# Application of Geospatial Technologies in Landscape Assessment: Upper Alaknanda & Bhagirathi River Basin, Uttarakhand

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**Abstract:** The Alakhnanda–Bhagirathi rivers, originating in the north-western part of Uttarakhand are characterized by rugged river drainage systems. The Alakhnanda–Bhagirathi rivers are the Himalayan River basin located in the state of Uttarakhand, India. Studies on Landscape assessment of Alaknanda-Bhagirathi River Basin using Geospatial technologies play a significant role in planning. Establish a comprehensive geospatial data collection system to gather information on various aspects, including topography, land use, infrastructure, natural resources, climate, and socio-economic indicators etc. will play a crucial role in achieving sustainable development goals in the Badrinath – Gangotri area. The approaches are adaptive and flexible to accommodate changes in technology, environmental conditions, and societal needs over time. The main objective of the present research paper is to analysis and illustrate the Landscape Assessment of Upper Alaknanda-Bhagirathi River Basin using geospatial data specially GNSS and Satellite data. The study of development of landscape 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. The surface configuration of the Alaknanda River valley 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 Alaknanda- Bhagirathi River valley area terrain. The Alaknanda- Bhagirathi basin has enormous potential for emerging land base resources particularly for widespread agriculture and horticulture. Through the ages, the River Bhagirathi has been considered mythologically the main source stream for the Ganges River; however, in hydrological terms, Alaknanda rather Dhauliganga is considered the source stream on account of length and discharge. River Alaknanda and its tributaries have a total length of about 664.5 km, whereas Bhagirathi and its tributaries have about 456.5 km.

**Keywords:** Landscape Assessment; Geospatial technologies; environmental hazards, Alakananda & Bhagirathi River

## Introduction

The Chamoli-Devprayag area with in Alaknanda Basin (Figure 1) 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 (Figure 2). 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 (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 (Figure 1) emphasizing valley in valley, U-shaped valley, numerous waterfalls, nick points etc.


**Fig. 1** Confluence of Alaknanda & Saraswati River; Saraswati River is a tributary of Alaknanda River flowing in Uttarakhand State, India. It joins Alaknanda River at Keshav Prayag, near Mana village,

Badrinath. A natural stone bridge, named "Bhim Pul", lays across flowing Saraswati river, making a passage towards Vasudhara falls and Satopanth Lake. Source: Google Image, 2022.

Hence, the present work is an effort to illustrate the importance of the landscape assessment. Simple landscapes are those which are the product of a single dominant geomorphic process, compound landscapes are those in which two or more geomorphic processes have played major roles in the development of the existing topography. 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.

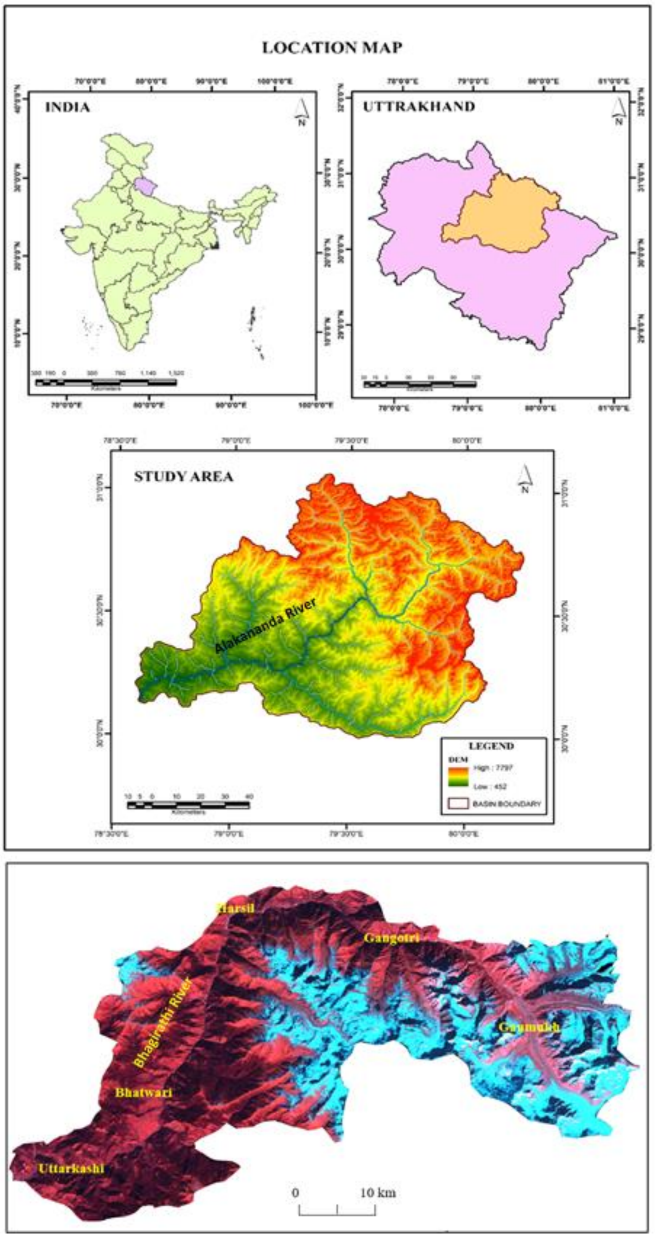


**Fig. 2** Map of the Alakananda-Bhagirathi Valley, Uttarakhand & Satellite Image of the Gangotri Area, LISS-III, 13th Nov, 2005; The Alaknanda River originates from the foot of Satopanth and Bhagirathi Kharak glaciers and flow downwards past Mana village meeting with the Saraswati River and The Bhagirathi River originates from snout (Gaumukh) of Gangotri Glacier, which is the largest valley glacier originating from the western face of Chaukhumba ridge and flow north-west to Gaumukh through a broad U-shaped valley.

## Materials and Methods

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, (Figure 2) 1997, 2005, 2015, 2019 and LISS IV, 1997, 2005, 2015) 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 another main purpose 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.

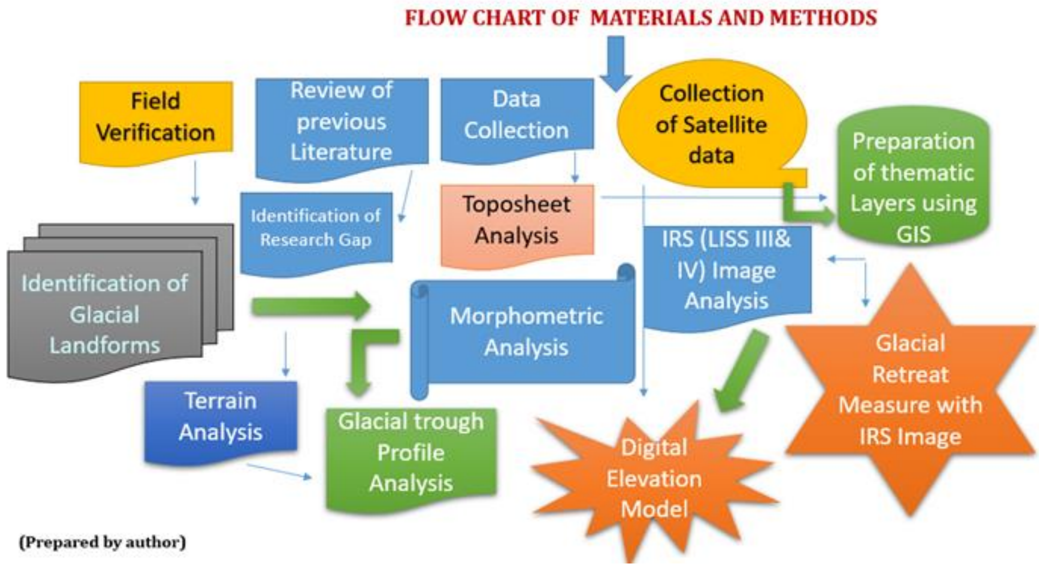


**Fig. 3** Flow Chart of Materials and Method.

Field study (Figure 3) 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 software 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.

## Results

*Landscape Analysis:* The present-day landforms of the Earth's surface result from a complicated interaction among different physical processes and environmental factors, such as underlying rock structures, tectonics, rock types, climate and climatic changes, and human activities, all occurring over a wide range of spatial and temporal scales. Landform evolution is a vital aspect of the earth sciences because landforms are usually the first and simplest of natural features we observe when we study global change and the impacts of human activities on our environment. Landforms also contain important clues to past processes which have operated over extended periods of geological time. Thus, landform evolution is an ideal aspect of the geosciences for training students in a systems approach to studying the Earth, an approach which involves the observation of interacting processes in space and time. In terms of areal extent, glaciers occupy about 11% of the total land area. About 3% of the permanent snow and ice is available in the mountains outside the polar regions. Asian high mountain glaciers occupy an area of about 50% of all glaciers existing in the mountains and a large proportion drain into the landmass of the Indian subcontinent.

The Himalaya has the greatest concentration of the glaciers outside the polar region and occupies about 0.77% of the total glacierized area of the earth. This glacier system not only acts as a perennial water source, but is a marker of climate change in the region. As a whole about 17% of the Himalaya is permanently covered with glaciers and additional nearly 30-40% area is seasonal snow covered (Vohra, 1978). Garhwal Himalaya (Uttarakhand) is second largest glacierized areas in Indian part of the Himalaya and covering an area of 3550 km2 which is source of four major river systems (Yamuna, Bhagirathi, Alaknanda and Kali) of the region. There are more than 968 glaciers in the Garhwal Himalaya (GSI, 1999), which ranges in length from 1 km to 30km. These glaciers are generally classified as mountain glaciers. It is widespread evidence that glaciers are retreating in all mountain areas of the world. Enhanced recession rates of glaciers reported during the recent years has initiated wide spread discussions, especially in context to global warming and its effects on glacier systems. Himalayan glaciers are also receding like the rest of the glaciers in the world.

However, the rate of recession and amount of volume change are different from other mountain glaciers of the world. Realizing the important of the glacier and its recession, a study on glacier retreat in Garhwal Himalaya has been carried out to evaluate the processes and recession trend. Uttarakhand Himalaya is blessed with huge resources of snow, ice and glaciers that act as freshwater reservoirs. The upper reaches of the state encompass glaciers, perennial snow, the proglacial regions, and areas down below that are covered with seasonal snow cover during the winters. Out of this Ganga basin is most glacierized with 645 glaciers whereas Yamuna basin has least number of glaciers, i.e. 52. District-wise distribution of glaciers is also skewed. Out of the 968 glaciers in Uttarakhand, 310 glaciers are found in Chamoli district and 277 glaciers (Table 1) are also found in the

Uttarkashi district while Tehri Garhwal district has only 13 glaciers. The Himalayan glaciers are a storehouse of freshwater and almost all the major river systems in the Indo-Gangetic Plain owe their origin to them. The Gangotri Glacier situated in the Uttarkashi district of Uttarakhand, Western Himalaya, is one of the largest valley glaciers of India. The glacier is around 30 km long, 0.5 to 2.5 km wide and covers an area of around 143 km2. It originates from the Chaukhamba group of peaks (7000m) and flows in the northwesterly direction forming the source of Bhagirathi River at Gaumukh (4000 m asl), snout of Gangotri Glacier.

**Table 1** shows Major tributary glaciers of the Gangotri Glacier Uttarakhand, (*Source: Toposheet, SOI)*.

| Glacier | Height (m) | Length (km) | Area (sq.km) | Feeding bank |
|---|---|---|---|---|
| Maiandi Bamak | 5200–6300 | 5.0 | 6.0 | Right |
| Swachhand | 4900-5800 | 8.0 | 17.5 | Right |
| Ghanohim | 4800-6400 | 5.5 | 14.0 | Left |
| Kirti Bamak | 4500-6800 | 8.0 | 24.0 | Left |
| Suralaya Bamak | 5100-6400 | 7.0 | 16.0 | Right |
| Chaturangi Bamak | 4400-5400 | 15.0 | 14.0 | Right |
| Meru Bamak. | 4300-5700 | 7.0 | 8.0 | Left |
| Raktavarn | 4600-6000 | 15.0 | 19.0 | Right |
| Pilapani Bamak | 5200-6400 | 6.0 | 4.5 | Right |
| Nilambar Bamak | 5200-6400 | 4.0 | 5.5 | Right |
| Thelu Bamak | 5100-5800 | 3.0 | 2.8 | Right |
| Bhujbas Dhar | 47,00-5800 | 3.0 | 0.75 | Right |
| Swetvarn Bamak | 4800-5900 | 6.0 | 8.5 | Right |
| Bhrigupanth Bamak | 4000-6400 | 9.0 | 14.0 | Left |
| Manda Bamak | 3800-5800 | 4.0 | 3.0 | Left |
| Matri Bamak | 4000-6400 | 3.5 | 4.0 | Right |

*Drainage characteristics:* Unique in its complex and diverse drainage characteristics, the antecedent river Bhagirathi offers a fascinating study for all Geomorphologists and other earth scientists interested in the Himalayan drainage basin evolutionary processes under glacio fluvial and fluvial environment in particular. Himalaya, the great mountain chains of Asia are the source of the major river system of the world. The Ganga River, which occupies nearly one third of the geographical area of India, is the most important and sacred river in India. Gangotri glacier may be considered the 'Heart of Northern India' as it is the source to the life-line of the northern plains- the river Ganga. Bhagirathi basin (Figure 4 & 5) is drained by Bhagirathi River which originates from Gangotri glacier snout known as "Gaumukh", at an elevation of 3972.73m (Sangewar, 1997). The elevation in the basin ranges from 7138m asl (Chaukhamba peak) to 442m asl at Devprayag near the confluence of Bhagirathi with Alaknanda River. Bhagirathi is the main channel for drainage sustains several tributary rivers e.g. Jahnvi Ganga, Pilang, Jalandhari and Bhilangana River with diversified topographic expressions and varied resources. These are water (surface and subsurface), forest, minerals, soil, agriculture, landscape (aesthetic resources), and human resources. The salient points of the main findings and observations on the analysis of the interactions between the physical and cultural (social) parameters have been presented here.

The Bhagirathi River flows from its source for 205 km before meeting the Alaknanda River in the town of Devprayag. Downstream of this confluence, considered holy by Hindus, the river is known as the Ganga or Ganges River. Bhagirathi river is 96.25 km long in the area under study (Gaumukh to Uttarkashi). Several rivers in the Garhwal region (Figure 6) merge with the Alaknanda at Panch Prayag or 'holy confluence of rivers'. These are as follows:

1. Vishnuprayag, where the Alaknanda is met by the Dhauliganga River
2. Nandaprayag, where it is met by the Nandakini River
3. Karnaprayag, where it is met by the Pindar River
4. Rudraprayag, where it is met by the Mandakini River
5. Devprayag, where it meets the Bhagirathi River and officially becomes the Ganges River.

The Gangotri glacier is a vital source of freshwater storage and water supply, especially during the summer season for a large human population living downstream. The discharge from the glacier flows as the river Bhagirathi initially before meeting the Alaknanda River at Devprayag to form the river, Ganga. Snow and glaciers contribute about 29% to the annual flows of the Ganga (up to Devprayag) and hence any impacts on these glaciers are likely to affect this large river system (Singh et al., 2009). Bhagirathi river is joined by its tributaries; these are, in order from the source:

- Kedar Ganga at Gangotri (elevation 3,049 m),
- Jadh Ganga at Bhaironghati (elevation 2,650 m),
- Kakora Gad and Jalandhari Gad near Harsil (elevation 2,745 m),
- Siyan Gad near Jhala (elevation 2,575 m),
- Asi Ganga near Uttarkashi (elevation 1,158 m).

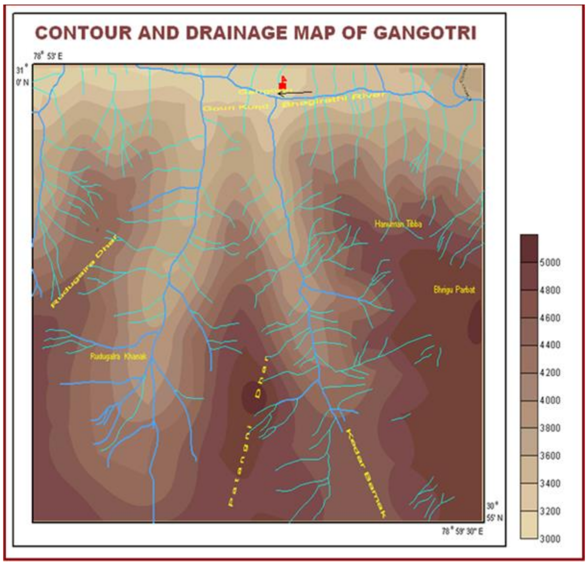


**Fig. 4** Contour and Drainage Pattern of Gangotri Area; About 1km down stream of Gangotri temple Kedar Ganga joins with Bhagirathi along its left bank in a form of waterfall. At this confluence, the water pool created by these two rivers is known as Gaurikund. About 7km down stream from this point at Bhaironghati, Jadganga River also known as Janhavi, joins with the Bhagirathi along its right bank. Source: LISS IV Image, 2005 & SOI Topomap.

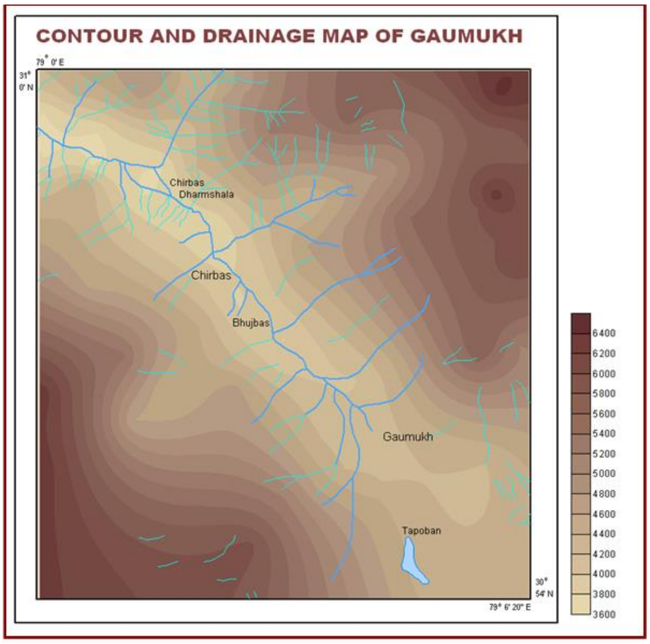


**Fig. 5** Contour and Drainage Pattern of Gaumukh and Tapoban Lake Area; Bhagirathi basin is drained by Bhagirathi river which originates from Gangotri glacier snout known as "Gaumukh", at an elevation of 3972 m; Source: LISS IV Image, 2005 & SOI Topomap.

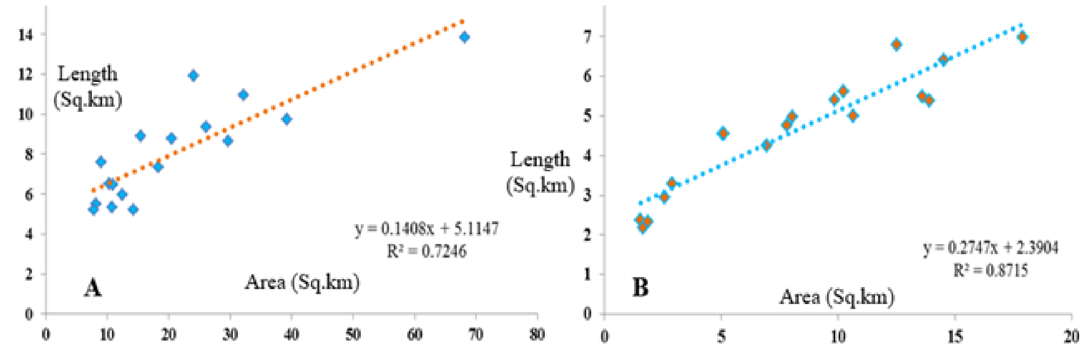


**Fig. 6** Relationship between Basin Area and Basin Length of Tributaries (Left Bank-A & Right Bank-B) of River Bhagirathi ; Source: Topomap, SOI.

*Evaluating terrain characteristics:* 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. Efforts have been taken by the Geomorphologists since the first half of the twentieth century to find out techniques which will specifically evaluate the status of a landform in the entire gamut of an evolution process. Qualitative assessments were practiced beforehand, but they could not reveal the exactness of the landform character. Thus, a trend of quantification has been in progress in order to draw very indifferent and imperative inferences. The science of morphometry has evolved in this regard comprising the aspects of identifying landform status as well as drainage network relationship. The quantitative assessment as well as morphometric methods are applied and measured from the topographical maps, which provide us with detailed information about the landform.

In the Bhagirathi channel there are many depositional features which are very important channel geomorphic units characterized with fluvial depositional process. These depositional features are various types of channel bars i.e. mid channel bar, point bar, alternating bar, braided bar etc. In Barahat area (Uttarkashi), several mid channel bars are observed by the present researcher and it is also very remarkable fact that both right and left banks of the Bhagirathi River are shifting as a mid-channel bar is developed. That is why the main Bhagirathi River channel has been bifurcated in two branches and these two branches are shifting towards both sides. As a result, Hotel Akash Ganga, Ganga Sagar etc. manmade constructions, situated on the left bank of the Bhagirathi River already under threat. On the other hand, left bank of the Bhagirathi River is already in vulnerable condition. As in Uttarkashi area Bhagirathi River has developed a complete meander that is why point bar deposition also observed in the inward part of the meander. According to the meandering channel pattern slip of slope terraces are very prominent which is unpaired in nature.

In Harsil area, according to the recent geo scientist the channel geomorphology of the entire area greatly influenced by neotectonic movement. Scientists think that there is a subsurface ridge (Delhi-Haridwar-Harsil ridge) which is tectonically very much unstable. Due to neotectonic movement of this sub surface ridge several faults and lineaments have developed declining channel gradient in Bhagirathi River. As a result, river velocity falls in this area accumulating channel sediments which has developed prominent braided channel.

*Geometric Investigation:* The Alaknanda River basin is seventh-order basin which is visible in sub-basins B1, B3 and B4. Each sub-basin has many streams of various orders; hence, the length varies for each sub-basin. But the mean stream length is highest for the highest-order stream of each sub-basin (Shukla, 2014). The morphometric analysis showed that first-order streams in all the sub-basins (Figure 7) are having maximum stream length and the highest order stream is having minimum stream length.

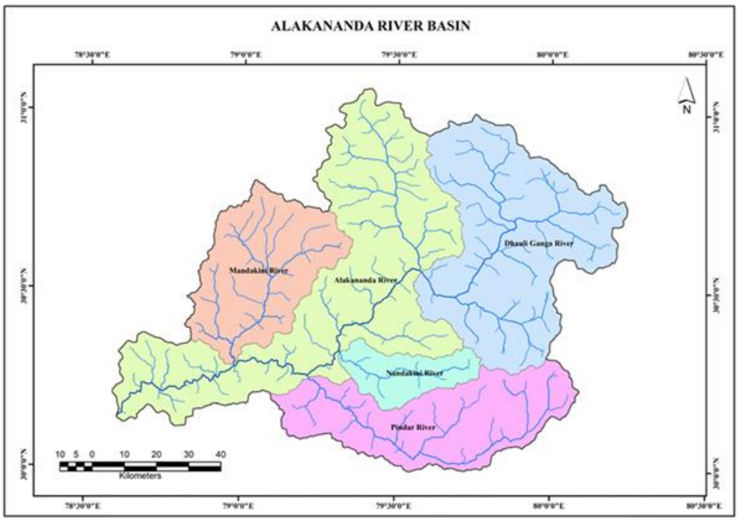


**Fig. 7** Sub Basin Map; River Alakanada, flows from South-west to South-east part of Chamoli district. The Alaknanda River is one of the two headstreams of the Ganges River, with the other being the Bhagirathi River. The confluence of the Alaknanda and Bhagirathi rivers takes place at the town of Devprayag, from where the river is known as the Ganges. Source: Topomap, SOI, 2011.


**Fig. 8** Channel pattern of Alaknanda River at Rudraprayag and downstream area. Source: Topomap, SOI, 2011.

Morphometric 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 (Figure 9) provide a synoptic view of a large area and is very useful in the analysis of drainage basin morphometry. The parameters like form factor (Rf), circulatory ratio (Rc) and elongation ratio (Re) describe the shape of the sub-basin and is mainly concerned with the length and frequency of streams, geological structures, climate, relief and slope. The sub-basins 2 and 3 have least values of form factor 0.210 and 0.224, circulatory ratio 0.315 and 0.310 and elongation ratio 0.518 and 0.534, respectively, which indicates that they have extremely elongated shape and fall in very high tectonic zone. While sub-basins 7 and 8 have high value and hence are more circular in as shape (Shukla, 2014). Hypsometric integral of the Alaknanda valley (Figure 8) basin varies from 0.635–0.323.

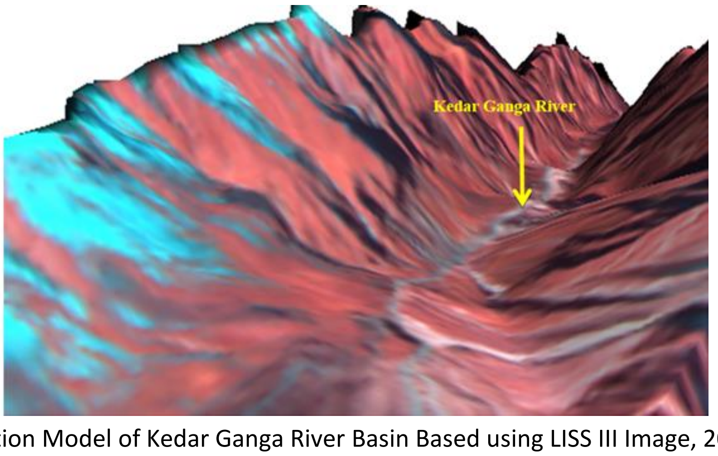


**Fig. 9** Digital Elevation Model of Kedar Ganga River Basin Based using LISS III Image, 2005 Source: Topomap, SOI.

## Results and Analysis

Land use pattern in Chamoli district Land topography comprises undulating and rugged terrain. It requires persistent efforts and hard labour to terrace the steep hills. In the river valleys, land is relatively fertile. According to statistics available for agriculture as appears in Statistical Bulletin 2008-09, the total available area to be 851764 ha. Out of this available land, 59.42% was under forests, 8.34% cultivable waste, 0.11% under fallow and other fallow land, 8.35% under unfit for agriculture, 7.18% land put to other uses, 3.27% under orchards and fodder and 3.89% under net area sown Change in land use components may affect the processes of natural phenomena as well as ecology (Turner, 1989), including surface run-off, erosion (Burel et al., 1993; Fu et al., 1994) and soil properties.

Soil resistance may be modified due to environmental changes in particular that can increase the vulnerability of semi-arid ecosystems. The effect of terrain conditions or landform on land use pattern may be considered as direct, which set the foundation of land use and ultimately reflected in their spatial variations over different components of landform. Different terrain (Figure 10) conditions like altitude, relief measures, slope morphology, drainage aspects etc. have significant role in the pattern on land use. But as the discussion of each and individual is an elaborative task the most important three parameters i.e. altitude, slope and dissection index are considered here as the basic determinants of land use. Altitude or relief height has a direct impact on the land use pattern.

The river terraces are intensively utilized for road construction, agriculture, and other constructional purpose. Not only the river terraces but also the micro alluvial fans are intensively utilized for agriculture and settlement areas. The micro point bars are also utilized for same purpose. Beside these, manmade terraces are also observed along the valley by the author. These terraces are made of boulders and gravels by the villagers. These manmade terraces are utilized mainly for agriculture. To establish the relationship between landform nature and land use pattern some quantitative analysis has been done by the present author. Three case studies have been done for better understanding the impact of landforms on land use pattern of the study area.


**Fig. 10** Meander of Alaknanda River near Mandoli; The River Alaknanda flows in the centre along with bow shape meander. Source: Google Image, 2021.

**Fig. 11** Fluvial Landforms of the study area (a) Panoramic view of Bhagirathi Valley, Chirbasa (b) Meander of River Bhagirathi, Uttarkashi (c) waterfalls at Harsil (d) Meander of Kakora Gad, Harsil (e) Close view of Channel Bar of River Bhagirathi at Jhala (f) braided pattern of River Bhagirathi at Harsil with sandbar (g) Terraces of Indrawati River, Uttarkashi. Source: Field Survey, 2019.

**Fig. 12** Fluvial Landforms of the Alaknanda River (a) Panoramic view of Badrinath Valley, (b) Meander of River Alaknanda, Badrinath (c) Close view of Badrinath town (d) Meander of River Bhagirathi, Devprayag.

## Discussion

The study area has a great diversity of landscape with many striking contrasts of landform which is the combined effect of structure, process and stage. From the nature and association of different landforms and materials three major geomorphic processes seem to be obvious in the area on a large scale especially in the respect of Alaknanda Basin area. These are glacial, periglacial and fluvial. Of these, glacial is more important process in so far as denudation of the land is concerned. The magnitude of this process is much higher than the fluvial process in given space and time in this part of the Himalaya. The entire area (Figure 11 & 12) 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. 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 intensities through time. Erosional and depositional glacial– periglacial features are well developed all around the study area.

## Conclusions

The study of development of landscape 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 Alaknanda River valley 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 Alaknanda River valley area terrain. As a consequence of climatic, geologic and topographic setup people of the study area face different types of environmental hazards as well as disasters like earth-quake, cloudburst induced flash flood, avalanches, landslides, soil erosion, etc. Alaknanda valley presents a well-developed watershed in which snow, glaciers, running water and mass gravity movements are the important factors in sculpturing surface geometry. The Alaknanda basin has enormous potential for emerging land base resources particularly for widespread agriculture and horticulture.

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