CHAPTER VI

HAZARD SCENARIO AND IMPACT OF NATURAL AND ANTHROPOGENIC FACTORS ESPECIALLY IN REGARD TO CLIMATE CHANGE IN THE SUBANSIRI AND THE ALAKNANDA BASINS

6.1 INTRODUCTION

The Himalayan region holds a significant importance in terms of biological (species) richness, biodiversity, socio-cultural diversity, and natural resources. The region's indigenous people consider the Himalayas sacred and look upon them with reverence. In essence, the Himalayas are both pride and necessity of the region (Gautam et al., 2013). Climate Change is one of the major challenges faced on the planet today. It is a global environmental issue that relates to global common atmosphere. Mountains are early indicators of climate change (Singh et al., 2010). As the glaciers recede, and snowline move upwards, river flows are likely to change and alteration in water flow regime may lead to plethora of social issues and affect hydropower generation, endanger biodiversity, forestry and agriculture based livelihoods and overall well being of the people (Negi et al., 2012). Though the Himalayas are among the most vulnerable regions to climate change, have unique biodiversity and are undergoing rapid environmental change, there is no systematic analysis of climate change and its effects on ecosystems and biodiversity, nor on hydrology, agriculture, and livelihoods in this important and extraordinary region of the world (Shrestha et al., 2012). The Himalaya seems to be warming more than the global average rate (Liu & Chen 2000; Shrestha et al., 1999), temperature increases are greater during the winter and autumn than during the summer; and the increases are larger at higher altitudes (Liu & Chen, 2000). According to the report of IITM Pune, there is a decrease in precipitation over 68% area of India over the last century (Kumar et al., 2006). However, significant increase in rainfall was noticed in Jammu and Kashmir and some parts of Indian peninsula (Agarwal, 2009). The mean annual temperature in the Alaknanda valley (western Himalaya) has increased by 0.15ºC between 1960-2000 (Kumar et al., 2008 a). Satellite imagery suggests that almost 67% of the glaciers in the Himalaya have retreated (Ageta & Kadota, 1992). Climate change has a powerful impact on human health and livelihood. The poor are the main victims of the adverse effect of climate change who have less contribution to the climate change. Gangotri glacier, one of the major and important glaciers in the Himalaya was 25 km long when measured in 1930s and has now shrunk to about 20 km (Hasnain, 1999). The average rate of recession of this glacier between 1985 and 2001 is about 23 m per year (Hasnain, 2002). The scientific evidence that the Himalayan region is being impacted by climate change is growing, with serious ramifications for Himalayan river basins and the Indian sub-continent.

Studies have shown that the hydrological characteristics such as discharge pattern, sediment load, snowmelt run off and intensity and frequency of flooding in Himalayan Rivers are changing due to climate change. The Brahmaputra river basin is particularly sensitive to climate change impacts, implying changes in volume of water, sediments and biogeochemical processes (Das, 2010).

The Himalayas have warmed by 1.5ºC from 1982 to 2006, at an average rate of 0.06 ºC /yr, but the rate of warming varies across seasons and eco-regions. The greatest increase, 1.75 ºC is observed in winter with an average increase of 0.07 ºC /yr, whereas the least increase, 0.75 ºC, is in summer, average increase being 0.03 ºC /yr. The

Brahmaputra valley semi-evergreen forest eco-region has experienced the greatest rate of warming, 2.0 ºC (Shrestha et al., 2012). Average annual precipitation has increased by 163 mm during the 25 year period (1982-2006). The Brahmaputra valley semi-evergreen forest eco-region had the greatest increase, 269.25 mm. The study reveals that the temperature increase in the Himalayas from 1982-2006 is 1.5 ºC (0.06 ºC /yr), considerably higher than the global average for the comparable, but longer period (1975-2005).

In regard changing trend of precipitation in Himalayan region, both increasing and decreasing trends in eastern Himalayas (Sharma et al., 2000), lack of consistent trend in Central Himalayas (Shrestha et al., 2000) and decreasing trend in Western Himalayas (Kumar and Jain, 2009) have been reported. However, a consistent trend of increasing average precipitation in the Himalayas as a whole and also in most of the eco-regions was found (Shrestha et al., 2012).

Rainfall has decreased in the Indian Himalayas lying in Uttarakhand State during last century as a sudden shift, rather than a gradual trend. The most probable year of change in annual as well as monsoon rainfall is 1964. The period 1902–1964 shows mostly an increasing trend, which reversed during 1965–1980. This pattern in rainfall is most conspicuous over the Shivaliks and southern part of the Lesser Himalayas (Basistha et al., 2009).

Studies on selected glaciers of Indian Himalaya indicate that most of the glaciers are retreating discontinuously since post-glacial time indicating probable impacts of climate change. For example Gangotri glacier in Himalayas has shrunk from 25 km (measured in 1930) to about 20 km (Hasnain, 1999). The Milam Glacier in the Kumaon Himalaya has retreated at an average rate of 9.1 m/yr between 1901 and 1997 (Shukla and Siddiqui, 1999). Dobhal et al. (2004) monitored the snout position of the Dokriani glacier during 1991–1995 and revealed that during the period 1962–1995 the glacier has receded by 550 m with an average rate of 16.6 m/yr.

6.2 Hazard scenario of the Subansiri basin

6.2.1 Flood hazard of the Subansiri basin

Flood is common and recurring phenomena in the Subansiri basin. It is the result of heavy or incessant rainfall exceeding the absorptive capacity of soil and the river channel. The Subansiri basin especially in the plain part lying in Assam suffers from flood havoc every year leaving intolerable miseries for the inhabitants of the basin. The associated flood of the 1950 earthquake had the most devastating effect in the basin. It has changed the morphology of the Subansiri river along with the Brahmaputra and several other tributaries. The earthquake caused heavy landslide which blocked the river forming a natural dam in the higher gorge section at Sipoumukh. The large amount of sediment generated by landslides was brought down into the rivers raising their beds considerably (Poddar, 1952, CSE 1991). River bank erosion is another threat to the basin. The Subansiri is a meandering river and due to lack of proper maintenance of the embankments, the river banks erode and this lead to the breaching of the embankments every year especially during the rainy season. Erosion and aggradation both affect the lower Subansiri basin.

6.2.2 The 1897 Shillong earthquake

On 7th June, 1897, the great Shillong earthquake occurred with magnitude of 8.7 Richter scale. It is the first event in India that was instrumentally recorded by a few stations outside the country; a detailed macroseismic study was done by R. D. Oldham (1898). The epicentre of the 1897 great earthquake lies to the south of the Brahmaputra river fault, which is about 150 km south of MBT (Kayal, 2014). Loss of life was only 1,542 compared to the magnitude. It was fortunately less because the earthquake occurred at 1.15 pm local time and most of the persons were outdoor, and also might be due to bamboo and wood made house type practiced in the region. Within an area of 30,000 square miles, all brick and buildings were destroyed. Both the earthquakes of 1897 and 1950 caused extensive landslips and rockfalls on hillslopes, subsidence and fissuring of ground in the valley, and changed the morphology of several tributary rivers (Oldham, 1898; Poddar, 1952).

6.2.3 Assam Earthquake, 1950

The earthquake occurred on 15th August, 1950 was one of the biggest earthquakes in the north eastern region and the 10th biggest earthquake of the world in the 20th century. The epicentre of the earthquake was near Rima, in a region claimed by both China and Tibet with Richter magnitude 8.7 which is referred as the Great Assam Earthquake. This shock was more damaging in Assam, in terms of property loss, than the earthquake of 1897. To the effects of shaking were added those of flood; the rivers rose high after the earthquake, bringing down sand, mud, trees, and all kinds of debris. The region experienced widespread devastation because of this earthquake specially the Upper Assam area, Abor hills and the Mishmi hills. This earthquake was more damaging than the 1897 earthquake. Fissures and sand vents occurred. Railway lines and roads were damaged. Its damaging intensity was such that the Brahmaputra river bed got aggraded by several meters (Goswami, 1985). This earthquake has changed the terrain condition of the region. An acceleration of 0.5g was estimated from the damage survey in the epicentral region. The repetition of major earthquakes, having magnitude 7 and above in the NE Indian region is severely affecting the rivers of the region due to which flood and erosion is common in this region.

This earthquake of 1950 triggered landslides to create a natural dam in the gorge section of the Subansiri river close to the ongoing Subansiri Lower Hydroelectric Dam project at Gerukamukh. The landslides impounded the water from 15th August to 18th August, 1950. The volume of water impounded by that dam was equivalent to the amount of water to be impounded by the present NHPC Subansiri Lower dam (NHPC Report on Subansiri Lower HEP, 2010). On the other hand due to the breaking of that natural dam a catastrophic flood occurred which changed the morphology of the river. The flood water attained a height of more than 12 m above ground level and deposited barren sand up to a thickness of above 10 m (NHPC Report on Subansiri Lower HEP, 2010). Major earthquakes in the NE India and adjoining region are listed in Table 6.1.

Table 6.1: Major earthquakes in the North East India and adjoining regions

Sl. No.	Date	Epicentral area	Magnitude	Lat(ºN) Long(ºE)
1.	12.06.1897	Shillong Meghalaya	8.7	26º00' N 91º00' E
2.	31.08.1906	India-Burma boarder	7.0	27º00' N 97º00' E
3.	02.07.1930	Dhubri, Assam	7.1	25º80'N 90º20' E
4.	04.08.1932	India-Burma boarder	7.0	26º00' N 95º30' E
5.	23.10.1943	Hojai, Assam	7.2	26º00' N 93º00'
6.	29.07.1947	Tammu, Arunachal Pradesh	7.7	28º80' N 93º70' N
7.	15.08.1950	India-Burma-China boarder	8.7	28º50' N 96º50' E
8.	21.03.1954	Manipur-Burma boarder	7.7	42º2' N 95º1' E
9.	01.07.1957	Indo-Burma boarder	7.0	25º00' N, 94º00' E
10.	06.08.1988	Manipur-Burma boarder	7.3	25º149' N, 95º127'E

(Source: Gogoi, 2013)

6.3 HAZARDS SCENARIO OF THE ALAKNANDA BASIN

In Kumaun Himalaya, Dharchula area of Pithoragarh district has been an active zone for earthquake of magnitude 6.0-6.5 in Ritcher scale. Several earthquakes of magnitude 6.0-6.8 have occurred in Kapkote (1958) and Dharchula (1966) in Pithoragarh district. Few noteworthy earthquakes that occurred in the Alaknanda basin are: 1803 Garhwal earthquake which destroyed Srinagar town and damaged the Badrinath temple; 1991 Uttarkashi earthquake of magnitude 6.4 and Chamoli earthquake of 6.8 magnitude. Figure 6.1 shows theMorpho-tectonic active map of the Alaknanda basin.

Cloudburst is one of the major environmental hazards in the Himalayan region including the Alaknanda basin. It is a micro climatic phenomenon of the great Himalaya. Most of the cloudburst phenomena are observed between Higher and Lesser Himalayan region in the Alaknanda basin. It is believed that the Alaknanda flood 1970, Belakuchi flood of 1970 (Birahi Ganga), Kaurtha landslip tragedy of 1978 in Mandakini valley happened due to the cloudburst in that region. It has been noticed that on average 2-3 villages in the Alaknanda basin come under the grip of cloudburst every year which has far reaching effects like landslide, loss of human and animal lives, property damage and loss, landscape deformation, soil erosion, flood, debris flow which again in return affects normal life and destroyes habitation. Notable example of cloudburst was the one in 1991 in Gopeshwar in Alaknanda basin and the most damaging recent cloudburst event occurred in 2013.

Flood creates temporary lakes in the upper catchment of basins. One of the notable examples of such floods occurred is in 1803 which swept away one third of Srinagar, the capital city in Garhwal Himalaya. In 1857, a massive landslide had blocked the flow of the river for three days. In 1868, the Alaknanda river swept away two bridges and killed 70 pilgrims sleeping on the river bank in Chamoli. In 1893, a landslide in the Birahi Ganga formed a 350 m high dam near Gohna village (Panwar and Sharma, 2010). In 1970, flood occurred as a consequence of many temporary dams that were formed and breached sending surges of water down the valley.

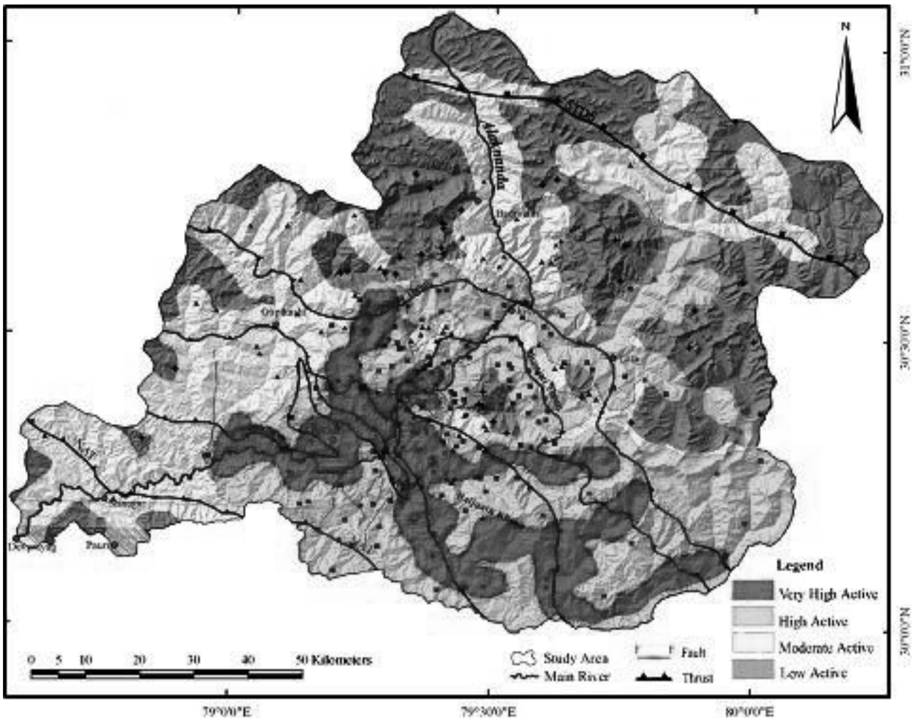


Figure 6.1: Morpho-tectonic active map of the Alaknanda basin

(Source: Shukla et al., 2014)

6.3.1 Harmony Landslide in Garhwal Himalaya, 1986

A major landslide occurred in 1986 near Harmony village on left bank of Pinder River, along Karnaprayag - Gwaldam road in Chamoli district of Alaknanda river basin which caused traffic blockade and consequent economic and environmental losses.

6.3.2 Uttarakhand Disaster 2013

The natural disaster that occurred in Kedarnath area of Uttarakhand in the month of June, 2013 is a classic example of flash floods and the biggest ever devastating in the state and also one of the biggest in the country, causing loss of thousands of human life and livestock. Plate 6.1 and 6.2 shows the devastation of Uttarakhand disaster, 2013.

The principal triggering factor of the tragedy was very high rainfall in a confined area which produced multiple hazards including landslides, and generated a very large flood, the return period of which is unknown because of lack of reliable long-term gauged flow records (Ziegler at al. 2014).

On 16 and 17 June 2013, heavy rains together with bursting of a moraine dammed lake (Chorabari Lake, 3960 above msl) lead to flooding of the Saraswati and Mandakini Rivers in Rudraprayag district of Uttarakhand which caused the biggest ever destruction in the state of Uttarakhand. Prolonged heavy down pour on 16 and 17 June 2013 resembled 'cloudburst' in the Kedarnath valley and surrounding areas that damaged the banks of River Mandakini for 18 km between Kedarnath and Sonprayag, and completely washed away Gaurikund (1990 above msl), Rambara (2740 above msl) and Kedarnath (3546 above msl) towns. The Chorabari Lake is a snow melt and rain fed lake, located about 2 km upstream of Kedarnath town which is approximately 400 m long, 200 m wide having a depth of 15–20 m. The incessant rainfall together with melting of snow in the surrounding Chorabari Lake washed off both the banks of the Mandakini River causing massive devastation to the Kedarnath town (Dobhal et al. 2013).

On 16 June 2013, at 5:15 p.m., the torrential rains flooded the Saraswati River and Dudh Ganga catchment area, resulting in excessive flow across all the channels of the rivers which activate extreme erosion in all the other gulleys causing excessive water and sediment accumulation in the major rivers. The routes of the town picked huge amount of debris and damaged the road communication and the large volume of water completely washed off the upper part of the city. The meteorological stations of Wadia Institute of Himalayan Geology (WIHG) recorded 325 mm rainfall at the base of the glaciers in two days on 15 and 16 June 2013. The second event occurred on 17th June, 2013 at 6:45 a.m. after overflow and collapse of the moraine dammed Chorabari Lake.

Post-disaster satellite images depict that the river banks were eroded completely along the Kedarnath valley due to the flash floods and few new channels were visible.

Unprecedented rainfall between 10 and 18 June 2013 in the Alaknanda and Bhagirathi catchments was the main cause of the disaster in the state. According to the India Meteorological Department, cumulative rainfall during 14–18 June 2013 at Tehri, Uttarkasi, Tharali and Jakoli was 381, 359, 326 and 390 mm respectively. This high rainfall was due to strong interaction between an oncoming trough in the westerlies and the strong south easterly monsoon wind flow in association with a monsoon low-pressure system over the North Indian region, resulting in the development of lower tropospheric wind convergence over Uttarakhand and neighbouring regions (Rao et al. 2014).

Plate 6.1: Uttarakhand disaster 2013 (Source: www.google.co.in)

Plate 6.2 Devastation of Uttarakhand disaster 2013, in between Kedarnath and Chorabari Tal area

A number of HEPs have suffered extensive damage in the Uttarakhand disaster 2013, including the 400 MW Vishnuprayag project across the Alaknanda river near Joshimath, that was covered completely with debris and the river had changed its course; the diversion tunnel of 520 MW Tapovan-Vishnugard project was washed away; the 76 MW Phata Byung HEP of Lanco and 99 MW Singoli Bhatwari HEP of L&T on the Mandakini were also extensively damaged; the powerhouse of the 280 MW Dhauliganga project of the NHPC in Pithoragarh was also submerged (Rajkhowa, The Assam Tribune, 9th Feb. 2015).

The macro hydroelectric projects in the region are not sustainable because of fragility and instability of mountain terrain. There are conflicts between the dam building agencies and the local people and social workers regarding this issue. Meeting with energy need for development processes, and harnessing water resource potential optimally, micro hydroelectricity projects appear to be the need of the hour which will reduce the environmental degradation and rehabilitation problems. There are numerous places, where these small projects can be commenced (Sati, 2009).

6.3.3 Glacial lake outburst flood (GLOF)

The Himalaya is the highest mountain chain on earth and the mountains have profound effect on global climate. In the last half century, several glacial lakes have developed in the Hindu-Kush-Himalaya and Tibetan Himalayan region cause severe floods after breaching which are known as the glacial lake outburst flood (GLOF). These are caused by the rapid retreat of glaciers. GLOF is defined as the sudden outburst of lakes, dammed by glacier and ice or moraines, producing flows of water that are often of an order of magnitude greater than normal rain derived peak flows and may travel tens of kilometres downstream, transporting a large amount of debris. These lakes may contain large quantity of water which may cause flash floods in the downstream areas. Due to the possible glacial retreat in the Himalaya, runoff of the Himalayan Rivers may be significantly affected in near future as a result of which there may be increase in the melt-runoff in the Himalayan Rivers both in terms of flow discharge and sediment load. Besides these, the outburst of the GLOF may pose problems for the inhabitants of the region by creating extremely high loss of human life, washing away of the agricultural crops and land in a large scale, destruction of road and dams etc (WIHG, ICIMOD, APN, START and UNEP, 2005).

Photographs related to natural and anthropogenic activities in the Subansiri and the Alaknanda basins are shown in plates 6.3 to 6.14.

Photographs related to natural and anthropogenic activities in the Subansiri and the Alaknanda basins

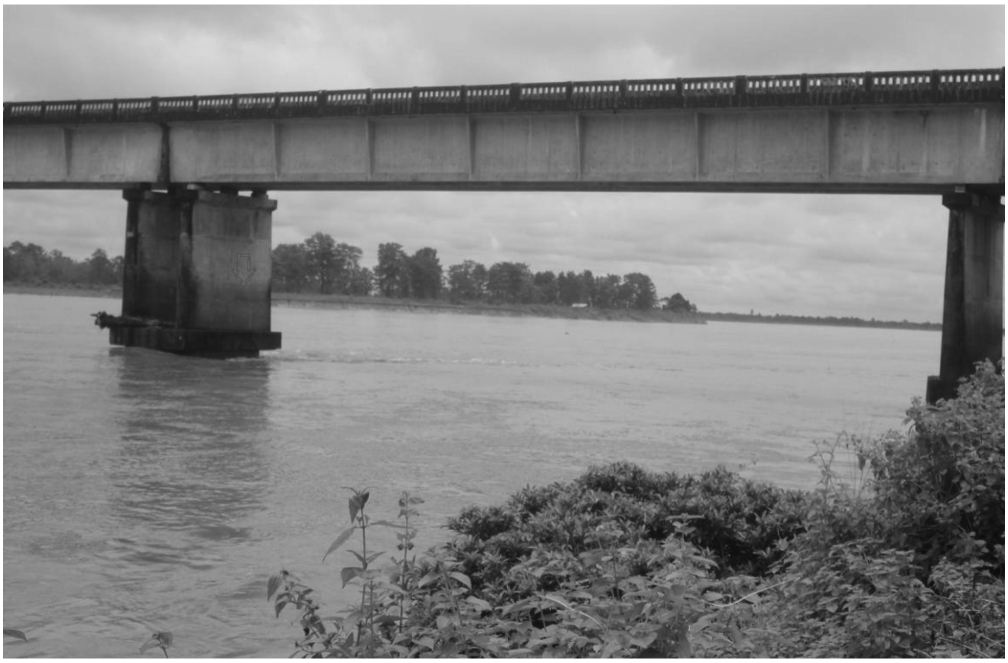


Plate 6.3: The red mark on the bridge pier indicates the highest flood level in the Subansiri river during 2012

Plate 6.4: Siltation after flood at Matmora in the Subansiri basin

Plate 6.5: The hanging bridge connecting the villages of Tehri and Pauri districts in Garhwal

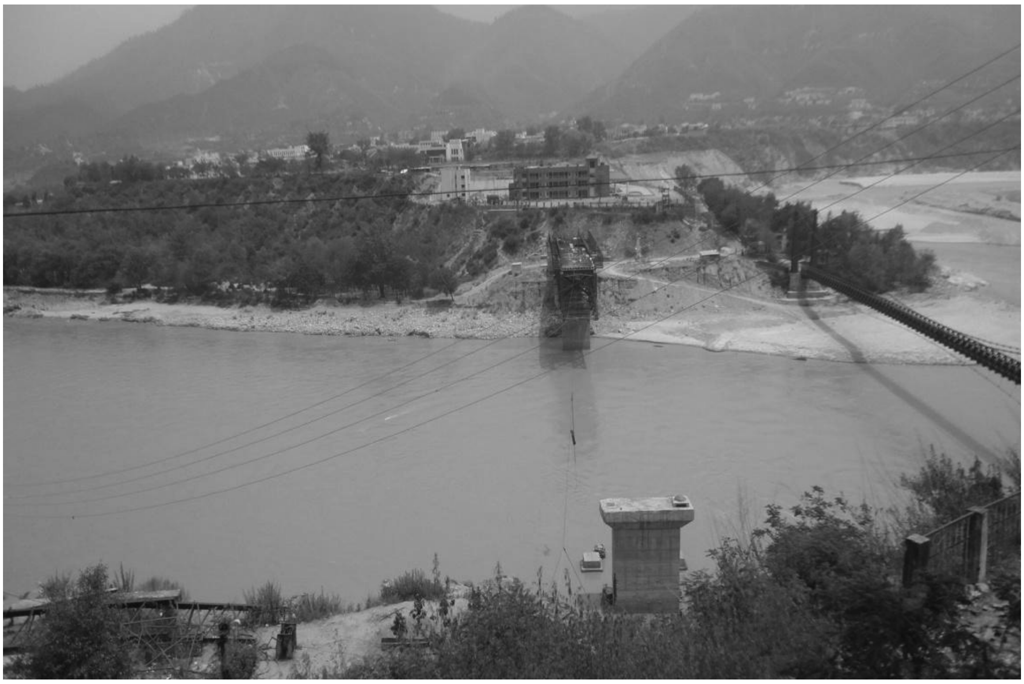


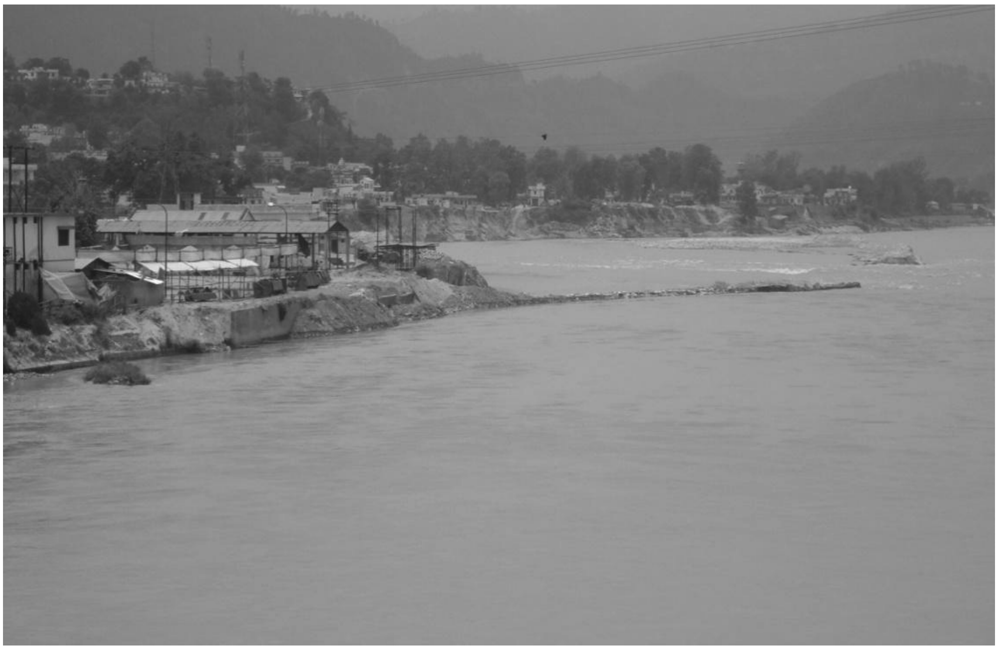
Plate 6.6: Construction activities in Srinagar in Alaknanda basin

(a)

(b)

Plate 6.7: Construction of dams (a) in the river Alaknanda in Garhwal and (b) in the river Subansiri in Arunachal Pradesh

(a)



(b)

Plate 6.8: Settlements on the bank of the river Alaknanda (a) in Srinagar and (b) in Rudraprayag

Plate 6.9: Devastation of Uttarakhand disaster 2013 in Srinagar near Ganga Ghat

(a)

(b)

Plate 6.10: Bank erosion in (a) Srinagar during Uttarakhand disaster 2013 and (b) near Khabolughat in Subansiri basin during the flood of 2008

Plate 6.11: Red mark showing the destroyed road in Rudraprayag because of landslides during Uttarakhand disaster 2013

Plate 6.12: Risky transportation in landslide prone areas of Rudraprayag

Plate 6.13: Submerged area of Khabolughat in Subansiri basin during the flood of 2008

Plate 6.14: Bank erosion of the Subansiri river in Kamalpur area, 2012

6.4 DISCUSSION

The hill slopes are prone to landslides, landslips, rockslides and soil creep. These hazardous features have hampered the overall progress of the region as they obstruct the roads and flow of traffic, dislocate communication, block flowing water in streams and create temporary reservoirs and also bring down lot of soil and debris and thus add enormous silt and gravel to the streams. The slides are of two types: first, slides formed due to natural factors such as geological, tectonic, additional moisture percolation, surface water percolation and slopes more than 35°, and second, slides induced by man and his activities. A few major landslides of the district e.g., Satpuli, Banghat, Patal, Kaliasaur and Lansdowne Landslides are a result of these practices. In the Alaknanda River and its tributaries, major landslides and floods are known to occur every ten to twenty years (http://pauri.nic.in/pages/display/66-natural-calamities).

From the above study, it is noticed that both natural factors as well as anthropogenic activities have influenced the eastern and western Himalayan basins to create hazards and their related impacts. But on the whole, floods in the monsoon season and earthquakes are more frequent in the Subansiri basin, while flash floods due to cloudbursts and landslides are relatively more common in the Alaknanda basin. However, the human intervention is seen to be comparatively more dominant in the Alaknanda basin of western Himalaya than the Subansiri basin of eastern Himalaya.