological behavior and determining policies for optimum utilization of water resources of that basin.

V. CONCLUSIONS

Present paper presents an example that explores the advantages of applying remote sensing technologies and GIS application for the delineation of a drainage network and demarcation of watershed boundary and some of the hydromorphological parameters. Output of hydromorphology study has several advantages for the use to policy makers, hydropower companies and watershed planners. In the present paper, methodology of delineating drainage network has been discussed and then various characteristic parameters of watershed are determined. Subansiri basin is an important sub-basin of Brahmputra river where huge untapped water resource potential could be used to develop hydro-power and irrigation projects in that area.

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