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THE USE OF REMOTE SENSING DATA FOR MAJOR MORPHOLOGICAL CHANGES & TERRAIN ATTRIBUTES OF THE GLACIAL VALLEY, UTTARAKHAND, INDIA

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Abstract: Remote sensing technique has emerged as an effective tool for systematic survey, analysis, and better management of natural resources and understanding the morphological changes and terrain analysis. Morphological analysis of a watershed provides a quantitative description of the drainage system which is an important aspect of the characterization of watersheds (Strahler, 1964). Morphometric analysis requires measurement of linear features, areal aspects, gradient of channel network and contributing ground slopes of the drainage basin (Nautiyal, 1994). The remote sensing technique is a convenient method for morphometric analysis as the satellite images provide a synoptic view of a large area and is very useful in the analysis of drainage basin morphometry. The surface configuration of the Alaknanda Basin-Uttarkashi-Gangotri area can be analyzed with the help of different morphometric techniques like relative relief, dissection index, drainage density, drainage frequency and average slope, nature of long profile, sinuosity index etc. to find out the characteristics of Uttarkashi-Gangotri terrain. Alaknanda valley and Bhagirathi valley presents a well-developed watershed in which snow, glaciers, running water and mass gravity movements are the important factors in sculpturing surface geometry.

Index Terms **- Morphological changes, terrain analysis, remote sensing, polygenetic landscape**

1. Introduction:

The Chamoli-Devprayag area with in Alaknanda Basin and Uttarkashi-Gangotri area within the Bhagirathi Basin and are the representative of polygenetic and multicyclic landscape characterized with distinct glacial, glacio-fluvial, fluvial and tectonic landform units with many complex-compound-composite drainage peculiarities. The area under investigation predominantly belongs to the domain of glacial landforms developed during the last glacial period (Pleistocene) cold climate and presently being worked over by glacial, periglacial and fluvial processes with decreasing intensity southward. In geomorphology especially in the present context, the evaluation of terrain can be better expressed based on the morphometric analysis of the Uttarkashi Gangotri area. Terrain evaluation incorporates a major role to analysis the characteristics of the landforms of Uttarkashi Gangotri area, Uttarakhand. Pioneering work on the drainage basin morphometry has been carried out by Horton (1932, 1945), Miller (1953), Smith (1950), Strahler (1964) and others. In India, some of the recent studies on morphometric analysis using remote sensing technique were carried out by Nautiyal (1994), Srivastava (1997), Nag (1998), Srinivasa et al (2004). Gangotri, the largest glacier of Uttarkashi District is a place of pilgrimage since time immemorial. In 1842, Hodgson and Herbert were the pioneers to visit the area for scientific work and J.B.Auden Auden, J.B. (1937) of the Geological survey of India initiated the systematic survey on 1:4800 scale in 1935 (G.S.I, 1937) and he deserves the credit for preparing the first ever detailed map of the snout of this glacier and also calculated the retreat amount over the last century. After then the snout of Gangotri glacier was surveyed in 1956, 1967 and 1971 by Jangpangi

(1958), Tewari (1968), and Vohra (1971) respectively (Tiwari, A.P. 1972). V.M.K. Puri and V.K.Raina (Raina, V.K. 2009) also conducted some glaciological studies during 1973 to 1977. V.M.K. Puri again analyzed the glacier in 1990 and C.V.Sangewar (1997) studied it in 1996. In recent years various projects have been sponsored for this region by the Department of science and technology, Govt. of India. Pratap Singh, K. S. Ramasastri, Naresh Kumar from the National Institute of Hydrology, Roorkee and Umesh K. Haritashya, from the department of Earth Sciences, Indian Institute of Technology, Roorkee studied for the meteorological condition of Gangotri Glacier region with the help of the department of Science and Technology, New Delhi. Naithani (2001) vividly discussed topographical expressions of multicyclic landscapes in Gangotri Gaumukh area emphasizing valley in valley, U-shaped valley, numerous waterfalls, nick points etc. From the basis of different type of soils and geomorphic processes (glacial, glacio fluvial and fluvial) of the region, it is clear to us that the entire study area is representative of a polygenetic landscape at the lower elevation where glacier melts there are some depositional landforms created by glacial as well as glacio fluvial dynamics like terminal, lateral, ground and surface moraines, earth pillar, out wash plain etc. The present landforms are results of polycyclic endogenetic and exogenetic processes operating at varying intensi¬ties through time.

1.1 STUDY AREA:

Joshimath and Badrinath lie in the Great Himalaya physiographic zone and also in the Alaknanda basin (Fig.1). This is a mountainous zone consisting of ridges and slopes formed by valleys of Alaknanda river and its tributaries. The study area is located between 30°00' N to 31°00' N and 78°45' E to 80°00' E, covering an area of about 11,396 Km2. Alaknanda River, a main tributary of the Ganga River originates from the Satopanth and Bhagirathi Kharak group of glaciers. Alaknanda River is also contributed by tributaries namely; Saraswati, Dhauli Ganga, Nandakini, Pindar and Mandakini. The river flows ~230 km before it joins the Bhagirathi River at Devprayag at an altitude of 450 amsl. The basin 433 km2 is under glacier landscape and 288 km2 is under fluvial landscape. The river Alakananda flows from South-west to South-east and Saraswati flows from North-east to South-east part of Chamoli district. Bhagirathi basin is drained by Bhagirathi river which originates from Gangotri glacier snout known as "Gaumukh" at an elevation of 3972 m asl.

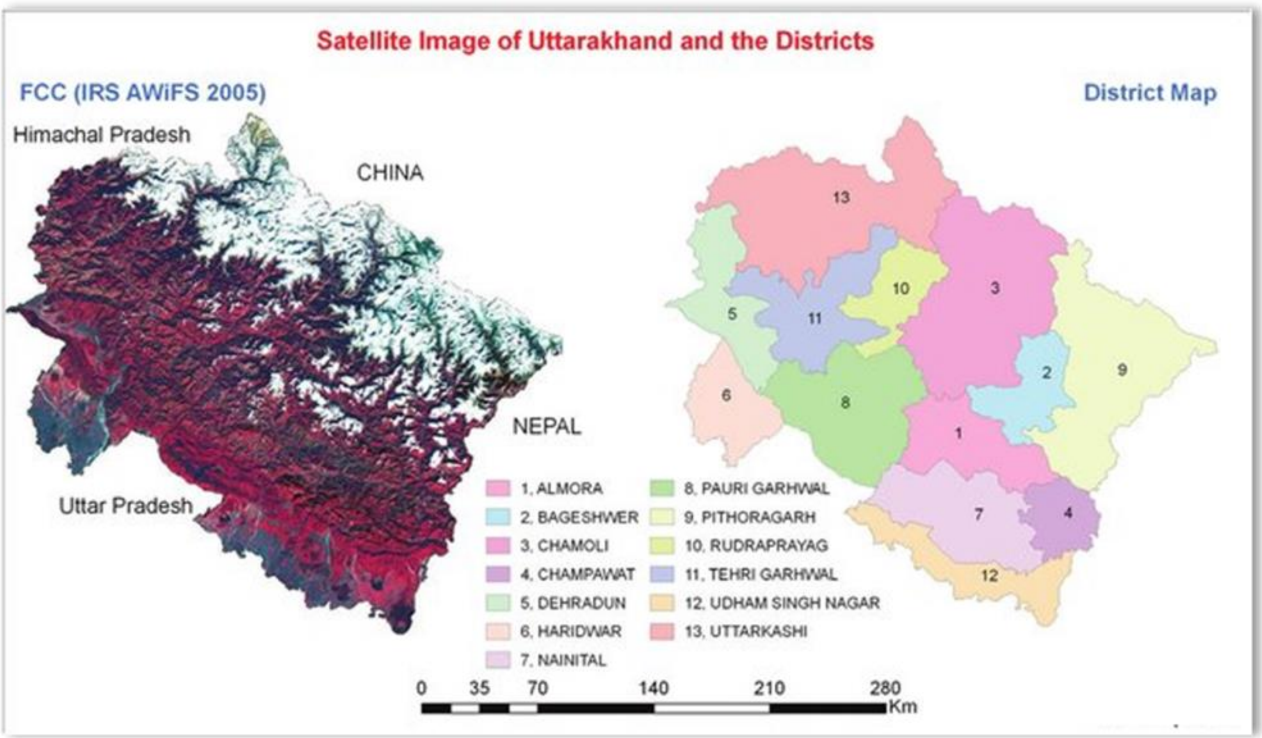

Figure 1: Satellite Image of Uttarakhand & District Map. Source: http://www.india-wris.nrsc.gov.in

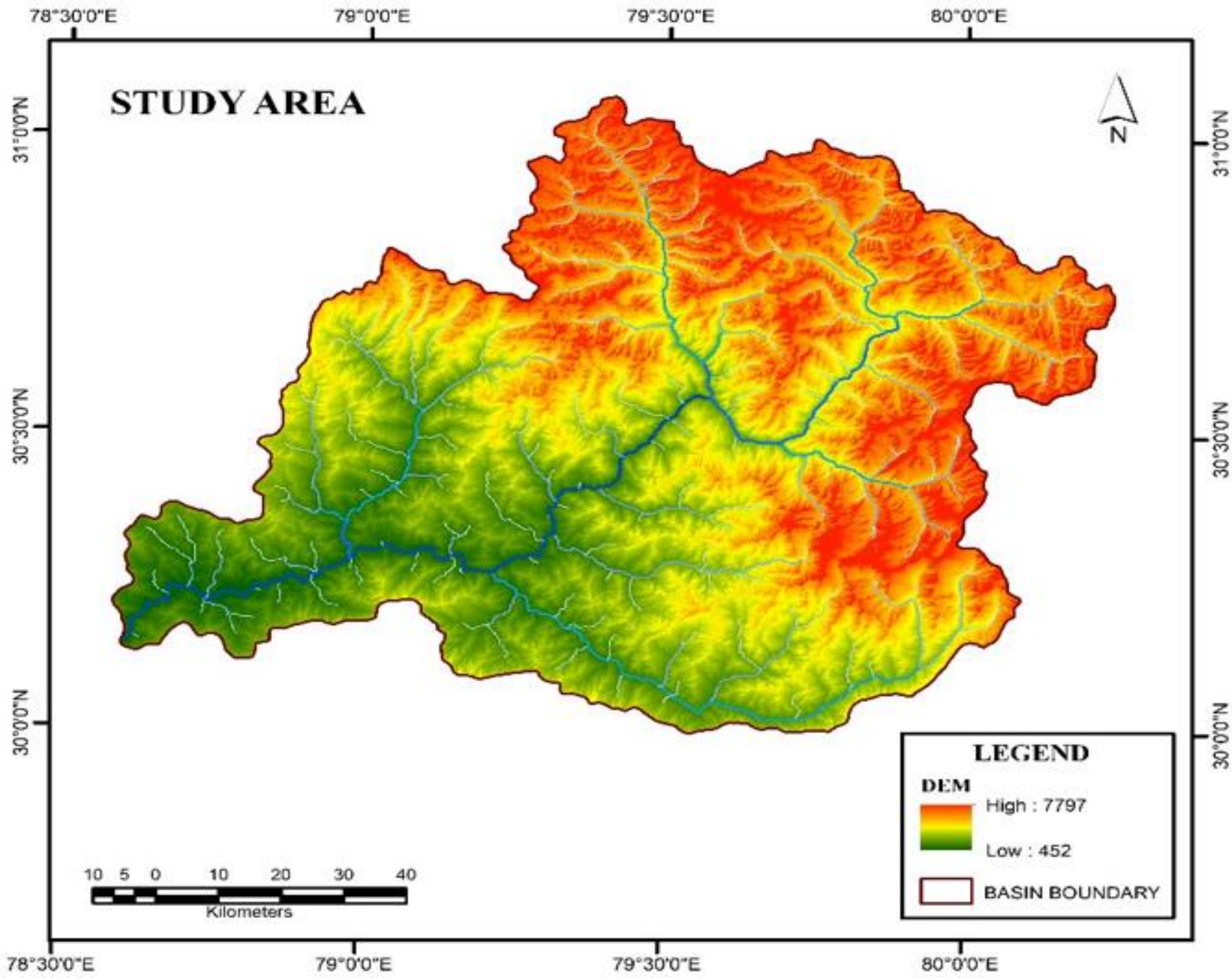

Fig. No. 1a: Location Map of the Alaknanda Basin (Source: S.O.I & NRSC)

1.2 Methods and Data used:

In order to fulfilment the objective of the research work this research worker has adopted modern methodology, procure the necessary data, information and evidences. Most of the observations in this study have been based upon intensive field work in the area under consideration. The study thus is based on available data and empirical observations. At first the study related maps were collected from different Govt. organization like topographical sheets (53 N/1, 53 J/13, etc.) from Survey of India, Dehradun and Kolkata, Satellite Imagery (LISS III, 1997, 2005, 2015, 2019 and LISS IV, 1997, 2005, 2015) (Fig.2) from National Remote Sensing Centre, Hyderabad Most of the geomorphological research also depended mainly on the intensive field work. To fulfil the objective of research one of the main purposes of field study was to identify the major glacial-glacio fluvial-fluvial landform in relation to their order of evolution and the another main purposes of the field study was to identify the major existing landuse pattern and the recent landuse changes with the Uttarkashi-Gangotri area. It should be mentioned that detailed field investigation was carried out in and around the Uttarkashi-Gangotri area to ascertaining the precise relationship between the characteristics of landform and land use pattern and also between the tectonic movements and topographic forms. Field study involves the ground truth verification, collection of soil samples from different soil horizons and sites, water samples (ground and surface) and primary data about slope, river velocity, terrace study, cross sectional study of river Bhagirathi, identification of the location of snout of the Gangotri glacier and also the analysis of glacier retreat, location of moraines, identification of various geomorphic features and zoning of landslide prone areas and other related hazards, house hold survey accompanied by interviewing local people, land use observation of the area under consideration with help of the instruments like GPS, Clinometer, Abney Level, Dumpy Level and Prismatic Compass etc. and secondary data were collected from various offices and Institutes like Wadia Institute of Himalayan Geology, Dehradun, IIT of Roorkee, Forest Research Institute, Dehradun, Collectorate House, Uttarkashi, Forest Department, Uttarkashi and Nainital, Disaster Management Cell of Uttarkashi. Post field study involves the processing of raw data, tabulation and preparation of diagrams and finalization of maps like Physiographic Zonation, Geology, Drainage, Geomorphology, broad land use map (supervised classification from LISS III and LISS IV Landsat images), Digital Elevation Model (DEM using ERDAS Imagine 8.4), TIN etc. The researcher herself has prepared the maps with the help of advanced GIS and Remote Sensing softwares like Geometica, Map Info V-9, ERDUS Imagine, Arc view etc. and other software like MS Excel, Origin 6.0 have also been used to process the data.

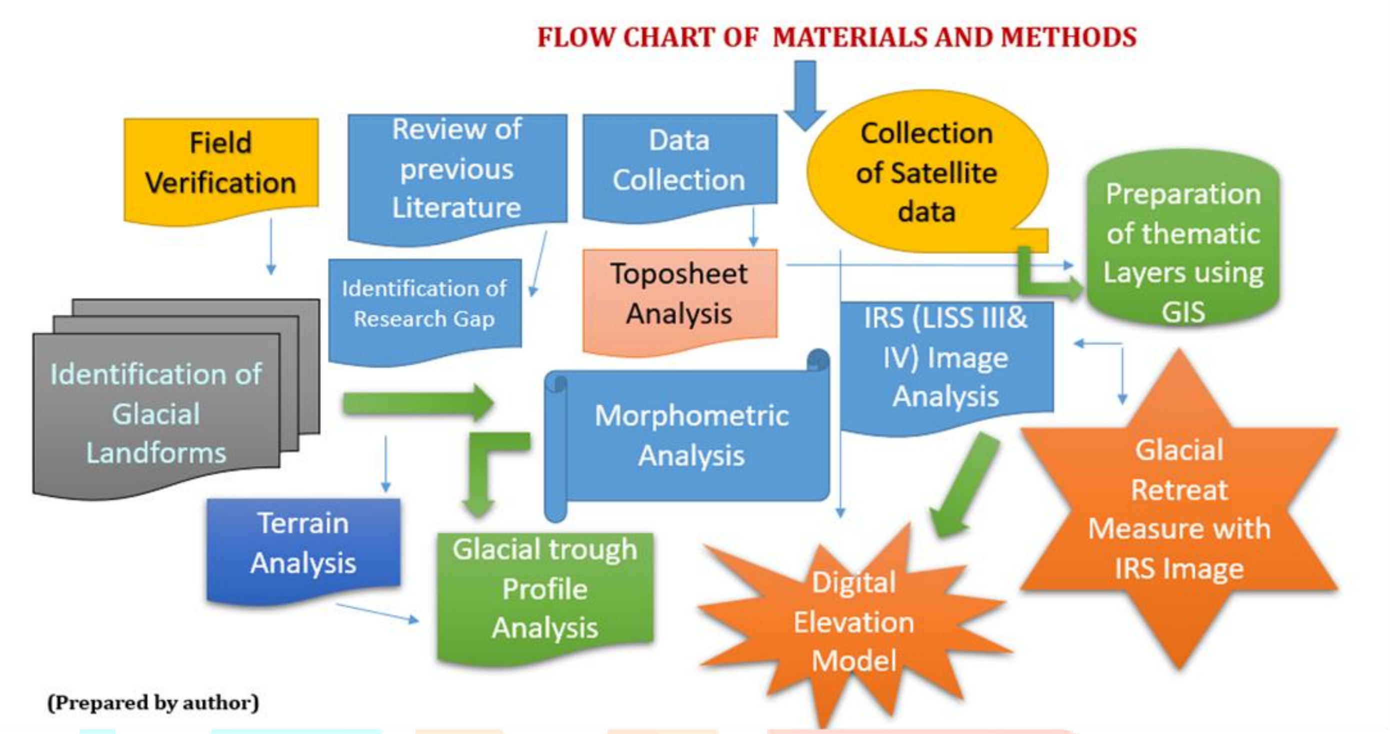

Fig. No. 2: Flow Chart of Materials and Method (Prepared by author)

2. STUDY OF LONGITUDINAL PROFILES WITL LISS III DATA:

The longitudinal course of a river from its source to mouth is called longitudinal or simply long profile. Longitudinal profile of a river represents channel gradient of the river from its source to mouth. The longitudinal channel course is generally smooth curve which rises upstream. The longitudinal profiles of the Gangotri and its tributary glaciers were drawn on the basis of the study of Survey of India toposheet maps (53N/1, J/13, J/5, J/6, J/9, I/16, J/10, I/12 etc.) on a scale 1:50,000. The longitudinal profile of the Gangotri glacier (Fig.3) shows that there are mainly three breaks. The first break, at an altitude of 5600 m at the base of the western slope of Chaukhamba peak. The slope segment up to this break is almost straight with a slight concavity. The upper part of this slope segment forms a steep escarpment, which forms the headwall of the Gangotri glacier. The second break in this profile at an altitude of 4840 m is near the confluence of Swachhand and Sumeru glaciers with Gangotri. The slope is concave between the first and second breaks showing that a portion of the cirque is inhabited by the Gangotri glacier.

The longitudinal profile of Kirti glacier shows four breaks. The Kirti glacier is 11.05 km long, covering 13.4 sq km area located on the left side of the trunk glacier. Three glaciers, the 1st and 2nd tributary glaciers of Kirti located on the right side are rock glaciers, while the 3rd tributary glacier is located on the left side of the Kirti and originates from the northern slopes of Bharte Khunta peak. In Kirti glacier the first break was observed at 5600 m, second at 5080 m, third at 4760 m and the fourth at 4680 m. The slope segment between headwall and first break is convexo – straight, while convex slope element was observed between first and second breaks as well as second and third breaks, which reflect the zone of accumulation. The slope segment between third and fourth breaks is convex while that further beyond up to the snout is straight with some concavity which shows considerable melting and reflects the zone of ablation.

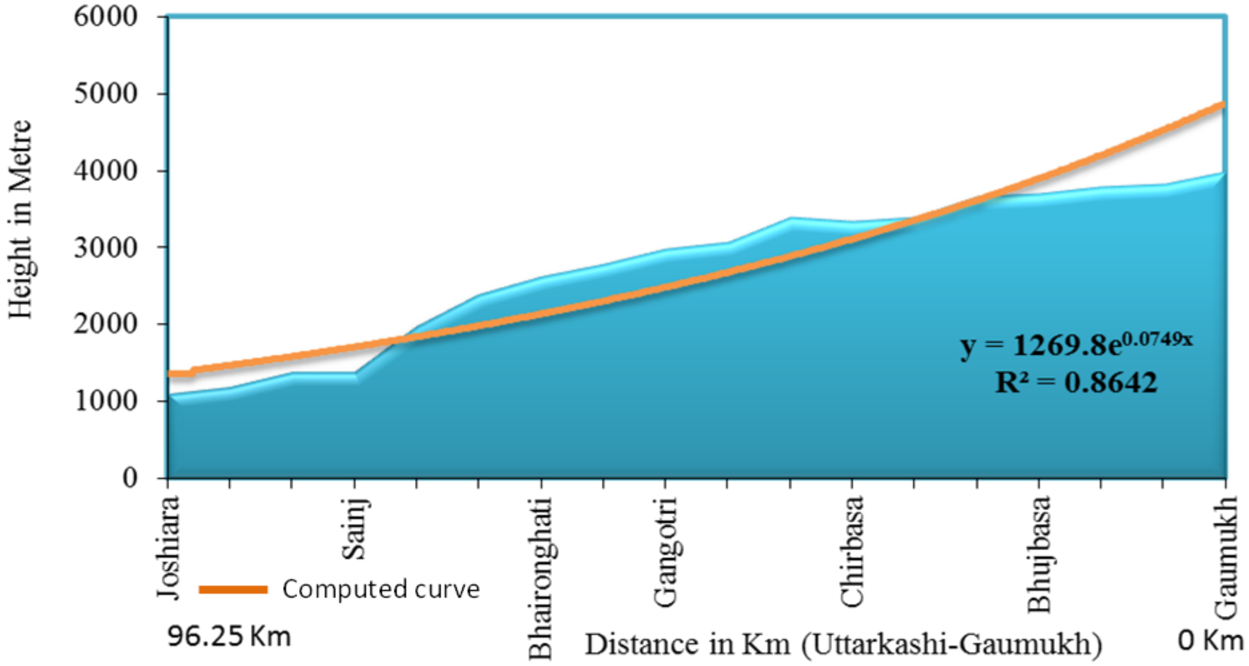

Fig:3 Long Profile of River Bhagirathi from Gaumukh to Uttarkashi in terms of the computed and actual curves showing the occurrences of breaks (Knicks), Geomorphic (Erosion) Surfaces, terraces which relate with interruption in the Progress of Cycle of Erosions mainly due to tectonic activities.

An analysis of the long-profile of the Bhagirathi river has been made from Gaumukh to Uttarkashi. The profile shows seven breaks of slope from Gaumukh to Gangotri. The important breaks in the long-profile are shown in the Figure 3. The concavity around the snout turns into convexity at the first break (3880 m) which may be because of the presence of accumulation of moraines of the glacier. The convexo-straight profile in between second (3760 m) and third break (3560 m) suggests stabilized condition. This segment may indicate the presence of an outwash plain, which may extend upto Bhujbas. The slope segment near Chirbas is almost straight up to the fourth break (3400 m). Beyond this point the slope is steeper showing concavity in between Chirbas and Deogad indicating rapid erosion by glacio-fluvial stream. The slope segment is convexo-straight up to Gangotri that suggest glacio fluvial erosion in the segment. The major break of slope after Gangotri is located in 1.5 km upstream from Bhairanghati (2800m) and it is almost convexo-straight up to Sainj (1400m). Beyond this point the slope is showing concavity up to Joshiyara, (1120m) Uttarkashi.

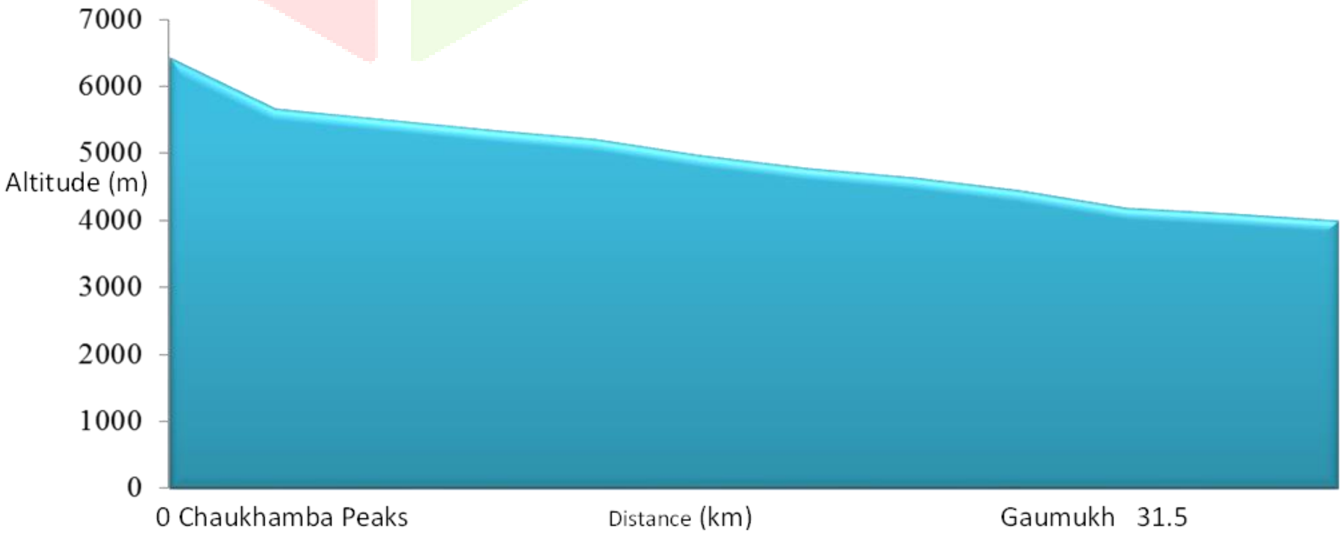

Fig. 4: Long Profile of Gangotri Glacier (Based on LISS III data, 2019 & Toposheet SOI, Google image 2020

EXPONENTIAL CURVE TO THE LONG PROFILE OF THE BHAGIRATHI RIVER:

The researcher has made an attempt to fit (Yc, modified exponential, or mathematical curves; Croxton et al. 1969) to profiles plotted for actual Y (Mukhopadhyay, 1980). The researcher has used the exponential curve of the type Yc = abx + k, where a = altitude, b = slope and k is a constant, which involves a constant ratio of change and, therefore, a constant ratio of change in the amount of change. Actually the equation of the modified exponential is Yc = abx + k, where k is the asymptote (Log.a + x log. b when k is a constant), when a and b are constants and Yc = computed Y.

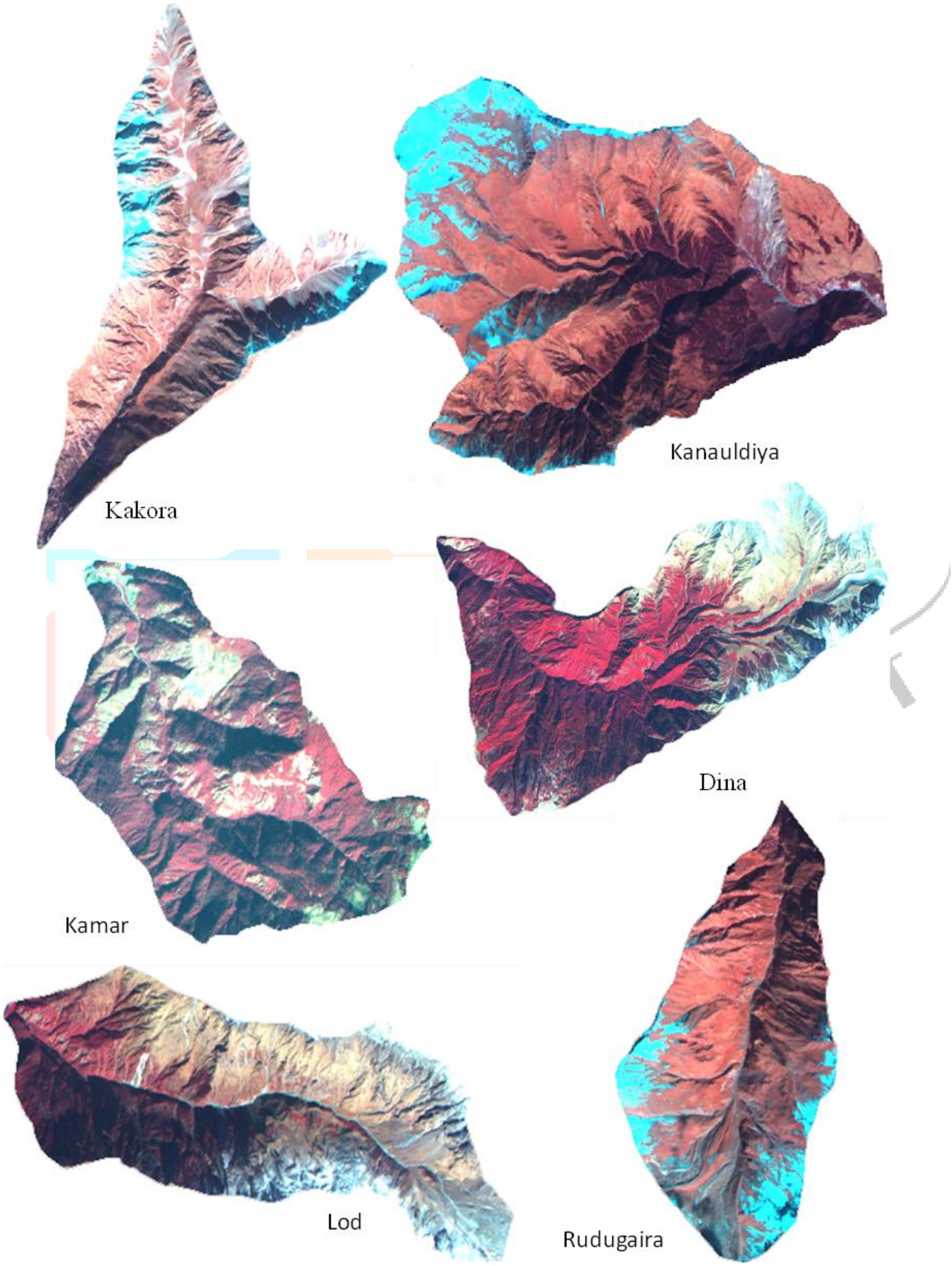

Fig. 4: LISS III Image (2005) of different drainage (Gad) Basin

3. Tributary Glaciers & Digital Elevation Model:

The upper reaches of Bhagirathi valley, carved out by Gangotri Group of glaciers, is a typical glacial valley. The head of Bhagirathi basin is surrounded by Shivling, Kedar dome, Kedarnath, Sumeru, Chaukhamba Group, Satopanth, Bhagirathi Group of peaks, Sudarshan parvat. There are some important tributary glaciers of Gangotri glacier which join the glacier both from the right and left side. Meru and Ghanohim are the tributary glaciers which feed the main glacier from left and Raktavarn, Chaturangi, Swachhand and Manda feed from the right (Fig.4).

Table 1: Morphometric Analysis of Gangotri Glacier Area

Parameters	Right Valley	Left Valley
Basin area (sq. km)	33.1	33.9
No. of streams of different stream order	I- 182	I- 56
	II- 36	II- 17
	III- 10	III-4
	IV- 2	IV- 0
Total no. of streams	230	77
Length Of stream (km)	I- 39.67	I- 14.94
	II- 13.07	II- 7.31
	III- 5.45	III- 1.28
	IV- 1.58	IV- 0
Total Length of streams (km)	56.77	23.53
Mean length of Different stream order (km)	I- 0.22	I- 0.26
	II- 0.36	II- 0.43
	III- 0.55	III- 0.32
	IV- 0.79	IV- 0.00
Mean length of Different stream basin (km)	0.25	0.31
Drainage destiny	0.00727	0.00907
Stream Frequency	6.78	2.29
Bifurcation ratio	I- 5.06	I- 3.29
	II- 3.60	II-4.25
	III-5.00	
Area occupied by debris cones (sq. m)	18866749	504302

This glacier has three main tributaries, namely Raktvarn (15.90 km), Chaturangi (including Kalandini bamak) (22.45 km) and Kirti (11.05 km) and more than 18 smaller tributary glaciers (Fig.5). The Raktvaran system contains 7 tributary glaciers; among them Thelu, Swetvarn, Nilambar and Pilapani are important. Similarly the Seeta, Suralaya and Vasuki are the major tributaries, which make up the Chaturangi system, while the Kirti system is made up of only three tributary glaciers. Three other glaciers, Maitri, Meru, Bhrigupanth drain into the river Bhagirathi. The total glaciarized area (Table.1) of the catchment is 258.56 km², out of which the Gangotri system comprises 109.03 km², followed by Chaturangi (72.91 km²), Raktvarn (45.34 km²) and Kirti (31.28 km²). The remaining four glaciers contain 29.41 km² of glaciarized area among them maximum contribution is Bhrigupanth glacier (14.95 km²). Numerous small sized glaciers join the main Gangotri glacier from all sides and from the Gangotri group of glaciers. The total ice covers approximated 200 km2 with 20 km3 of ice volume (Vohra, 1981), and it is the valley total glaciarized area is about 258.56 km2 long (Naithani et al. 2000).

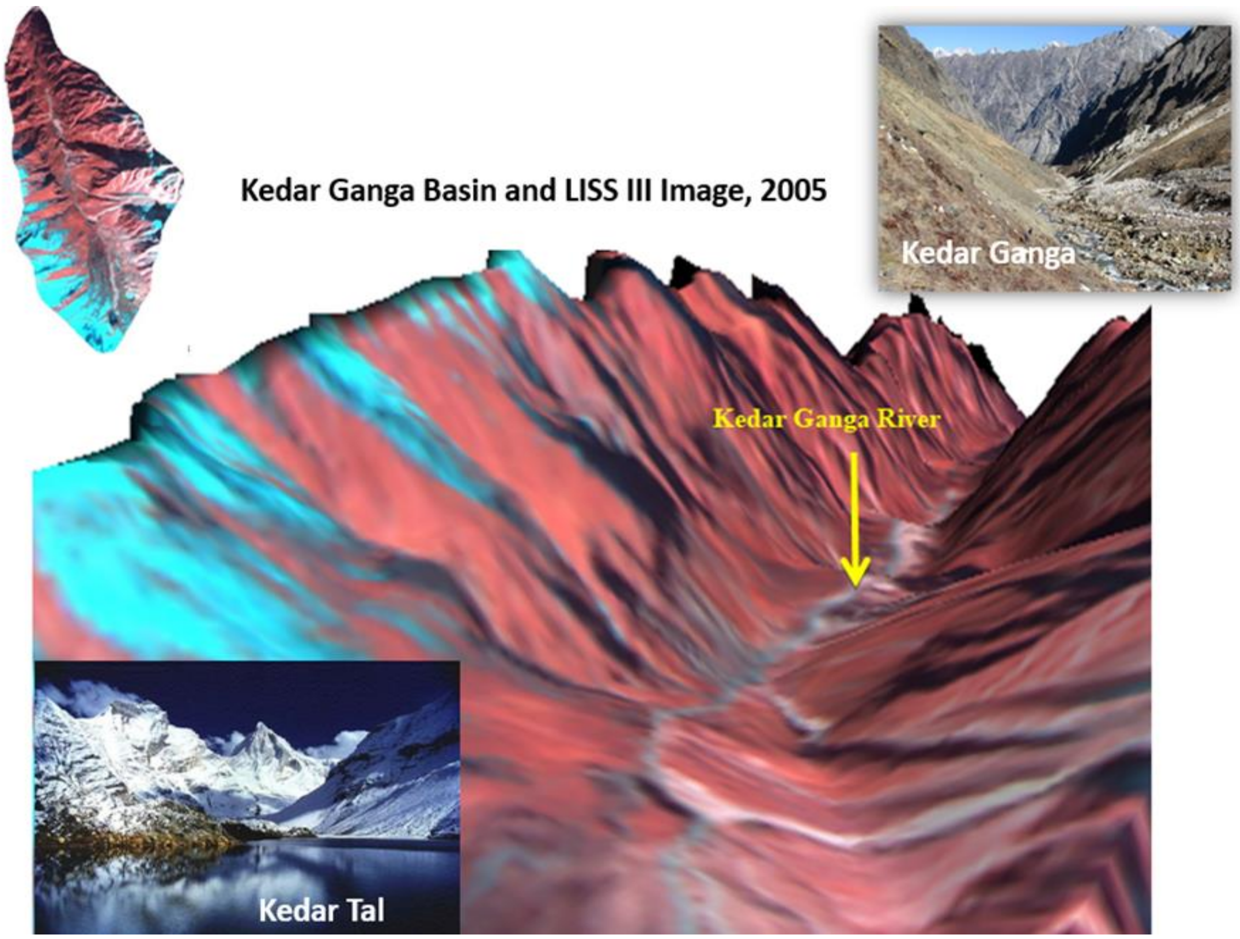

Fig. 5: Digital Elevation model of Kedar Ganga River Basin based on LISS III Image (2019), NRSC (Prepared by Author)

Depending upon their present-day location with respect to the main glacier, these tributary glaciers are classified into two categories, active and inactive (Singh & Misra, 2002). Active tributary glaciers are those, which are still connected to the main glacier, contributing ice budget to it and are also forming the new landforms. Inactive tributary glaciers (Table.1) are five those which are now detached from the main glacier but were connected to it in the past. These are neither contributing ice budget to the main glacier nor forming any new landform. Whatever they are contributing nowadays is only in the form of melt water coming out of them. So we prefer to call these remnant tributary glaciers as inactive. However, the inactive tributary glaciers are modifying the pre-existing landforms only because of their melt water.

4. RESULTS AND ANALYSIS:

A relative analysis of the glacier's snout position was carried out using data from primary and secondary sources and interpretations from various satellite imageries over the past three decades. Present researcher also analyzed the rate of retreat with the help of the G.P.S. study and Satellite Imagery of LISS III (1997 & 2005) and S.O.I toposheet (1962) using Erdas Imagine 8.4. The glacial area was calculated using satellite imageries and toposheets of 1962, 1976, 1997, and 2005 by delineating the glacier boundary using ERDAS 9.0 and auto calculating the area using GIS methodology. Based on the intensive field survey and the analysis of satellite imagery and S.O.I toposheet proofs (Fig.6) that Gangotri glacier receded 1429.30m from 1962-2005 (43 years analysis). It is very clear to us that in the 2005 image the amount of snow covered area is less than the Nov 1998 image.

Based on the comparison of satellite imageries of the Gangotri glacier for the years 1976, 1990, 1997, 1999 and 2005, 2006, the analysis shows that the glacier is not only receding in length but also in terms of glaciated area from all the sides. The possible reasons behind this retreat may be linked with two main factors: (a) reduction in snowfall and (b) an increase in the temperature of the region. A study of data from all available sources illustrates that the main trunk of the Gangotri glacier has been in a continuous state of recession and fragmentation during the past century. The length of the glacier has been computed for different years based on available data. The trend shows that the length of the glacier has reduced by about 1.42 km in 53 years, from 1962-2015. This is a very common and natural phenomenon, but we can¬not neglect the interference of human activities particu¬larly to this glacier. Every year thousands of tourists, pilgrims, mountaineers and trekkers visit this area, and have left huge amounts of waste material there. Thus there is an immediate task to prevent any type of human activity, except scientific research work to preserve this holy place Gangotri, and to maintain its aesthetic beauty.

5. Conclusion: The study of development of landform and land use is of prime importance for the economic development, resource planning and cultural advancement of people. The entire area is characterized by some important erosional and depositional features, which indicate the rejuvenation of landscape as well as tectonic movement of the entire area. The topographical expressions of multicyclic landscape of the terrain are valley in valley, U-shaped valley, numerous waterfalls, nick points etc. in river channel. From the basis of different type of soils and geomorphic processes (glacial, glacio fluvial and fluvial) of the region, it is clear to us that the entire study area is representative of a polygenetic landscape with diverse land use patterns. The area has a great potential for economic development as it is well enriched in varied natural resources and there is a great scope for eco tourism. The surface configuration of the Uttarkashi-Gangotri area can be analyzed with the help of different morphometric techniques like relative relief, dissection index, drainage density, drainage frequency and average slope, nature of long profile, sinuosity index etc. to find out the characteristics of Uttarkashi-Gangotri terrain. Bhagirathi valley presents a well-developed watershed in which snow, glaciers, running water and mass gravity movements are the important factors in sculpturing surface geometry.

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