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Drainage Morphometric Analysis and Water Resource Management of Hindon River Basin, using Earth Observation Data Sets

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Abstract: *In the present work a comprehensive quantitative analysis has been carried out for the Hindon River Basin based on earth observation data sets and GIS techniques. Quantitative evaluations of drainage basins are providing the important data base for hydrological investigation and river basin management plans. All the drainage Morphometric components, topographical and land use maps of the basin are mapped and evaluated with reference to water resource management of basin. The important surface hydrological component such as aerial, linear and relief aspects were delineated and computations using SRTM DEM using Hydrological analysis tool of ArcGIS software. The basin possesses the dendritic drainage pattern with maximum 5th order of stream, which is a sign of the homogeneity in texture and lack of structural control. The drainage density of the basin has been found very low which indicates that the basin possesses very good permeable subsurface formation and prospect for water management. The results observed from this study shows that there is good prospect for water management plan in the basin using remote sensing and GIS techniques.*

Keywords: *Drainage Morphometry, Satellite Images, Hindon River Basin, ArcGIS*

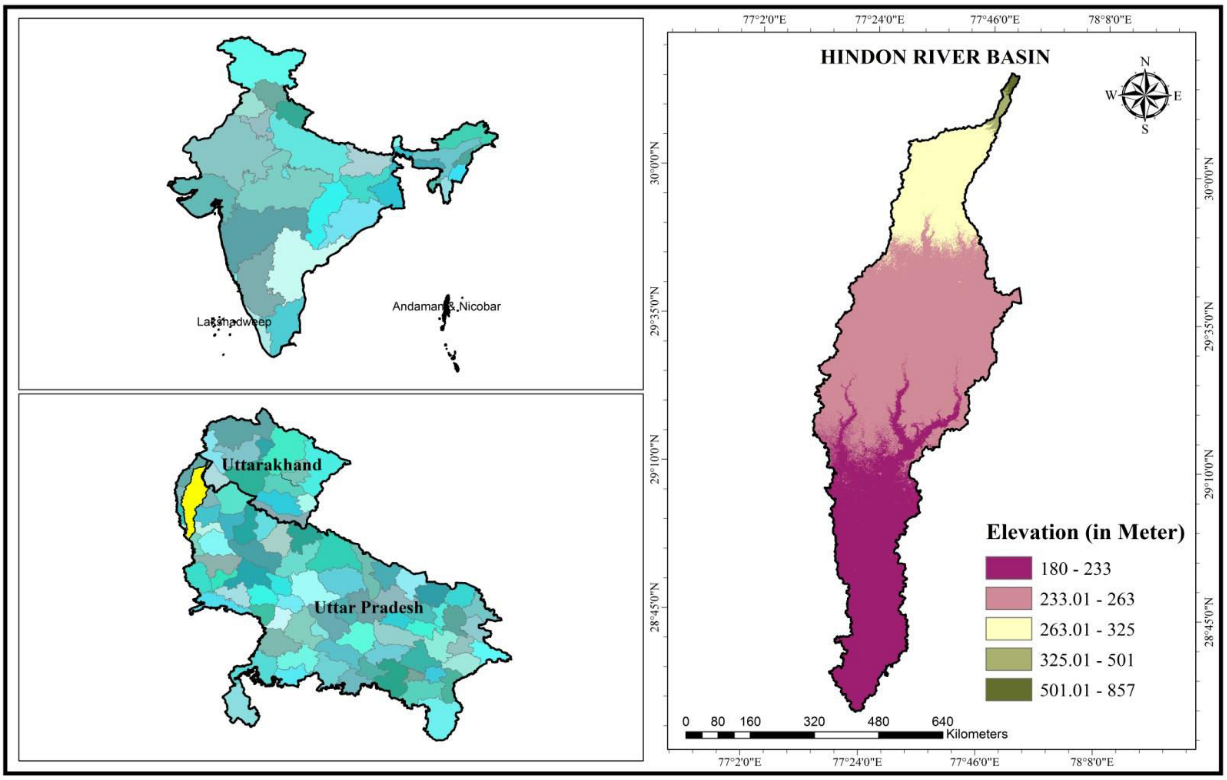
1. Introduction

The analysis of the drainage system and evaluation of its characteristics can be understand only through the morphometric analysis of the river basin and it's provide the important hydrogeological information of the area for watershed modeling and water resource management. The recent trend in drainage morphometric assessment through the use of space borne satellite images for extraction of streams and their associated features are one the important advancement in geospatial technology for drainage system mapping and their periodic monitoring in GIS environment (Singh et al, 2013 & 2014). The use of Digital Elevation Model (DEM) in specific has made watershed demarcation a comparatively a smooth process. Furthermore, morphometric analysis was employed for characterizing watersheds (Nag 1998; Sreenivasa et al. 2004, prioritization of watersheds and for the development of ground water resources (Sreedevi et al. 2005, 2009). Vijith and Satheesh (2006); Manu and Anirudhan (2008); Rai et.al. 2014; evaluated the drainage characteristics using remote sensing and GIS tools. Magesh et al. (2011) calculated numerous morphometric parameters from Survey of India (SOI) topographical maps and shuttle radar topography mission (SRTM) DEM in GIS platforms. The objective of this paper is to build spatial database for Hindon river basin to explore the hydrological behavior through the of SRTM DEM and GIS techniques to evaluate linear, aerial and relief aspect of the basin and their hydrological inferences.

2. Study Area

Hindon River basin originates in the lower Himalaya in Saharanpur district and flowing through the important cities of Uttar Pradesh Muzaffarnagar , Meerut, Bhagpat , Ghaziabad and lastly merged with Yamuna river in Gautambudh Nagar and make an important river basin. The Hindon River, basin which is important tributary of Yamuna river of Indo-Gangetic plain and contributes important source of water resource of the area for surface and ground water resources. The basin forms a part of Middle Ganga alluvial aquifer of North India with flat topography under the geographic latitudes 290 10' - 290 30' N and longitudes $78^0$0'-78^0 15' E (Fig.1).The normal average annual rainfall of the basin is about 750 mm. May is the hottest month in the basin and maximum temperature reached upto 46^0 C and lowest temperature reached upto 6^0 C in the month of January.

Figure 1: Location map of Hindon River Basin



3. Data and Materials used

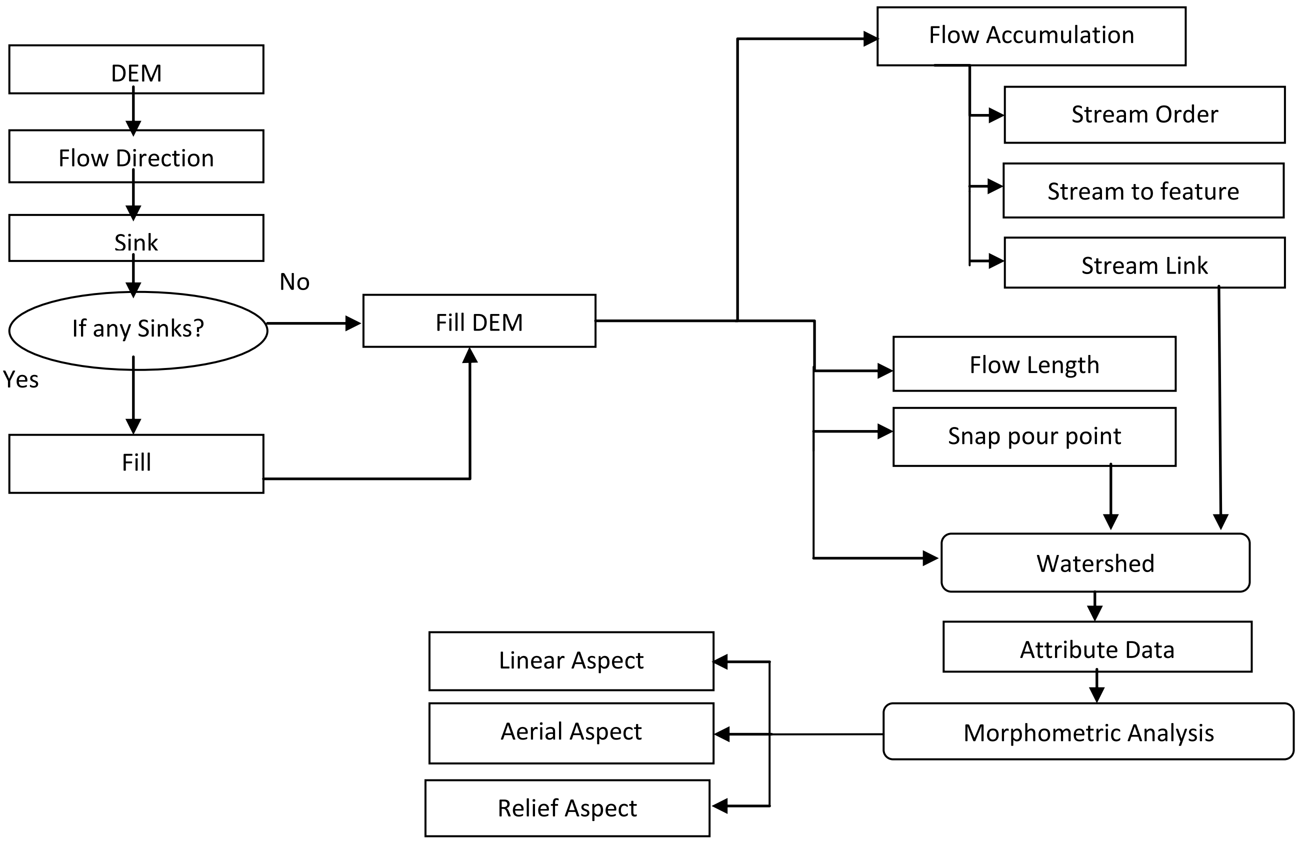
The main title (on the first page) should begin 1-3/8 inches (3.49 cm) from the top edge of the page, centered, and in Times 14-point, boldface type. Capitalize the first letter of nouns, pronouns, verbs, adjectives, and adverbs; do not capitalize articles, coordinate conjunctions, or prepositions (unless the title begins with such a word). Leave two blank lines after the title.

Table 1: Data Used in the present work

Types of data/software	Details of data/software	Sources
SRTM DEM	90 m, Year 2004	http://srtm.csi.cgiar.org/
Landsat 8 satellite imagery	Path/row: 146/39 and 146/40, Dated 30/01/2016 and 02/03/2016	https://earthexplorer.usgs.gov/
ArcGIS software	ArcMap 10.3	http://desktop.arcgis.com/

4. Methodology

The initial process in any hydrologic modeling is to fill the elevation grid. Fill process is completed by filling in sinks.Flow direction is a significant factor in hydrologic modeling to identify where landforms drains, it is essential to determine the flow direction for each cell in the landscape. Flow direction was deliberated for each pixel using the filled DEM (Fairfield & Leymarie 1991; Bhatt & Ahmed 2014). Arc Hydro in Arc GIS-10.3 platforms, permits water from a given cell to flow into only one adjoining cell. Flow accumulation is the subsequent step in hydrologic modeling. In order to produce a drainage network, it is obligatory to determine the eventual flow path of every cell on the landscape grid. Flow accumulation was used to produce a drainage network, dependent on the flow direction of each cell (Mark 1983; Bhatt & Ahmed 2014). The detail methodology for SRTM DEM processing and extraction of drainage morphometric parameters were presented in the Flow Chart (Fig.2)



(Source: http://webhelp.esri.com/arcgisdesktop/9.3/printBooks_topics.cfm?pid=6050)

Figure 2: Methodology adopted for Drainage Morphometric Analysis

5. Results and Discussion

Quantitative morphometric assessment provides very reliable information to evaluate and understand the hydrological behavior of the rocks and their hydraulic characteristics. Hydrogeological observations, integrated with drainage analysis, provide useful clues regarding broad relationships among the geological framework of the basin (Singh et al; 2014). Therefore, the results reveal different levels of agreement using morphometric analysis, which were supposed to be different from one region to another. Various important linear, areal and relief aspect of Hindon river basin and their hydrological inferences were discussed in detail in the table 2,3,4 & 5, basin delineation map shown figure 3 and drainage map with stream order shown figure 4. Most of the observed morphometric variables from aerial, linear and relief aspect of the Hindon river basin comes under the good potential for water resource management programs as presented in tables.

Figure 3: Basin delineation of Hindon river basin

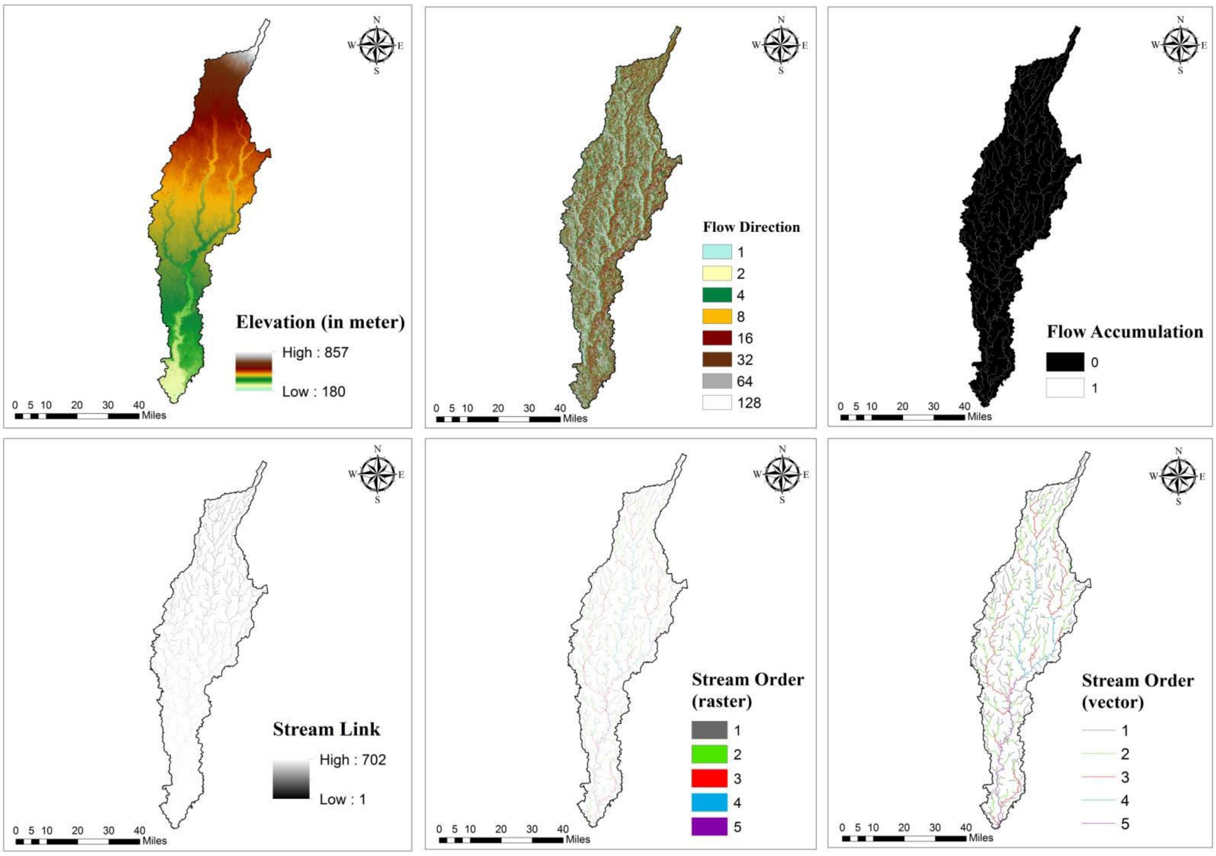


Table 2: Methodology of calculating morphometric parameters

Sl. No.	Morphometric Parameters	Formula	Reference
A	**Linear aspect**		
1.	Stream Order	Hierarchical Rank	Strahler (1952)
2.	Stream length (Lu) (km)	Length of the stream	Strahler (1964)
3.	Mean stream length (km) (Lsm)	Lsm = Lu/Nu	Strahler (1964)
4.	Stream length ratio (Lur)	Lur =Lu/(Lu-1)	Strahler (1964)
5.	Bifurcation ratio (Rb)	Rb= Nu/Nu+1	Strahler (1964)
6.	Mean bifurcation ratio (Rbm)	Rbm = average of bifurcation ratios of all order	Strahler (1964)
B	**Aerial aspect**		
7.	Form factor Ratio (Rf)	Ff = A / Lb2	Horton (1932)
8.	Elongation Ratio (Re)	$Re= 2\sqrt{(A/\pi)}/L$	Schumm(1956)
9.	Circulatory Ratio (Rc)	$Rc=4\pi A/P2$	Miller (1953)
10.	Drainage Texture (Dt)	Dt = Nu / P	Horton (1945)
11.	Drainage Density (Dd)	Dd = Lu / A	Horton (1932)
12.	Stream Frequency (Fs)	Fs = Nu / A	Horton (1932)
13.	Length of overland flow (Lo)	$Lo= 1/Dd\times2$	Horton (1945)
C	**Relief aspect**		
14.	Total Basin relief (H) (m)	H = Z - z	Strahler (1952)
15.	Relief Ratio (Rhl)	Rhl = H / Lb	Schumm (1956)

Table 3: Linear aspect of Hindon river basin

Stream Order	Stream number (Nu)	Total Stream Numbers	Stream length (Lu) (km)	Total Stream length (km)	Mean stream length (km) (Lsm)	Stream length ratio (Lur)	Bifurcation ratio (Rb)	Mean bifurcation ratio (Rbm)
I	354		1205.444914		3.405212			
II	71		526.490133		7.415354	0.43	4.98	
III	13	441	309.511207	2296.22	23.808554	0.59	5.46	4.735
IV	2		143.417623		71.70881	0.46	6.5	
V	1		111.356859		111.356859	0.77	2	

Table 4: Aerial aspect of Hindon river basin

Basin Perimeter (km) (P)	Basin Length (Lb) (km)	Basin Area (km2) (A)	Form factor Ratio (Rf)	Elongation Ratio (Re)	Drainage Density (Dd)	Circulatory Ratio (Rc)	Drainage Texture (Dt)	Stream Frequency (Fs)
688.89	171.12	5299.66	0.18	0.49	0.64	0.14	0.64	0.08

Table 5: Relief aspect of Hindon river basin

Max. Basin Height (Z) (m)	Min. Basin Height (z) (m)	Basin Relief (H) (m)	Relief ratio (Rh)
857	180	677	3.956

This watershed have a dendritic drainage pattern which identifying the homogenous subsurface strata of this study area. The drainage pattern of this basin has provided quantitative description of basin geometry. The basin is characterized by dendritic type of drainage pattern with varying density (Figure. 4). The hard sandstone and shales are found on the high density. The total number of streams of this basin is 441 and the total length of the streams of this basin is 2296.22 km. The Hindon river basin is a 5th order basin with a total drainage area of 5299.66 sq. km (Table-4). The total number of streams in each order gives a good idea of the distribution of the water channels of the smallest to largest level in the region and how well the area is covered in the water flow network.

The relationship between the stream length ratio and the bifurcation ratio is determined by hydrogeological, physiographical and geological characteristics.

The value of total stream length, mean stream length and stream length ratio of different stream orders of the Hindon watershed are shown in Table 3. The mean bifurcation ratio of watershed is 4.735, indicating that the drainage pattern is not much affected by tectonic and structural disturbances.

The maximum height of this basin is 857 m and the minimum height of this basin is 180 m. The elevation difference between the highest and lowest points on the basin floor is known as the total relief of that basin. In the present study the relief ratio (Rh) value of the basin is 3.956 which shows that the major portion of the basin is having steep slope (Table 5).

Figure 4: Drainage network with stream order of Hindon River Basin

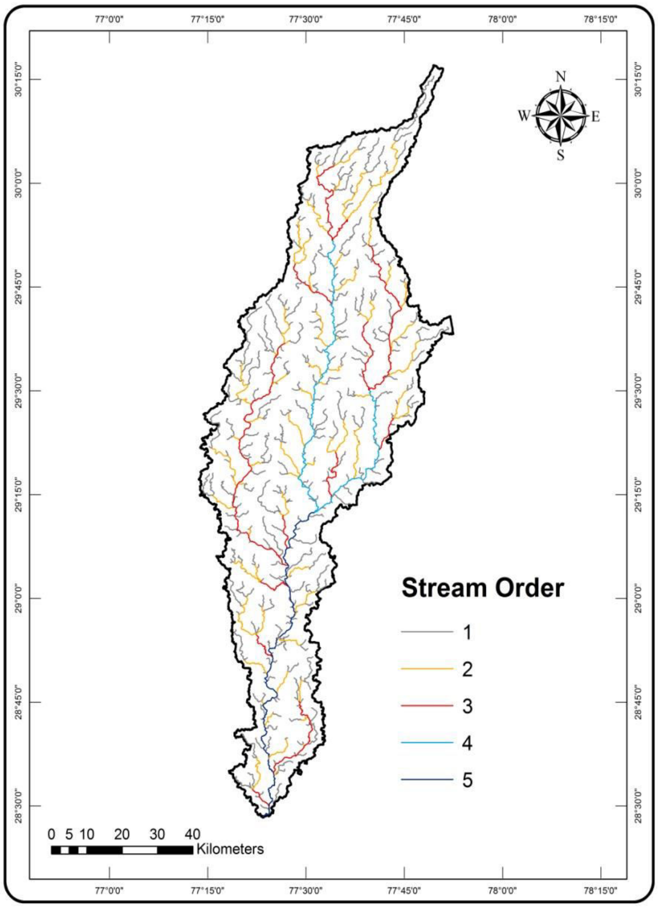


Figure 5: Slope of Hindon River Basin

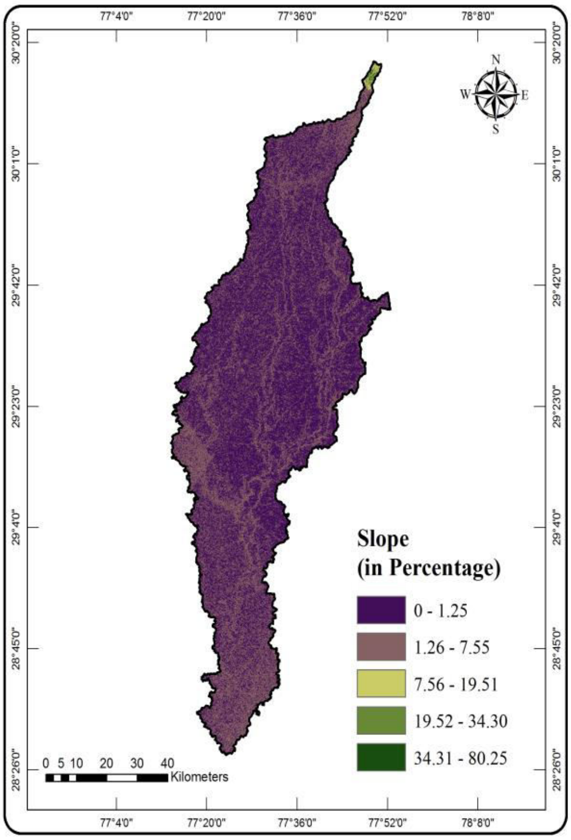
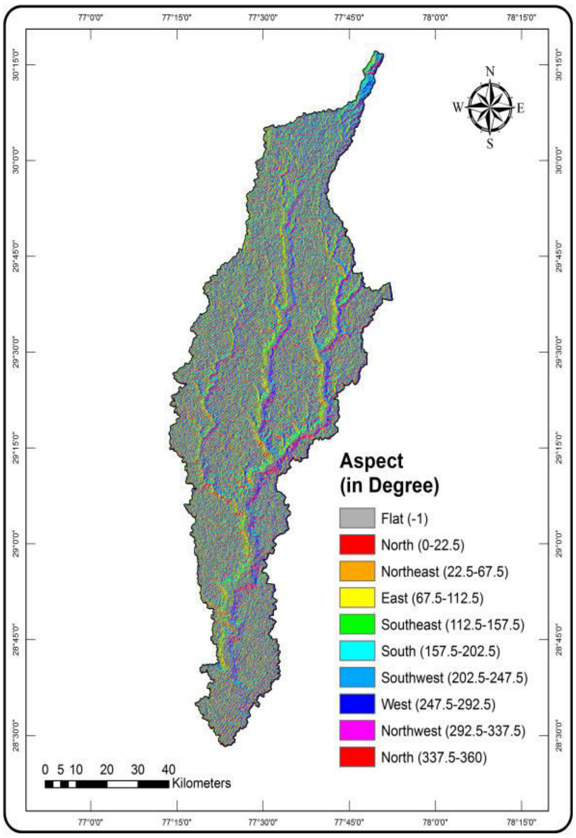


Figure 6: Aspect of Hindon River Basin



6. Conclusion

Remote sensing and GIS techniques have an effective tool in drainage extraction through DEM data. GIS based study of morphometric factors extraction at basin level is good data base for water resource management. The results observed from various linear, aerial and linear aspects of the basin revealed that basin have good prospect and potential for groundwater management activities. The assessment of drainage characteristics of Hindon basin and its fifth order streams revealed the significance of morphometric studies in terrain characterization and basin evolution studies. Morphometric analysis of Hindon basin in India offers not only an well-designed description of the basin landforms, but also helps as an influential means of associating the form and process of river basins that may be extensively separated in space and time and its outcomes did show that rainfall has a substantial part in the drainage development whereas structure and relief of rocks dictate the drainage pattern.

7. Acknowledgements

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