Application of Geomatics for Drainage Network Delineation for an Urban City

Kaushal Kumar and Raj Mohan Singh

Abstract Traditionally, topographic maps are usually employed for the drainage analysis. However, channel network extraction and watershed delineation from topographic maps require time and expertise in cartography. The application of Geomatics (Remote Sensing (RS) and Geographic Information Systems (GIS) and other land topographic informations) is imperative for drainage network delineation. In the present study, drainage network of an urban city, Allahabad in U.P., is delineated using ArcHydro. The ASTER Global DEM (GDEM) data of 30 m resolution is processed to determine the primary natural flow routes and catchment. Hydrological analysis is performed for flow accumulation, slope, drainage path using DEM data. Results show that the maximum drainage length is 1.73 km, the longest flow path length in catchment is 2.10 km.

Keywords Drainage network · Geomatics · RS and GIS · ArcHydro · GDEM

1 Introduction

A drainage network is a linear connection of land units that can accumulate the most runoff in an area. It is difficult to determine the quantity of accumulation of runoff. However, GIS provides a platform, where the quantity of accumulation of runoff can be easily determinable [1]. Urban planners, nowadays, used different ways to deal with drainage network system, for example, headwater-tracing method [2], adaptive approach for determining stream course with heuristic information (AHI) [3], and D8 algorithm approach [4] for the outline of drainage networks using advanced DEM models of land surfaces on GIS platforms.

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The drainage network is characterized by the relative checks wherever the upstream drainage area surpasses a specified threshold [5]. The real issue with D8 approach is that it needs depressionless DEM information [6]. The raw DEM model has sinks or depressions in the data so it must be reconditioned before processing. Sinks are the cells which have no neighbors at a low elevation and consequently, have no downslope streamflow path to a neighboring cell [7].

Some investigation needs high-resolution DEM data for better or precise outcomes. But high-resolution DEM data needs processing with good quality and quantity of computer resources and time to extricate drainage network. GIS framework provides good agreement with real-time entities. For a large basin area, number of grids in basin become too large in high-resolution DEM data, hence complexity of the system increases [8, 9]. GRASS GIS software is based on least-cost flow routing method. This software improve the speed, functionality, and memory requirements and make least-cost flow routing method more efficient for drainage network analysis for large basin [10, 11].

1.1 Study Area

The city Allahabad is at the confluence of River Ganga and River Yamuna. The geographical coverage of the city is bounded between 25° 23′ 21″ N–25° 30′ 19″ N latitude and 81° 43′ 40″ E–81° 54′ 17″ E longitude. Topographically, the city is flat in nature and the temperature is ranged between maximum 47.8 °C in summer to lowest 4.1 °C in winter season. The city also receives an average rainfall of 930 mm. The geographic land area is divided into 80 wards. The geographical location of the city is shown in Fig. 1.

2 Methodology

The flowchart diagram for the delineation of drainage network is presented in Fig. 2. Data from various sources are collected, e.g., Survey of India (SOI), DEM data (30 m) from USGS etc., Allahabad ward map from Allahabad Development Authority, Allahabad for this analysis. DEM data with topographical map were used to extract the drainage channel networks. The delineation of the channel network from digital data was carried out in the ArcGIS 10.0 environment. The detailed methodology is represented in Fig. 2.

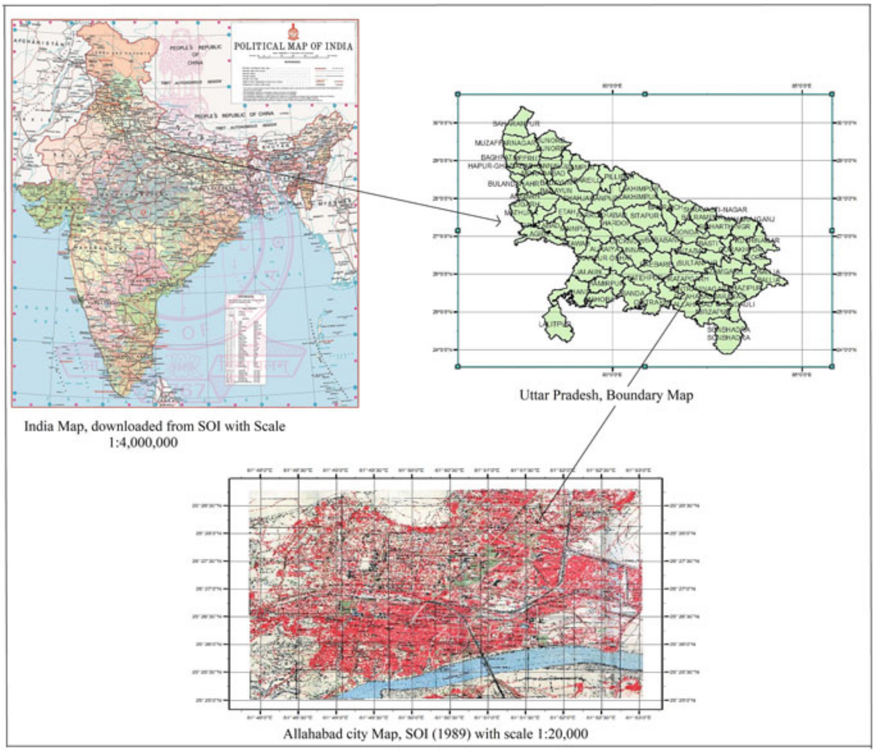

Fig. 1 Location map of the study area

3 Hydrological Analysis

The drainage channel network is delineated by utilizing DEM as input under GIS environment. ArcGIS software with the integration of Archydro tool is utilized to delineate the drainage network from DEM data [12]. The steps for the extraction of drainage channel delineation includes: preprocessing (or reconditioning) DEM, generation of flow direction, computation of the accumulation of flow, extraction of the drainage channel network. ArcHydro is working on the D8 algorithm is implemented for flow direction. A simple flowchart for extracting hydrological information and drainage network is shown in Fig. 3.

3.1 Flow Direction

For hydrological modeling, the flow direction is an important parameter. It is determined using D8 algorithm. A value ranging from 1 to 128 is assigned for each cell

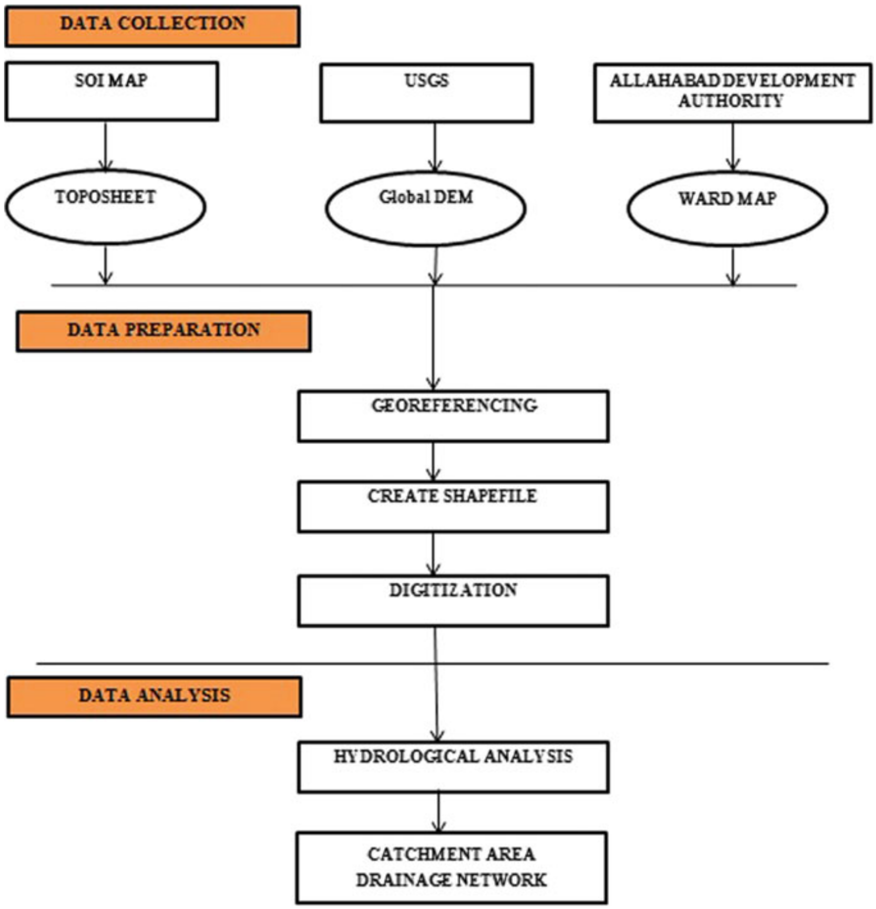

Fig. 2 Flowchart of methodology adopted

comprising the area. Flow direction is determined from higher to lower values. Flow direction calculation scheme and resulting flow direction in the study area are shown in Fig. 4 and Fig. 5, respectively.

3.2 Flow Accumulation

Flow accumulation, measure the additive amount of flow of water accumulated over the surface of land. This accumulated flow of water will help to the delineation drainage channel network extraction. Flow accumulation scheme and resulting flow accumulation in the study area are shown in Fig. 6 and Fig. 7, respectively.

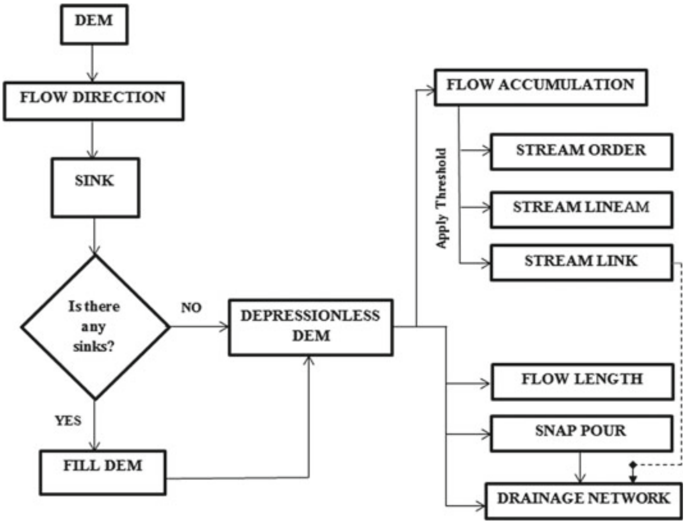

Fig. 3 Flowchart of process of extracting hydrological information from a DEM. *Source* Sitanggang and Ismail [13]

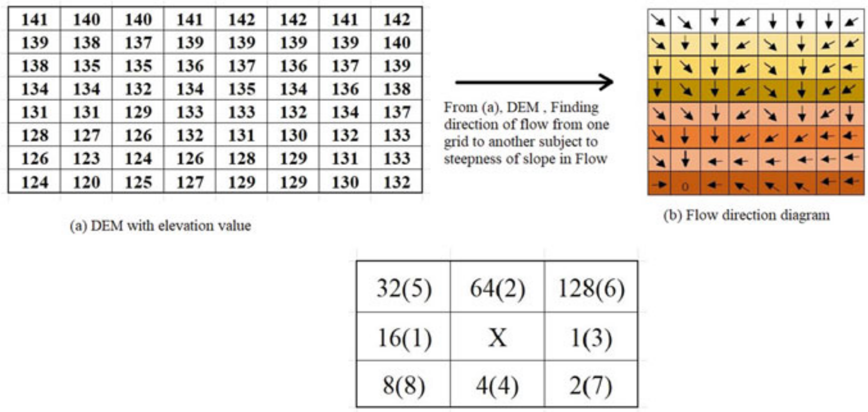

Fig. 4 Flow direction. *Source* Chukwuocha and Chukwuocha [14]

3.3 Stream Delineation

A stream network is delineated using a threshold value to cell. To understand the behavior of stream network, different values of stream threshold are applied to stream flow. The threshold value determines the number of cells contributing to stream flow. In the present study, the stream threshold (Ts) of 250, 500, 750, and 1000 are adopted. The stream delineation at different stream thresholds is shown in Fig. 8a, b, c, and d, respectively.

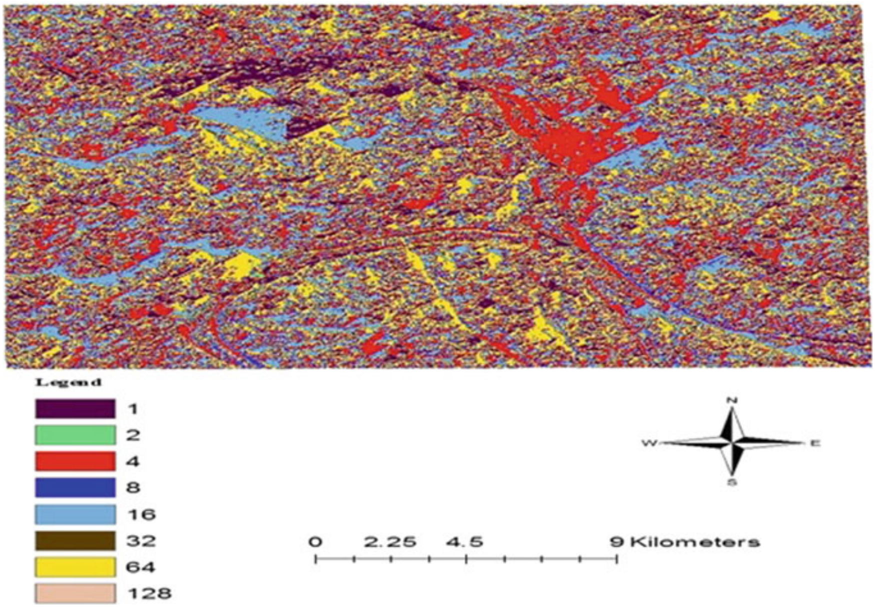

Fig. 5 Result of flow direction

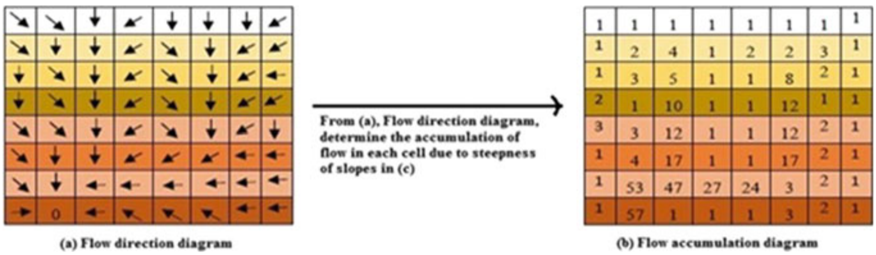

Fig. 6 Flow accumulation. *Source* Chukwuocha and Chukwuocha [14]

3.4 Drainage Network Delineation

The delineation of drainage network is carried out with flow direction and stream grid line as input. The network is extracted for city area with different stream threshold levels with the utilization of ArcGIS and ArcHydro tool under GIS framework. The different streams of different stream order contribute to mainline stream of the drainage networks which drained from different wards of Allahabad city area. The network delineated at different stream thresholds 250, 500, 750, and 1000 is shown in Fig. 9a, b, c, and d, respectively, and characteristics of the networks and its morphology are also studied.

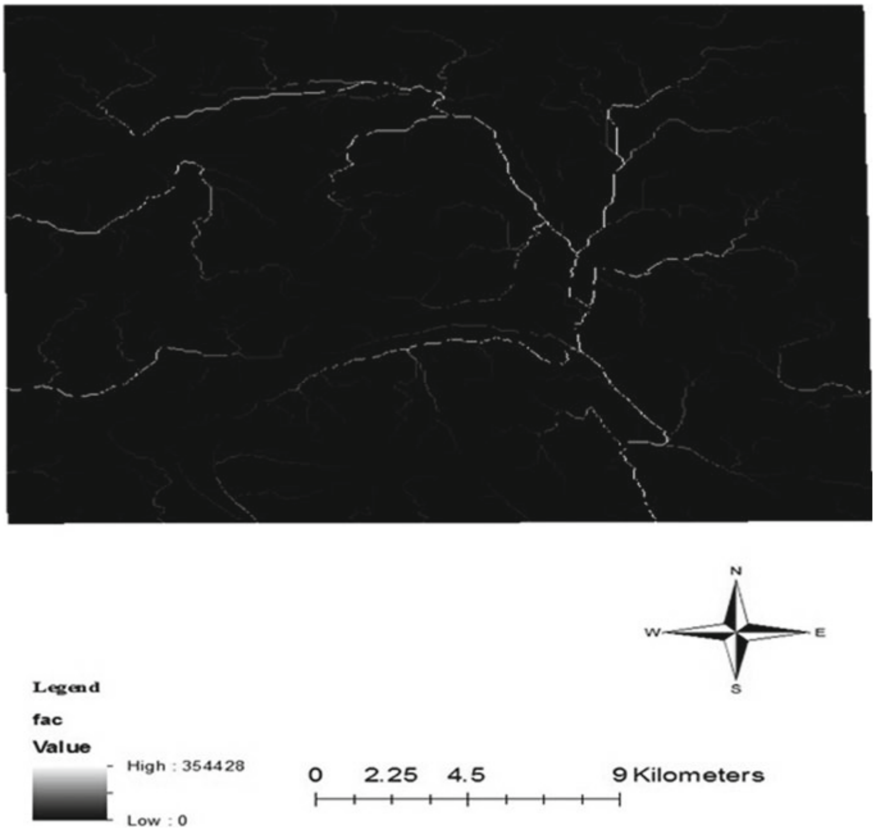

Fig. 7 Result of flow accumulation

The delineated drainage network at different stream thresholds is analyzed and summarized in Table 1.

4 Results and Discussion

The drainage network is delineated at different stream threshold values, for Allahabad city. From Figs. 8 and 9, it is clearly seen that the density of drainage network is high at low stream threshold and density of drainage network is low catchment at high stream threshold. At stream threshold 250, 500, 750, and 1000 maximum draining length are 1.15 km, 1.57 km, 1.73 km, and 1.57 km respectively, longest flow path length for catchment are 1.17 km, 1.80 km, 2.10 km, and 2.10 km, respectively, and longest flow path length for adjoint catchment are 11.79 km, 11.79 km, 11.79 km, and 11.79 km, respectively.

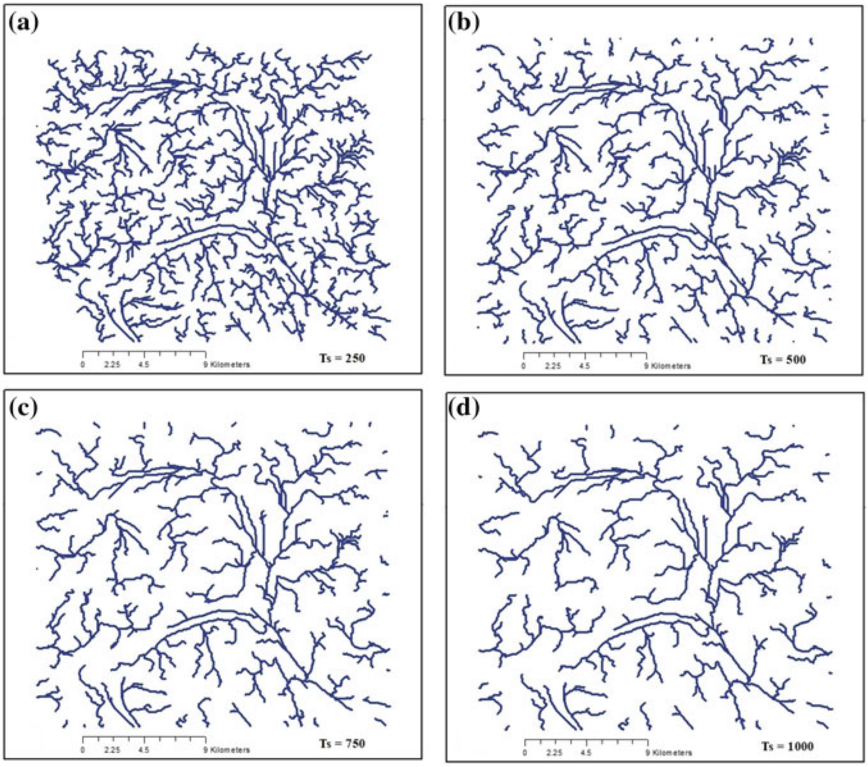

Fig. 8 Results of streamflow at different threshold values

The maximum area of catchment that contribute to the generation of drainage network at different stream threshold values of 250, 500, 750, and 1000 are 0.14 km^2, 0.31 km^2, 0.41 km^2, and 0.44 km^2 respectively, and maximum area of adjoint catchment is 11.79 km^2, 11.79 km^2, 11.79 km^2, and 11.79 km^2, respectively. The results show potential applicability of Geomatics for drainage network delineation for an urban city like Allahabad.

5 Conclusions

The natural drainage morphology is similar to the generated drainage network for the city. It is observed that longest flow path length for the contributing catchment saturate to a value (2.10 km). The longest flow length for adjoint catchment is the same in all cases even the maximum area of the adjoint catchment is the same (11.79 km) in all cases.

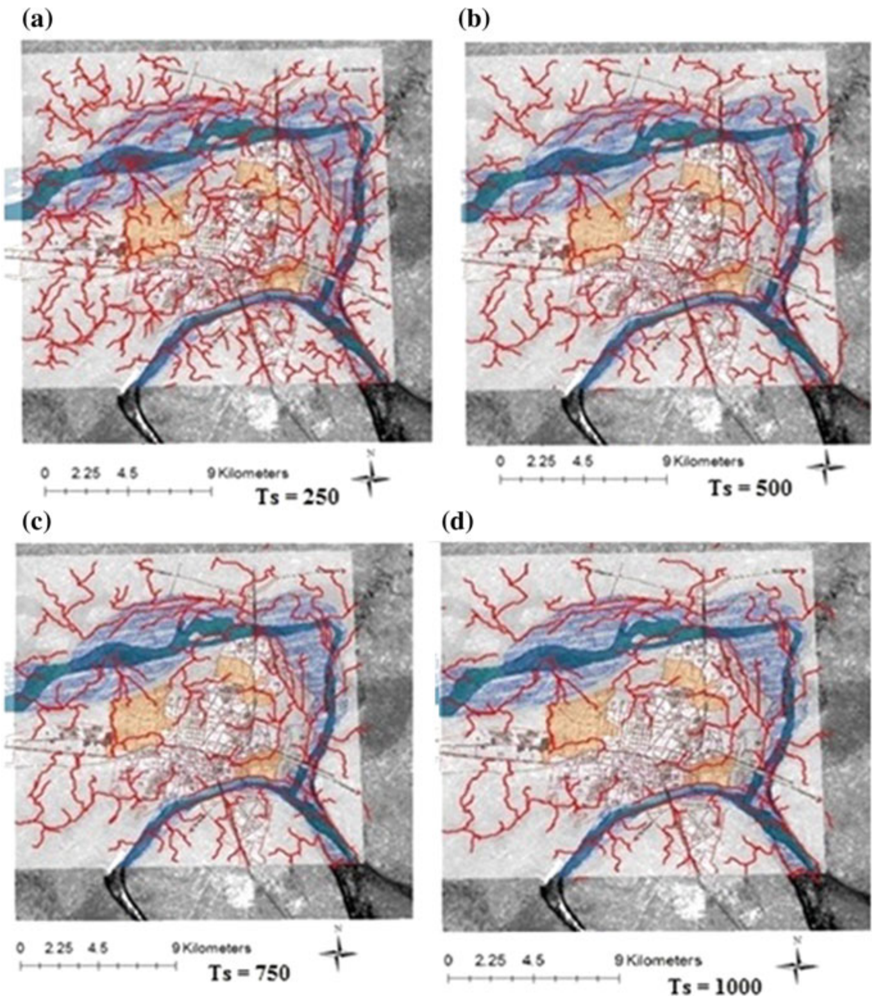

Fig. 9 Result of drainage network of Allahabad city

Table 1 Basic drainage network statistics

Stream threshold value (Ts) for cells	Maximum area of catchment (km^2)	Maximum area of adjoint catchment (km^2)	Maximum drainage length (km)	Longest flow path length for catchment (km)	Longest flow path length for adjoint catchment (km)
250	0.14	24.60	1.15	1.17	11.79
500	0.31	24.60	1.57	1.80	11.79
750	0.41	24.60	1.73	2.10	11.79
1000	0.44	24.60	1.57	2.10	11.79

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