HYDRO 2019 INTERNATIONAL CONFERENCE

(Hydraulics, Water Resources & Coastal Engineering)

18-20 December, 2019

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TEQIP - III

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Preface

HYDRO 2019 International Conference on Hydraulics, Water Resources, Coastal & Environmental Engineering, organized under the aegis of the Indian Society for Hydraulics, is an annual get together of Scientists, Researchers, Academicians, Practicing Engineers and Consultants all over the world and has evolved over the years and earned an international reputation and recognition. The conference mainly focuses on state of the art technologies and applied research in the field of Hydraulics, Water Resources, Coastal and Environmental Engineering. The present 24th conference is being held in Hyderabad for the first time since its inception 1992.

Osmania University was established by HEH Nizam VII Mir Osman Ali Khan through Firman to cater to modern, secular, cultural, Islamic and regional arts education making it the first university in the Indian subcontinent to provide education in native and Urdu language.

The University College of Engineering (UCE), which is part of Osmania University, was established in the year 1929, eleven years after its formation. It was the 6th Engineering College to be established in the whole of British India. The present HYDRO 2019 International conference is being celebrated on the occasion of University College of Engineering reaching 90 years of glorious service.

The Department of Civil Engineering is synonymous with University College of Engineering, as the Department started its illustrious journey along with it, in the year 1929. The department has grown from strength to strength and has been one of the pioneering departments in imparting quality education in the country.

On behalf of the Department of Civil Engineering, UCE, OU and Indian Society for Hydraulics, it is our proud privilege to welcome you all to this Conference. We received about **520** papers and after the review, about **370** full papers are finally accepted. The HYDRO-2019 Proceedings Volume contains peer reviewed technical papers included under 10 themes and covers a wide spectrum of research studies, case studies, review papers and papers related to management of Water resources and Coastal Engineering. We are indeed happy to bring on this occasion, souvenir containing abstracts of the Technical Papers selected for the presentation. Further, proceedings of the conference are also released in Electronic forms that are arranged on theme wise.

We take this opportunity to express our sincere thanks and gratitude to all members of International and National Advisory committee members, Technical Committee as well as the Organizing Committee members along with student volunteers, authors and reviewers.

We appreciate the untiring efforts of conference organizers, generous support from several sponsors, continuous guidance, support and encouragement from all academic and research institutions.

We hope that the deliberations and discussions in HYDRO 2019 International conference will promote useful and fruitful interactions among participants and thus help professionals working in the field of Hydraulics, Water Resources and Coastal Engineering.

Looking forward to fruitful deliberations in the HYDRO – 2019

-Editors

Contents

Comparative Study of Morphometric Parameters using Different Data Sets for Various Terrain Area

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Abstract

This paper proposes the comparative study of morphometric parameters using different data sets for various terrain area selected. The morphometric parameters are basic input for proper hydrological studies such as Runoff estimation, Flood forecasting and so on. Morphometric parameters are generated by digital elevation models (DEM) and Toposheets in ArcGIS platform. Here morphometric parameters are derived by using DEM data sets such as ASTER, SRTM, CartoSat-1, JAXA of 30m, TanDEM-X of 90m resolution and SOI Toposheets under ArcGIS10.1 software for various terrain area. In flat terrain stream order is generated with accumulation threshold >500 for 30m resolution data sets and >55.55 for 90m resolution data whereas in hilly terrain a value of >150 for ASTER, SRTM, CartoSat-1 and >100 for JAXA and >55.55 for 90m resolution data. Based on variation of observed elevation (Z-value) and cumulative Toposheet area from different data sets, ASTER, SRTM and JAXA of 30m spatial resolution are best to use with minimum Z-value correction and morphometric parameter comparison shows a coarse resolution data is enough for flat terrain areas and high resolution is required for hilly terrain areas with certain flow accumulation threshold value. An uncertainty in accumulation threshold value results in deficient morphometric parameters.

Keywords: ArcGIS, DEM data, Toposheet, Morphometric parameters, Terrain area.

1. INTRODUCTION

The measurement and analysis of earth's surface feature such as landform, water and air are important for a hydrologist to deal with his hydrological activities. The quantification of landform in all its aspects is termed to be Morphometry. The morphometric parameters are basic input for proper hydrological studies such as runoff estimation, flood forecasting, quantification of depression storage and so on (Kavitha and Nyamathi 2013). Morphometric parameters are generated by digital elevation models and toposheets in ArcGIS platform (Banerjee 2017). The effect of spatial resolution of different DEM data sets in the delineation of stream, extraction of stream length and area slope is considerable (Buakhao and Kangrang 2016). The elevation and slope value will change inCoarser resolution DEM than the high-resolution DEM and which causes decrease in value of morphometric parameter (Grohmann 2015). Basin, stream order and stream length are greatly affected by flow accumulation threshold value, lesser order stream length are resulted due to uncertainty in flow accumulation threshold (Mingliang et al. 2008). Hence the morphometric analysis using DEM is greatly dependent on resolution and certain flow accumulation threshold value (Paul 2015). Using a coarser resolution DEM, the accuracy of slope decreases in hilly terrain and great difference in aspect values in flat terrain area (Chang and Tsai 1991).

The main objective of this study is to extract the morphometric parameters from all DEM data sets with certain flow accumulation threshold value in ArcGIS platform for various terrain area (Dakshina Pinakini sub-watershed i.e., flat terrain and Uttara Kaveri sub-watershed i.e, hilly terrain) and make a comparison with the observed data.

ASTER (Advanced spaceborne Thermal Emission Reflection Radiometer) and SRTM (Shuttle Radar Topographic Mission) of 30m spatial resolution can be downloaded from USGS Earth Explorer. ASTER and SRTM DEMs can be used in both hilly and flat terrain (Rusli et al. 2014), CartoSat-1 of 30m resolution downloaded from Bhuvan portal, JAXA (Japan Aerospace Exploration Agency) of 30m resolution download from JAXA Global ALOS portal, TanDEM-X of 90mresolution downloaded from EcoGeoservice portal and Survey of IndiaToposheets (57G/16, 57L/13, 57L/14) are used in ArcGIS 10.1 software.

2. STUDY AREA

The study area selected is Dakshina Pinakini Sub-Watershed and Uttara Kaveri Sub-Watersheds. Dakshina Pinakinisub-watershed located in Hoskote taluk of Karnataka contributing its streams to Hoskote lake and Uttara Kaverisub-watershed located in Vaniyambadi taluk of Tamilnadu contributing its streams to Palar river. Dakshina Pinakini sub-watershed is usually a flat terrain area whereas Uttara Kaveri sub-watershed is a hilly terrain area. Based on Toposheets the area, perimeter, latitude and longitude are shown inTable 1.

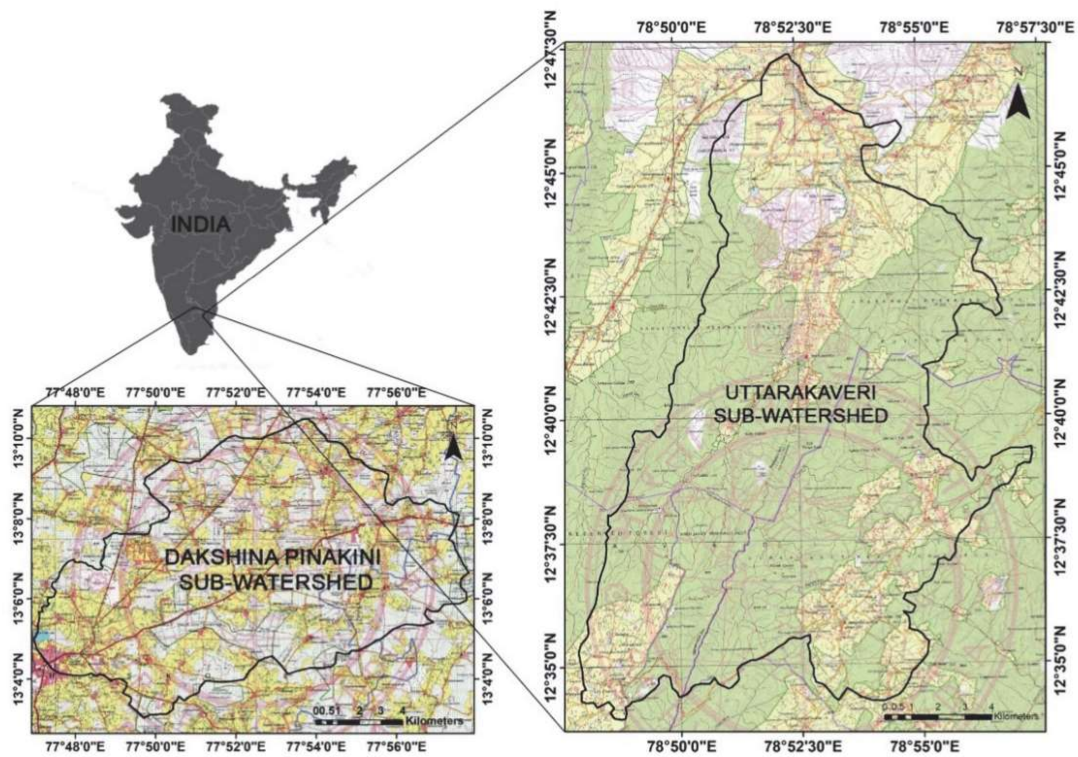


Figure 1 Location map of Study area (Dakshina Pinakini and Uttara Kaveri Sub-Watershed) in India

Table 1 Details of study area as per Toposheets

Toposheet	Dakshina Pinakini Sub-watershed	Uttara Kaveri Sub-watershed
Latitude	$13^0$3'0''N $13^0$10'30''N	$12^0$33'55''N $12^0$47'52''N
Longitude	$77^0$47'0''E $77^0$57'47''E	$78^0$47'52''E $78^0$57'20''E
Area (sq. km)	156.25	227.64
Perimeter (km)	62.93	91.36
Length (km)	19.58	24.9
Maximum elevation (m)	946	950
Minimum elevation (m)	870	316

3. MATERIALS AND METHODOLOGY

As shown in Fig. 2 the data sets required is downloaded at first; ASTER and SRTM of 30m resolution are downloaded from USGS earth explorer (https://earthexplorer.usgs.gov/), CartoSat-1 of 30m resolution is downloaded from Bhuvan website (https://bhuvan.nrsc.gov.in/), JAXA of 30m resolution is downloaded from Global ALOS portal (https://www.eorc.jaxa.jp/ALOS/), TanDEM-X of 90m resolution downloaded from eco Geoservice portal (https://geoservice.dlr.de/) and Survey of India toposheets are downloaded from Nakshe portal (http://soinakshe.uk.gov.in/). The DEM data sets are imported into the ArcGIS 10.1. Fill tool is applied to fill up all sink and to remove peak if any in the DEM. It is necessary to carry out this tool for proper delineation of basin and stream. Using basin tool, the sub-watersheds are delineated at required pour point.flow direction tool is applied to create the raster flow direction. Each DEM is composed of number of cellsof definite spatial resolution with a Z value. In GIS the raster flow direction takes from higher Z value cell to lower Z value cell in any one of the 8-direction. Next the flow accumulation tool is applied which results the accumulation from all neighboring cells to each cell depending upon the flow direction. When a cell contains an undefined flow direction then it will not contribute the flow. In order to obtain the stream, order the raster calculator is important. In raster calculator it is necessary to give proper threshold value, an uncertainty in accumulation threshold value will results in deficiency in stream order and stream length hence care should be taken in giving a certain flow accumulation threshold value. After raster calculation next step is stream order generation this is done using stream order tool, here streams are generated as proposed by Strahler. Once the stream order is generated stream length is extracted and the morphometric parameters are obtained and then it is compared with observed morphometric parameter. The morphometric parameters in all aspects such as linear, areal and relief aspects are calculated using the formula shown in Table 2.

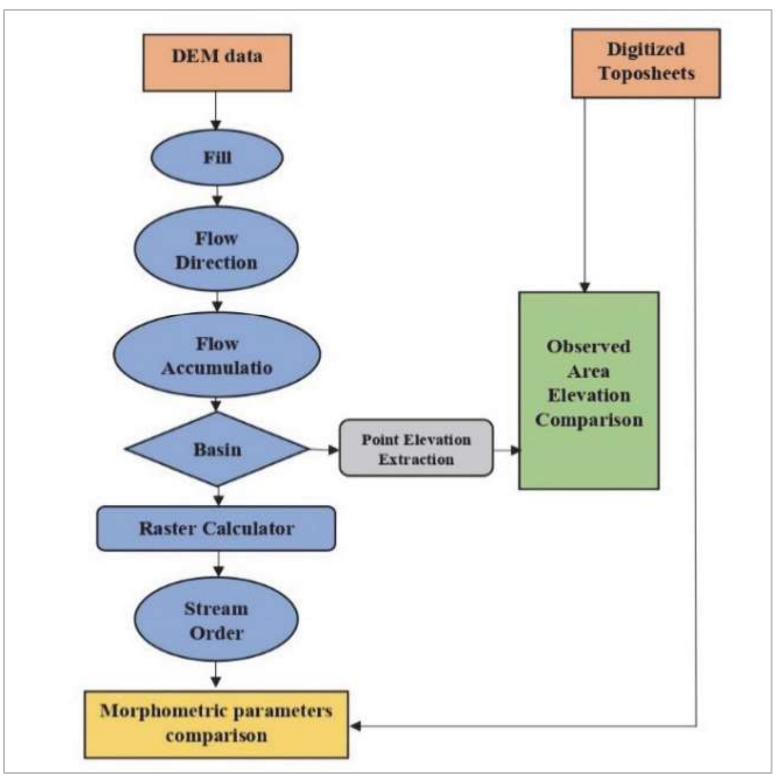
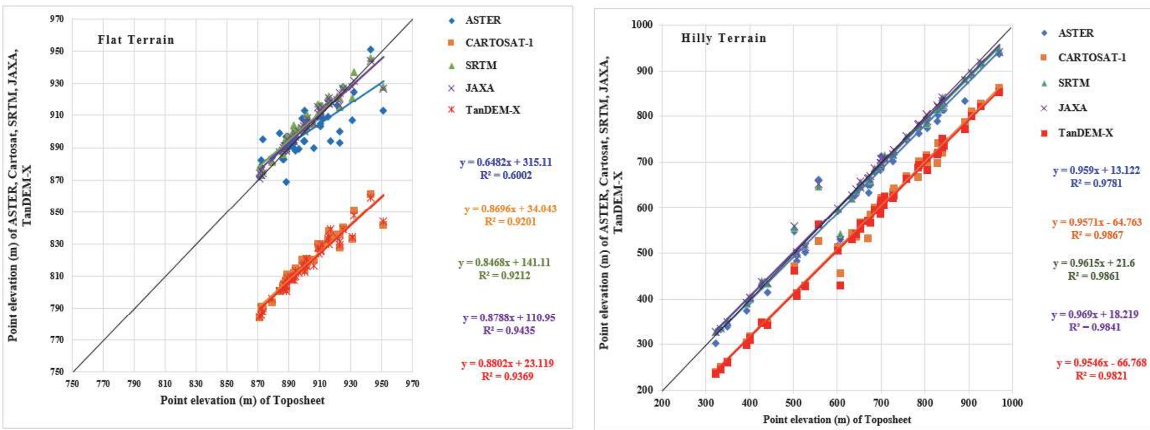


Figure 2. Flow chart showing methodology involved in achieving Morphometric parameter comparison

4. RESULTS AND DISCUSSION

4.1 Elevation Comparison

Suitable points are extracted from the toposheets and the observed Z values compared with DEMs Z value.



(a) (b)

Figure 3 Graph showing observed variation of Z-values (elevation) from different data sets
(a) Flat terrain (b) Hilly terrain area.

Based on above graphs in flat terrain most Z-Values of SRTM and JAXA DEM data coincides with observed Z-Values (Toposheets). The linear trendline of SRTM and JAXA DEM data are close to the observed linear trendline and they are having R^2 value 0.9212 and 0.9435 which are near to 1. In hilly terrain the linear trendline of ASTER, SRTM and JAXA DEM data are close to observed linear trendline with R^2 value of 0.9841, 0.9867 and 0.9861 which are close to 1.

Table 2 Morphometric parameters with formulas

Parameters (Source)	Symbol	Formula
Linear Aspects		
Stream order Strahler (1952)	Nu	Hierarchical rank
Bifurcation ratioSchumn (1956)Strahler (1957)	R_f	$R_f = \frac{Nu}{N_{u+1}}$
Stream length Horton (1945)	L_s	Stream length (km)
Mean Stream Length Strahler and Chow (1964)	L_{sm}	$L_{sm} = \frac{\sum_{i=1}^{N} L_u}{N_u}$
Stream length ratio Horton (1945)	R_L	$R_L = \frac{L_u}{L_{u-1}}$
Areal Aspects		
Form factor Horton (1945)	F_f	$F_f = \frac{A}{L^2}$
Circularity index Sharma et al. (2013)	R_c	$R_c = \frac{4\Pi A}{P^2}$
Elongation ratio Schumn (1956)	R_e	$R_e = \frac{2\sqrt{\frac{A}{\Pi}}}{L}$
Drainage density Horton (1945)	D_d	$D_d = \frac{\sum L_u}{A}$
Stream frequency Horton (1945)	S_f	$S_f = \frac{N_s}{A}$
Constant of channel maintenance Schumm (1956)	C	$C = \frac{1}{D_d}$

Table *Contd...*

Relief Aspects		
Watershed Relief Hadley and Schumm (1961)	R	R = H-h
Relief ratio Schumn (1956)	R_r	$R_r = \frac{R}{L}$
Relative relief Schumn (1956)	R_h	$R_h = \frac{R}{P}$
Ruggedness number Schumn (1956)	R_n	$R_n = \frac{R\,D_d}{1000}$

Note: N_{u+1} = Stream of order u+1, L_{u-1} = Stream length of order u-1, A = Area of watershed, L = Length of watershed, P = Perimeter of watershed, H = Maximum elevation, h = Minimum elevation.

4.2. Area comparison

Contour lines are generated with 20m interval for flat terrain and 100m interval for hilly terrain. The area between each interval is computed and the cumulative area is compared with cumulative area computed from toposheets. Based on graphs shown in Fig. 4 the cumulative area generated from ASTER, SRTM and JAXA DEM data in flat terrain is nearly same as that of cumulative toposheet area. The linear trendline of this DEM data sets showed R^2 value of 0.9975, 0.9966 and 0.9981 which are close to 1. In hilly terrain same ASTER, SRTM and JAXA shown nearby results with their linear trendline having a R^2 value of 0.9977, 0.999 and 0.9999 which are very much close to 1.

Based on overall observed variation of Z-value (elevation) and cumulative area from different data sets, in flat terrain and hilly terrain ASTER, SRTM and JAXA data sets can be used. TanDEM-X DEM data set failed to give a best correlation with observed data this is because of deficient pixel or coarse resolution. Z-value will change considerably with coarse resolution. A deficient Z-value DEM will result in improper delineation of basin, stream order and stream length. Hence it is necessary to use high spatial resolution DEM which exhibits best correlation with the observed data.

Morphometric analysis is carried out starting with basin and stream delineation. The area, perimeter, length, maximum elevation and minimum elevation generated from each DEM data sets and Toposheets is shown in Table 3 for flat terrain and Table 4 for hilly terrain. All the parameters generated from each DEM data sets are different from one another. The basin and stream delineated from each data sets are lied on google earth which is shown in Fig. 5. In both flat and hilly terrain basin delineated from all DEM data sets are similar to basin delineated from Toposheets except at the pour point. In flat terrain, parameters generated from all DEM data sets are very much similar to parameters computed from Toposheet.In hilly terrain, parameters generated from all DEM data sets are very much similar to parameters computed from Toposheet. CartoSat-1 and TanDEM-X DEM have deficiency in Z-Values as compared with Toposheets and other DEM data sets which is seen from Table 3 and Table 4. This deficiency may lead to deficient watershed delineation, Stream order and Stream length.

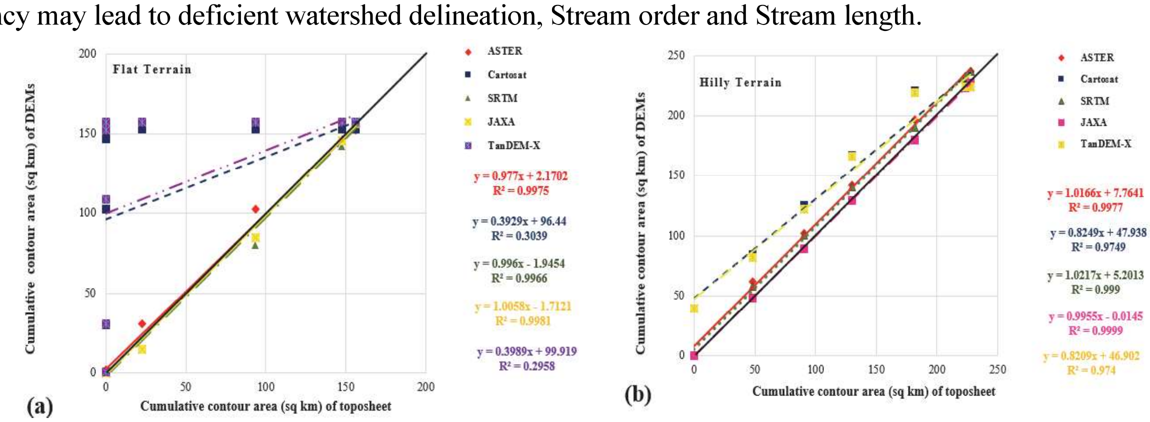


Figure 4 Graph shows variation of cumulative area between toposheets and DEM data sets (a) Flat terrain area (b) Hilly terrain area.

Table 3 Basic parameters of Flat terrain area from different data sets

Parameters	Flat terrain area					
	ASTER	**SRTM**	**CartoSat-1**	**JAXA**	**TanDEM-X**	**Toposheet**
Area (sq km)	153.36	156.27	153.28	157.01	157.77	156.25
Perimeter (km)	85.59	76.39	73.01	68.3	63.8	62.93
Basin Length (km)	20.41	20.24	20.18	19.4	19.51	19.58
Maximum Elevation (m)	987	955	867	951	864	946
Minimum Elevation (m)	835	859	773	864	779	870

Table 4 Basic parameters of hilly terrain area from different data sets

Parameters	Hilly terrain area					
	ASTER	**SRTM**	**CartoSat-1**	**JAXA**	**TanDEM-X**	**Toposheet**
Area (sq km)	226.92	237.15	226.32	227.05	224.36	227.64
Perimeter (km)	107.25	100.82	99.83	94.95	90.59	91.36
Basin Length (km)	25.4	25.83	24.93	24.91	24.87	24.9
Maximum Elevation (m)	968	978	886	939	842	950
Minimum Elevation (m)	288	306	221	307	220	316

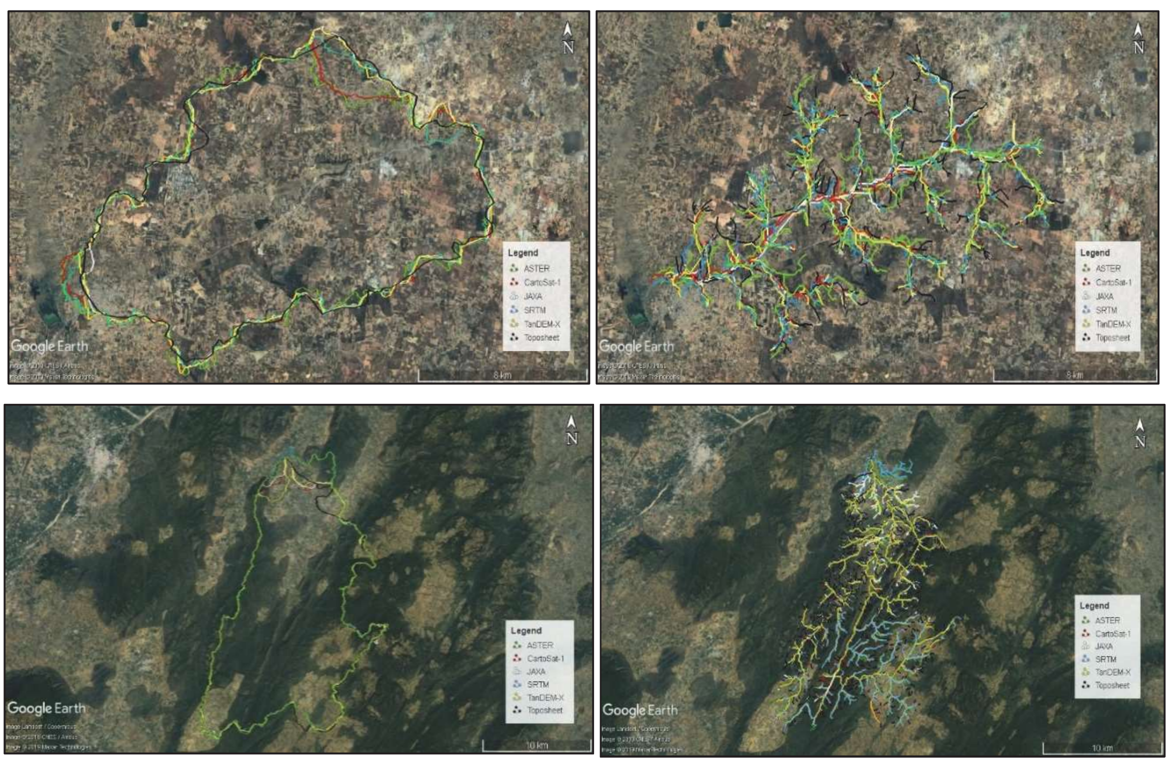


Figure 5 Delineated sub-watershed boundary and stream lied on Google Earth (a) Dakshina Pinakini Sub-watershed (flat terrain) (b) Uttara Kaveri sub-watershed (hilly terrain)

4.3 Generating morphometric parameters

The Morphometric parameters are important inputs to carryout hydrological studies. Morphometric parameters generated from DEM greatly depends on Z-Values, deficiency in Z-Value results in deficient watershed, stream order and stream length. The raster calculation is an important step in GIS. In raster calculation the flow accumulation threshold value should be certain for proper delineation of stream order and stream length. Here in this study a flow accumulation greater than 500 is given at first for all DEM data sets this has resulted in deficient stream order and stream length. Later flow accumulation threshold values are corrected to get stream order similar to that derived from Toposheets.

For flat terrain flow accumulation threshold value of >500 is given to 30m resolution DEM data and >55.55 value is given to 90m resolution DEM data, in hilly terrain a value of >150 is given to ASTER, SRTM, CartoSAT-1 DEM data sets, >100 is given to JAXA DEM data and >55.55 is given to TanDEM-X DEM data. In flat terrain a flow accumulation threshold value of >500 is given to all high resolution DEM data sets, here number of streams and total length of streams generated from ASTER and SRTM are close to Toposheet value shown in Table 5, whereas CartoSat-1 and JAXA DEM have lower number of streams and total stream length when compared with Toposheets values this shows CartoSat-1 and JAXA DEMs are coarser than ASTER and SRTM even though it is specified with 30m spatial resolution. In order to achieve nearer results flow accumulation threshold value should be lowered.

Table 5 Morphometric parameters from different data sets for flat terrain area

Sl.No	Details for flat terrain	ASTER	SRTM	CartoSat-1	JAXA	TanDEM-X	Toposheet
Linear Aspects							
1.1	Highest Stream order	4	4	4	4	4	4
1.2	Total number of streams	134	136	122	118	106	166
1.3	Total Length of Stream(km)	163.19	147.88	139.16	137.72	132.62	172.14
1.4	Drainage density (km/sq km)	1.06	0.95	0.91	0.88	0.84	1.1
Areal Aspects							
2.1	Watershed shape factor	2.72	2.62	2.66	2.4	2.41	2.45
2.2	Compactness Co-eff	1.95	1.72	1.66	1.54	1.43	1.42
2.3	Circularity Ratio	0.26	0.34	0.36	0.42	0.49	0.5
2.4	Elongation ratio	0.68	0.70	0.69	0.73	0.73	0.72
2.5	Form factor	0.37	0.38	0.38	0.42	0.41	0.41
2.6	Constant of Channel Maintenance	0.94	1.06	1.10	1.14	1.19	0.91
2.7	Stream Frequency	0.87	0.87	0.80	0.75	0.67	1.06
Relief Aspects							
3.1	Watershed relief 'H' (m)	152	96	94	87	85	76
3.2	Watershed relief ratio	0.0074	0.0047	0.0046	0.0044	0.0043	0.0038
3.3	Relative relief	0.0017	0.0012	0.0012	0.0012	0.0013	0.0012
3.4	Ruggedness number	0.16	0.090	0.085	0.076	0.071	0.083

TanDEM-X DEM has resulted lesser drainage density of 0.84 (km/sq.km) and Stream frequency of 0.67 than all DEM data sets and Toposheet mainly because of its coarser resolution. In hilly terrain a flow accumulation threshold value >150 is given to ASTER, SRTM and CartoSat-1, a value of >100 is given to JAXA and a value >55.55 is given to TanDEM-X in order to generate morphometric parameter, Table 6 shows parameters generated from all DEM data and Toposheet. ASTER data resulted a satisfactory result than compared with

SRTM and CartoSat-1 which are given with same accumulation threshold value. JAXA even given with lesser accumulation threshold value it has resulted lesser number of streams and total stream length, which shows JAXA DEM is coarser than high resolution data sets. With a lesser accumulation threshold value of 55.55 in TanDEM-X resulted in 4th order Stream with lesser stream frequency, further reduction in threshold value resulted in same 4th order stream. Based on comparison in hilly terrain it is necessary to have a high-resolution DEM. Higher the resolution of DEM, higher the input flow accumulation threshold value. Hence the flow accumulation threshold value depends on the resolution of DEM and nature of terrain. Fig. 6 and Fig. 7 shows the relationship between stream order versus number of stream and stream order versus stream length for flat terrain and hilly terrain.

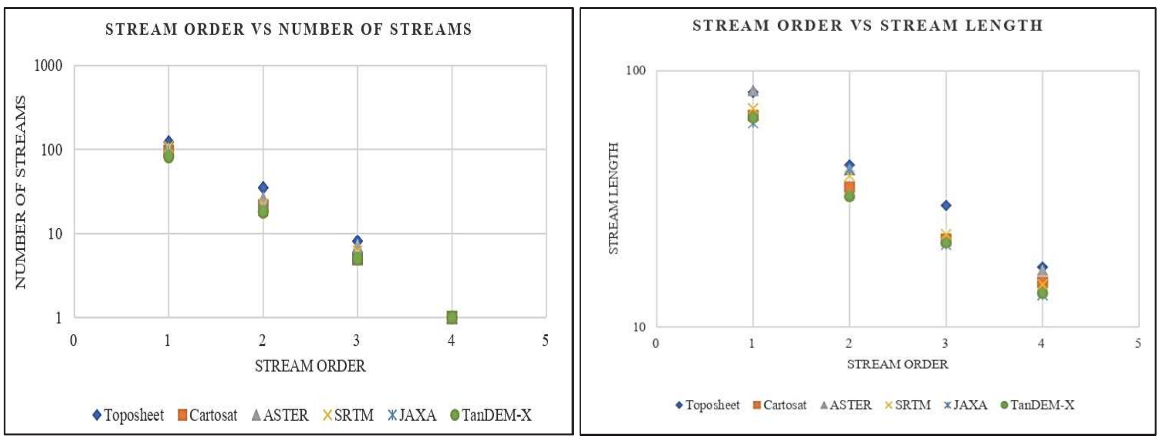


Figure 6 Variation of number of streams and stream length with stream order from different data sets for flat terrain area

Table 6 Morphometric parameters from different data sets for hilly terrain area

Sl.No	Details for hilly terrain	ASTER	SRTM	CartoSat-1	JAXA	TanDEM-X	Toposheet
Linear Aspects							
1.1	Highest Stream order	5	5	5	5	4	5
1.2	Total number of streams	596	562	547	561	158	601
1.3	Total Length of Stream (km)	452.62	428.59	429.04	415.88	228.1	535.5
1.4	Drainage density (km/sq km)	1.91	1.81	1.90	1.83	1.02	2.35
Areal Aspects							
2.1	Watershed shape factor	2.72	2.81	2.75	2.73	2.76	2.72
2.2	Compactness Co-eff	1.97	1.85	1.87	1.78	1.71	1.71
2.3	Circularity Ratio	0.26	0.29	0.29	0.32	0.34	0.34
2.4	Elongation ratio	0.68	0.67	0.68	0.68	0.68	0.68
2.5	Form factor	0.37	0.36	0.36	0.37	0.36	0.37
2.6	Constant of Channel Maintenance	0.52	0.55	0.53	0.55	0.98	0.43
2.7	Stream Frequency	2.52	2.37	2.42	2.47	0.70	2.64
Relief Aspects							
3.1	Watershed relief 'H' (m)	680	672	665	632	622	634
3.2	Watershed relief ratio	0.026	0.026	0.026	0.025	0.025	0.025
3.3	Relative relief	0.0063	0.0066	0.0066	0.0066	0.0068	0.0069
3.4	Ruggedness number	1.29	1.21	1.26	1.15	0.63	1.49

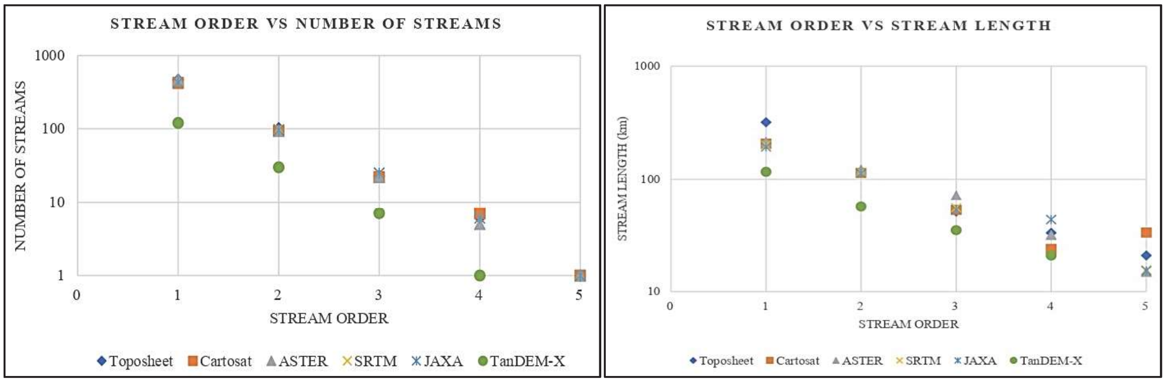


Figure 7 Variation of number of streams and stream length with stream order from different data sets for hilly terrain area

Lastly, we can say a low-resolution DEM is enough for flat terrain area with certain flow accumulation threshold value and a high-resolution DEM is required for hilly terrain area. An uncertainty in Flow accumulation threshold value results in deficient morphometric parameters.

CONCLUSIONS

The Morphometric parameters are important inputs to carryout hydrological studies. Morphometric parameters generated from DEM greatly depends on Z-Values, deficiency in Z-Value results in deficient watershed, stream order and stream length. Based on comparison of morphometric parameters from different data sets in flat terrain a coarser resolution DEM is enough whereas in hilly terrain it is necessary to have a high-resolution DEM data. Higher the resolution of DEM, higher the input flow accumulation threshold value.The flow accumulation threshold value depends on the resolution of DEM and nature of terrain. An uncertainty in flow accumulation threshold value results in deficient morphometric parameters. Hence spatial resolution of DEM and flow accumulation threshold value are important features in morphometric analysis.

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