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Impact of Dam Construction on River Flow Using River Connectivity Index

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Abstract – *River are under in rising pressure from anthropogenic effect with incremental dam construction, experiencing global and regional alterations due river disconnectivity, flow control and sediment reduction. Accessing the summative impacts of dam on the river disconnectivity in massive basins can assist us understand how human disintegrate the river system and natural flow regimes. Using the Stretch of Yamuna River basin as the study area. This study employed modified metrics river connectivity index to estimate the accumulative impacts on river disconnectivity. In present study, Stretch of Yamuna River basin has been selected for elaborated morphometric analysis. SRTM 1 arc-second global elevation (30-meter resolution) is used and further processed using ArcGIS 10.5 for the analysis. Several parameters such as trap efficiency, possibility, and Strahler weighted number are used for the computation of the river connectivity index. The study can help to encourage more environmentally sustainable river management policies in the Stretch of Yamuna River basin and other basins.*

Key Words: Geomorphometric assessment, River disconnectivity, Stetch of Yamuna River, River regulation. Trap efficiency.

1. INTRODUCTION

Dams are an important source of hydro-energy, shield against floods, for irrigation water purpose, and assist to increase water security, but also have considerable impacts on the ecological unity of aquatic systems and on the productivity of river systems that provide essential resources for rural communities and regional economies. Dam construction represents one of the most important anthropogenic features on earth. Dam has exerted various impacts on land – ocean processes, thus activating various adverse, often unwanted sequential both globally and regionally, including impacts on sediment remembrance and downstream sediment starvation, flow regulation, river disconnectivity, biodiversity loss, coastal erosion, and shoreline retreat.

ArcGIS 10.5 is a geographical information system (GIS) for working with maps and geographic data. It is used for procreating and using maps, acquiring geographic data, evaluating mapped data, sharing and discovering geographic data, using maps and geographic data in a range of applications, and managing geographic data in a database. The system allows an infrastructure for procreating maps and geographic data available throughout an organization, across a community, and openly on the Web.

As the quantitative indicator of River Connectivity Index (RCI), RCI is measured by using an accessibility method defined by the modified traditional accessibility method. Previous researchers defined accessibility as the intensity of the passability of interaction. Here, we define accessibility as the degree of difficulty for a certain volume of river flow to overcome various physical barriers from one particular location to the other one in the river channel. The quantitative assessment indicators of accessibility generally include time accessibility and distance, accessibility.

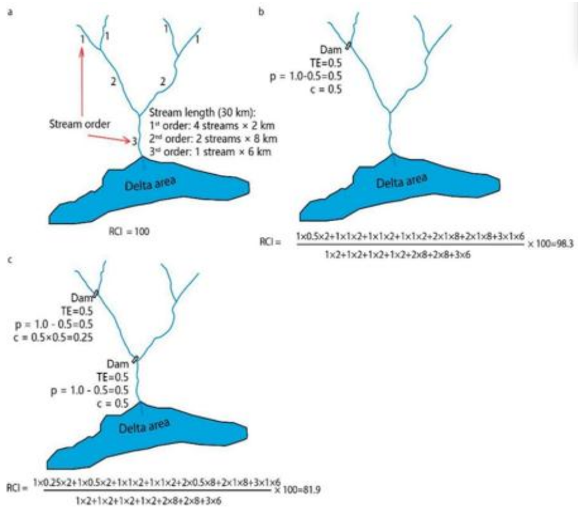

Fig. -1: River connectivity index

1.1 Study Area

The Yamuna also known as the Jumna or Jamna, is the second largest tributary river of the Ganges (Ganga) and the longest tributary in India. Originating from the Yamunotri Glacier at a total height of 6,387 meters (20,955 ft) on the southwestern slopes of Bander pooch peaks of the Lower Himalaya in Uttarakhand, it travels a total length of 1,376 kilometers (855 mi) and has a drainage system of 366,223 square kilometers (141,399 sq. mi), 40.2% of the whole Ganges Basin. It merges with the Ganges at Triveni Sangam, Prayagraj (Allahabad).

The aim of this study was to delineate the river basin using Arc GIS 10.5 then to calculate and compare the parameters linear, areal and relief aspects of the selected basin. Later, locate all the dams on the river stream and then finally evaluate summative impacts on river disconnectivity over years.

The Scope of the work was to help in promoting more environmentally sustainable river management policies for the river and to understand the hydrological response behavior of the study area.

1.2 Data Used

Remote Sensing and GIS techniques are the proven efficient tools in the delineation, updating and morphometric analysis of drainage basin. The drainage basin analysis is essential in any hydrological examination like evaluation of groundwater potential and groundwater management.

Table -1: Data Used

Data	Sources
Shuttle Radar Topography mission 1 Arc- second Global elevation data that is SRTM (30m).	Earth Explorer (http://earth explorer.usgs.gov/)

SRTM is downloaded directly from the U.S. Geological survey (USGS) portal of the earth explorer. The SRTM is operated by the organization NASA and the NGA (National geospatial-intelligence agency) to incorporate the radar data that have been used for creating global sets of land elevation. SRTM gives void filled radar data worldwide of 30m resolution.

Geomorphology is the consideration of shape, configuration of land surface features of earth, landform dimensions (such as plains, hills, rivers and valley). It can also be called as the scientific study of the evolution of features (viz. topography) and its origin that may be created by chemical, physical or biological processes that occurs at above or near the earth surfaces.

Morphology in general is the mathematical analysis and the measurement of shape, earth surfaces configuration and landform dimensions. Morphometric analysis is done basically by calculating the aerial, linear, relief, drainage density, gradient of basin network and slope of contributing basin.

River morphology or fluvial geomorphology is the study to explain or describe the shape of river channel, its meandering characteristics, and the way they change their shape and course with time. It is a function of various processes and conditions of environment like composition of rivers banks and beds, banks and bed erodibility, river path formation, river erosion, vegetation, availability of sediment, and sediment transport rate through river channel, deposition of sediments on banks, floodplains and beds.

River morphology is also affected by human interactions. Drainage basin refers to area supplying water to the channel as along with course of water, it is general term used for defining river. River system comprised of channel mainstream and its several tributaries and is well described by term drainage network or pattern which generally formed from tributaries of several systems of stream network.

Morphometric analysis for any kind of drainage basin or its stream networks plays a important role in analysing the basin hydrological behaviour. It helps in understanding the geometric characteristics for land surfaces such as stream networks, texture, slope, drainage pattern, soil condition, topography, relief characteristics, runoff characteristics and soil water potential.

2. METHODOLOGY

For morphometric analysis we mainly depend on the analysis of radar data (which is here used in the study is SRTM 1 arc-second Global elevation (30 meters). Firstly, the study area is selected and then radar data is collected from USGS earth explorer. Secondly, Watershed is delineated such as SRTM DEM, Mosaicking DEM, Filled DEM, Flow accumulation, Stream order raster, Stream order vector, Basin, Sub basin. After this extraction of the river basin boundary was done via clip tool in ArcGIS. Then Computation of morphometric parameters such as linear, areal and relief aspects was done. Then finally, locating all the dams on the river basin boundary and Computing the parameters (trap efficiency, passibility, width of the section, length of the section etc.) of analysing the impact of dam construction using RCI method.

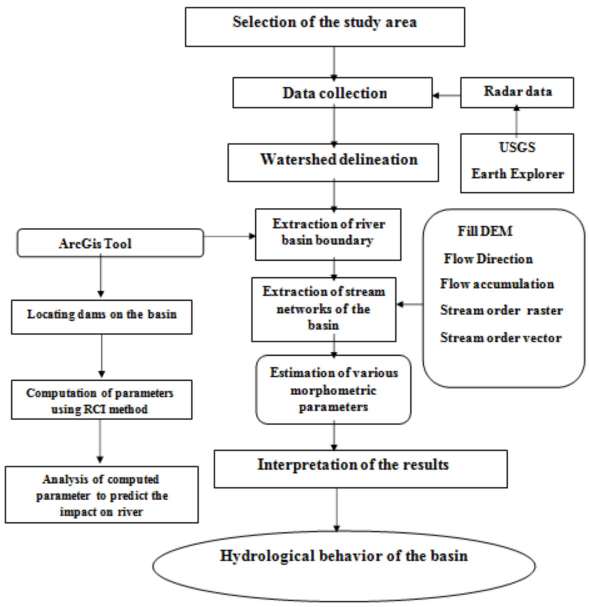

Fig. -1: Flowchart of methodology for present research

3. RESULT

The results obtained from the present study namely morphometric analysis is being carried out for the better understanding about the Stretch of Yamuna River basin. The study deals with the basin characteristics, linear, areal and relief aspects for the Stretch of Yamuna River and its sub-basins were calculated and discussed.

In the present study the Stretch of Yamuna River basin boundary was extracted from the DEM (mosaicked DEM to covers the entire basin boundary). Further in addition to this the stream networks were generated in the above-mentioned watershed. Sub-basins were found in the Stretch of Yamuna River basin region after analysis using Arc GIS 10.5. Each and every sub-basin along with the main basin was studied thoroughly and analyzed. The various morphometric parameters such as linear, areal, relief and basin characteristics of the Stretch of Yamuna River basin and its sub-basins were calculated, and the hydrological significance and importance of these above estimated parameters were discussed thoroughly.

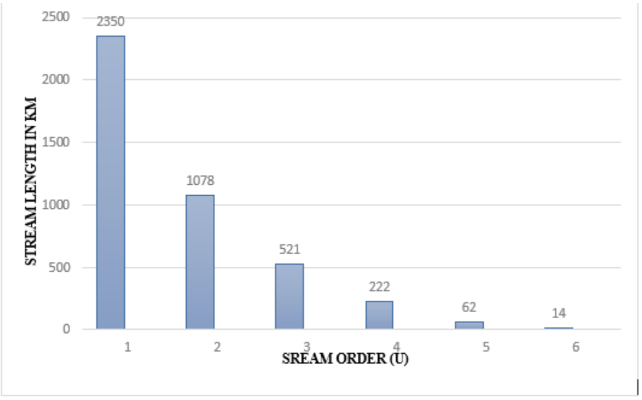

Fig. -1: Plot of stream length Vs Stream order

Plot showing geometric relationship between log of stream length (Lu) and stream orders (u) The streams of short length are representing the areas with large slopes and fine texture, wherein, the streams of longer length generally indicate lower slope or gradients.

The stream length of the channel decreases with the increase stream order and vice-versa.

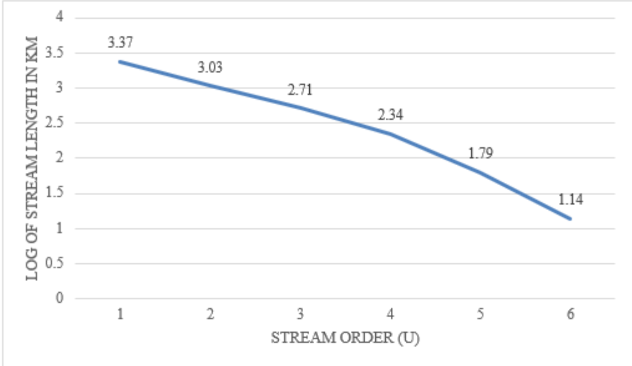

Fig. -2: Plot showing geometric relationship between log of stream length (Lu) and stream orders (u)

Plot between logarithms of stream length vs stream order above showed the linear pattern that indicates that there is a homogeneous rock material subjected to erosion due to weathering characteristics of the basin.

Table -1: The summarized value for morphometric analysis of the entire Stretch of Yamuna River

S.No	Morphometric Parameters	Symbol						
			Basin Characteristics					
1	Basin Area	A	3498.57 km^2					
2	Basin perimeter	P	1085.662 km					
3	Basin length	L_b	263.73 km					
			Linear Aspects					
4	Stream Order	U	1	2	3	4	5	6
5	Stream Number	N_u	2350	1078	521	222	62	14
			-	½	2/3	3/4	4/5	5/6
6	Bifurcation ratio	R_b	-	2.17	2.06	2.34	2.86	4.42
7	Mean bifurcation ratio	$(R_b)_{mean}$	2.91					
8	Stream Length	L_u	2717	1464	821	357	110	23
9	Mean Stream Length	L_{sm}	1.15	1.35	1.57	1.6	1.76	1.66
				2/1	3/2	4/3	5/4	6/5
10	Stream length ratio	R_L	-	1.17	1.16	1.01	1.1	0.94
11	Mean stream length ratio	$(R_L)_{mean}$	1.07					

Table -2: The summarized value for morphometric analysis of the entire Stretch of Yamuna River

Areal aspects			
12	Form factor	R_f	0.05
13	Elongation Ratio	R_e	0.25
14	Circulatory Ratio	R_c	0.63
15	Shape Factor	B_s	20
16	Compactness coefficient	C	5.17
17	Drainage Density	D_d	1.57
18	Length of overland flow	L_o	0.78
19	Constant of channel maintenance	C_c	0.63
20	Stream frequency	F_s	1.22
21	Drainage texture	T	3.91

Table -3: The summarized value for morphometric analysis of the entire Stretch of Yamuna River

Relief Aspects			
22	Basin Relief	R	1685
23	Relief Ratio	R_r	0.006
24	Ruggedness number	R_n	2.64

Table -4: Calculation of storage capacity of the reservoir

Parameters	Elevation (in Km)	Area (in Km^2)	Storage capacity	Storage Capacity/ Basin Area Ratio
Sub-basins	H	A	C	
1	0.448	570.83	85.24	0.149
2	0.640	612.257	378.51	0.618
3	0.644	1328.521	610.22	0.45
4	1.676	308.88	1272.63	4.12
5	0.049	536.059	20.44	0.038

4. CONCLUSION

These results indicate that the site of a dam finds its relative impact on river disconnectivity. The magnitude of the summative impacts on river connectivity is demonstrated by RCI. As shown in the tributaries of the Stretch of Yamuna River basin, dams positioned at the headwaters or small streams can lessen the loss of river connectivity, while dams placed at the main stem or major tributaries can lead to a notable impact on river disconnectivity.

This study evidenced a basin-wide river disconnectivity evaluated in the Stretch of Yamuna River basin. It allows environmental insights into the stretch of Yamuna River.

One more core value of this study is that the analyses will enable the copy of homologous assessments in other river basins, based on which the assessments can allow water resource managers to characterize watersheds, determine priorities for optimizing water resources allocation and infrastructure plans (placement of dams), and reports on river disconnectivity as a component of river intactness.

At present, the RCI value for the stretch of Yamuna River has decreased from 100 to 81.9, indicating that the Yamuna River has experienced strong alterations over the past decades. This study also showed that small dams can also drive eloquent impacts in flow regulation on regional river systems through their sheer number and density.

The impacts of small dams are analogous to large dams for the fourth- and fifth-order streams, or even exceed large ones for the first-, second-, and third-order streams. They also worsen the impact of large dams on large streams. As demands on energy and water resources increment in the Stretch of Yamuna River basin, the government is now engrossed in a new expansion of dams in great staircases.

This research can help address the environmental risks connected with further impacts caused by new dams. Integrating the approaches into environmental impacts assessments can also present a new framework to integrate river connectivity and free-flowing functionality into hydropower sustainability and add a basin-wide perspective to conventional environmental impacts evaluation.

The results evidence that the construction of dam should be in such a way that the disconnectivity in the river is very less. The results will be helpful to the policymakers for better planning and management over the study area. In addition, the presented result will be helpful for development of advance flood forecasting system, for preparedness of disaster relief packages and therefore should be integrated with current system which will in turn reduce the flood damages and human lives. This study will provide a guideline to water resource managers by analyzing watershed morphometrically using RS and GIS techniques with an aim to improve the management approach in sustainable way. The basin prioritization could be carried out from this study will be very helpful in water, soil and all other natural resource management this study and these computed parameters each signifying the specific characteristics of the basin is of greater importance for the geomorphologic study and in other future investigations in these fields.

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