Remote Sensing Applications: Society and Environment 7 (2017) 9–20

Contents lists available at ScienceDirect

Remote Sensing Applications: Society and Environment

journal homepage: www.elsevier.com/locate/rsase

A study of morphometric evaluation of the Son basin, India using geospatial approach

Praveen Kumar Rai[a,*], Varun Narayan Mishra[b], Kshitij Mohan[a]

[a] Department of Geography, Banaras Hindu University, Varanasi 221005, UP, India
[b] Department of Physics, Indian Institute of Technology (BHU), Varanasi 221005, UP, India

ARTICLE INFO

Keywords:
Morphometric evaluation
Son basin
ASTER data
Drainage density
GIS

ABSTRACT

This study deals that morphometric evaluation is feasible method of characterization of hydrological response behavior of the any river basin. In this study, Son basin a tributary of the Ganga river has been selected for the detailed morphometric evaluation. The Son basin is approximate 68,863 km^2 and shows sub-dendritic to dendritic drainage pattern. The measurement and analysis for Son basin and its five major sub-watershed are carried on GIS platform to describe the topography and drainage characteristics. The input parameters required to run this model are: a pour point, a minimum upstream area in sq km and a digital elevation model. Streams were automatically extracted from ASTER DEM data. The stream order of the basin is predominantly controlled by physiographic and structural conditions. The study area is designated as sixth-order basin and lower order streams mostly dominate the basin with the drainage density value of 0.26 km/km^2. The slope of basin varied from 0° to 70.4° and the slope variation is mainly controlled by the local geology and erosion cycles. The bifurcation ratio (*Rb)* for the Son basin varies from 2.41 to 7. The higher values of Rb in basin indicate a strong structural and geological control on the drainage pattern. The elongation ratio of the basin is 0.553 indicating that the study area is extended with moderate to steep slopes. The increase in stream length ratio from lower to higher order shows that the basin is part of a mature geomorphic stage.

1. Introduction

1.1. Background

The systematic study of the drainage encompasses within its bounds numerous aspects of its distributional and erosional character such as drainage patterns, drainage density i.e., the measure of the texture of dissection, drainage frequency, profile characteristics of the main and sub-streams, etc., guided by the controlling elements, such as, the degree of flatness of the area, the rock altitudes, structure and finally the climatic and biotic factors. Drainage lines of an area explain the existing three dimensional geometry of the region and help to describe its morphometric evolution process (Singh, 1980). In geomorphology, morphometry is dedicated to the quantification of morphology (Clarke, 1966). Shape indices used in drainage basin morphometry relate to the quantification of basin shape and provide a means for describing the hydrological characteristics of a river basin and it is an important aspect of characteristic of watershed (Strahler, 1964).

The morphometric study of the drainage basin provides accurate information of measurable features of stream network of the river basin. The various morphometric parameters like area, altitude, volume, slope, profile and texture of landforms comprise important parameters of study (Dury, 1952). It could be used for prioritization of small sub-watersheds (Biswas et al., 1999). It is well recognized that the influence of drainage morphometry is very vital in understanding the topographical and landform developments, soil and erosional characteristics (Rai et al., 2014) and also helps in any hydrological study like evaluation of groundwater potential and its management, basin management and environmental assessment. Drainage analysis is also very significant for watershed development and planning and also it provides a knowledge about the basin characteristics in terms topographical and soil characteristics, runoff behavior, surface water potential etc. (Astras and Soulankellis, 1992). Systematics study of drainage morphometric provides a quantitative description of the basin geometry to understand its geological and geomorphic history of drainage basin (Strahler, 1964) and also provide useful evidence about the hydrological behavior of the rocks exposed within the river basin or watershed.

Urban expansion and population growth in countries like India, leads to increasing stress on surface and ground water resources,

* Corresponding author.
E-mail address: rai.vns82@gmail.com (P. Kumar Rai).

http://dx.doi.org/10.1016/j.rsase.2017.05.001
Received 1 April 2016; Received in revised form 3 May 2017; Accepted 10 May 2017
Available online 11 May 2017

because of continuous demand of water for irrigation and industrial requirements (Singh et. al., 2011). The over exploitation of water has affected both surface and groundwater resources and resulting in a severe water crisis in any area (Thakur et al., 2011).

Important morphometric parameters requires the investigation of various related drainage parameters such as drainage network, basin geometry, relief characteristics and drainage texture etc. (Rai et al., 2014) and also helps for understanding of geological and geomorphological understanding of the area. Stream line of a basin not only describes the existing three dimensional geometry of the region but also help to describe its development process. River basins are the important elements of the fluvial landforms and a large quantity of study has focused on their geometric behaviors and characteristics, which contain the topology of the stream networks and quantitative analysis of drainage texture, pattern, shape, and relief characteristics (Abrahams, 1984a, 1984b; Huggett and Cheesman, 2002). Main focus in geomorphology over the last decades has been on the development of various quantitative physiographic methods to explain the evolution and behavior of drainage networks of the river basin (Horton, 1945; Leopold and Maddock, 1953; Abrahams, 1984a, 1984b).

The morphometric characteristics of the various river basins, watershed and sub-watershed have been done by many researchers and scientist and they analyzed these parameters for drainage basin characterization (Miller, 1953; Boulton, 1968; Gregory and Walling, 1973; Gardiner, 1975; Costa, 1987; Topaloglu, 2002; Moussa, 2003; Pareta, 2005; Mesa, 2006; Angillieri, 2008; Magesh et al., 2011; Bhagwat et al., 2011; Magesh et al., 2012, 2013; Magesh and Chandrasekar, 2014; John Wilson et al., 2012; Singh et al., 2011, 2013, 2014; Rai et al., 2014, 2017; Sujatha et al., 2014, 2015). Delineation of drainage networks within a river basin or sub-basin or watershed or sub-watershed can be achieved using conventional methods such as field based observations and old topographic maps or with advanced geospatial technologies like remote sensing and GIS (Verstappen, 1983; Rinaldo et al., 1998; Macka, 2001; Maidment, 2002; Ozdemir and Bird, 2009). The major problem in conventional methods is its tedious work to examine all stream networks from field observations due to their extent over a large area. On the other hand, drainage extraction from ASTER or SRTM digital elevation models (DEMs) is quite easy as it assumes that water will flow from higher to lower elevation but it needs systematic and organized method to get the results (Magesh and Chandrasekar, 2014).

The major streams like the Ganga, the Son, the Rihand etc. however renders the task of morphometric evaluations of the major basins or watersheds with respect to their parameters difficult, if not possible. Therefore the evaluations of their parameters are to be confined to the selected sub-basins from the tributaries or sub tributaries in the Son basin region of lithological diversities. The latest geospatial technology i.e. remote sensing, GIS, and GPS has significant tools to overwhelmed most of the problems of land and water resources planning and proper development on the account of tradition of conventional methods of data process. Yuan (2009) and Abubakr and Pradhan (2014) reported that the use of superior spatial analytical technologies such as GIS and remote sensing are very supportive for plans and policies designation. The present study area, Son basin which is originated from Vindhayan region is drained for a variety of agricultural fields, industrial purposes and also major source for the water supply to Madhya Pradesh, Uttar Pradesh, Bihar and Jharkhand.

1.2. Objective

The main objective of this study is to estimate drainage basin morphometric characteristics for various parameters and analyses the impact of structural control on the drainage pattern of the basin.

2. Material and methods

2.1. Physiography of the study area

The Son river (784 km long) is a vital branch of the Ganga river and its basin extended between 22°37′58.6″ N to 25°43′48.12″ N latitude and 80°5′35.68″ E to 84°58′31.47″ E longitude. Its geographical area is 68,863 km^2 and flows through the Madhya Pradesh, Uttar Pradesh, Bihar, and Jharkhand states of India. The Son river originates near Amarkantak in Madhya Pradesh, just east of the headwater of the Narmada river, and flows north-northwest through Madhya Pradesh state before turning sharply eastward where it encounters the south-west-northeast-running Kaimur Range. The Son river moves parallels the Kaimur hills, flowing east-northeast through Uttar Pradesh, Jharkhand and Bihar states to join the Ganges river just above Patna. Geologically, the lower valley of the Son is an extension of the Narmada Valley, and the Kaimur Range an extension of the Vindhya Range. Dehri on sone is a main town situated on Son river in Bihar state.

The maximum and minimum elevation encountered in the study area is 1245 m and 25 m above mean sea level respectively. Its main branches are the Rihand and the North Koyal. The Son river has a steep gradient (35–55 cm per km) with quick run-off and ephemeral regimes, becoming a active river with the rain-waters in the catchment area but turning rapidly into a fordable river.

The Son, being widespread and shallow, leaves detached pools of water in the remaining part of the year. The network of the Son is very wide (about 5 km at Dehri on sone) but the floodplain is narrow, only 3–5 km (2–3 mi) wide. In the past, the Son has been disreputable for changing course, as it is noticeable from numerous old beds near its east bank. In recent times this tendency has been checked with the anicut at Dehri, and now more so with the Indrapuri Barrage. The central east-west extending narrow gorge, occupied by the channel of the Son, divides the area into fractions, which differ from each other in respect of their hystogenesis as well as in the genesis and form of the land surface. The valley itself owes its formation partly to the tectonics and partly to the river action. In these areas where the tributaries of the Son discharge their waters and sediments, forming accordant junctions from the right hand and complex one from the left. In general, the valley is flat with high walls of uplands overlooking it from the north and south, differing in the nature of their local elevations significantly (Singh, 1980).

In Bihar state, this river develops a boundary line between Bhojpuri and Magahi speaking regions. Sir John Houlton, the British administrator, says, "After passing the steep slopes or escarpments of the Kaimur mountain range, Son river flows straight across the Ganga plain. For much of this distance it is over two miles – and at one point, opposite Tilothu – three miles wide. In the summer season there is huge spread of sand, with a stream not more than a hundred yards wide, and the hot west winds pile up the sand on the east bank, making natural embankments. After heavy rainfall in the mountainous hills side even this widespread bed cannot carry the waters of the Son and calamitous inundations in Shahabad, Gaya, and Patna are not rare" (Fig. 1).

2.2. Data used and methodology

The detail of the data used and methodology adopted for accomplishing the research objectives are briefly discussed below:

Georeferenced standard false colour composite (FCC) of Landsat etm+ data (30 m resolution) of band combinations 2 (green), 3 (red) and 4 (near infrared) were downloaded from the website of United States Geological Survey (USGS); Earth Explorer http:// earthexplorer.usgs.gov. ASTER DEM (Digital Elevation Model) of 15 m spatial resolution of DEM procured on 28th September 2012 by the TERRA satellite was also downloaded from downloaded from https://wist.echo.nasa.gov/api/ and was consequently developed for preparation of digital elevation model, slope and aspect map of the area. Digital