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Disaster events and management in the Himalayan Watershed Gori Ganga, Kumaun Himalaya

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Abstract
Global warming and disasters are fast emerging as the most defining challenges of the 21st century as global risks with impacts far beyond just the environment and implications on national security and development. The paper examines the natural disaster events due to anthropogenic accelerated global warming in context of Gori Ganga watershed, Kumaun Himalaya (Uttarakhand). The study area has been numerous devastating incidents of disaster events claiming huge losses of property, damages to forest wealth, road, agriculture land, infrastructure and livelihood. For present study mapping and data analysis on the basis of field survey for highly active flash flood and mass wasting sites during 2010-2019, earthquake epicenters occurred during 2011-2019, indiscriminate rock cutting for new road buildings and road induced landslide sites from 2014 to 2019 and isolated villages due to different disaster events during 2013-2019 in the Gori Ganga watershed. These disaster events suggested that the study area is being affected by global warming which being triggered different type of disaster events in the study area. A brief account of occurring disaster events in the study area such as earthquake, flash flood, mass wasting and road induced landslides is presented in the following paragraphs.

Keywords: Anthropogenic accelerated, global warming, implications, disaster

Introduction
Mountains are fragile resource zones and are highly susceptible to both natural forces and anthropogenic factors. Studies across the world have found that the health of the World's Mountains is in dire need of relief from modern anthropogenic activities that are causing lasting physical damages and human insecurities (Ives and Pitt, 1988; Ives and Messerli, 1989; Agenda-21 1992; Jodha 1995, 2005; UNEP-WCMC, 2002) [8, -9, 10, 15, 11, 14]. According to the analysis by the United Nations University, pressure from tourism, development, pollution, deforestation, climate change, and other forces is permanently eroding the landscape of many mountain ranges, with serious implications for society (National Geographic News, February 1, 2002) [12]. Global warming is accelerating the melting of glaciers in the Himalayas, which are melting faster than the global average (ICIMOD and UNEP 2000; Bajracharya *et al*., 2007) [7, 1]; the snow line will rise and potentially some glaciers could disappear or stabilize at a much reduced mass (IPCC, 2007) [6]. There is strong evidence that this observed warming can be attributed to anthropogenic accelerated global warming. The current scientific consensus is that 'most of the warming over the last 50 years is attributable to human activities' (IPCC, 2001) [5]. About 75 percent of the moderate hot extremes over land and 18 percent of moderate precipitation extremes are attributable to global warming (Fischer and Knutti, 2015) [3]. At present in different countries are already experiencing an increase in natural hazards. The number of people exposed to river floods could increase by 4 to15% in 2030 and 12 to 29 percent in 2080 and coastal flood risks can increase rapidly with sea level rise (Hallegatte *et al*., 2013) [4]. Various studies suggest that warming in the Himalayas has been much greater than the global average of 0.74°C over the last 100 years (Du *et al*. 2004; IPCC 2007) [2, 6] and high altitude ecosystems are even more at threat (New *et al*., 2002) [13]. Some of the major consequences of these processes include water shortages and increased natural disasters such as earthquakes, landslides, avalanches, catastrophic flooding, soil erosion; loss of genetic diversity; armed conflicts; wildfires; rock fall and extremes of temperature and radiation among others.

Objective
The fundamental objectives of the present investigation *viz*., implications in disaster management due to global warming in the Gori Ganga watershed Kumaun Himalaya, Uttarakhand, which incorporates the follows:

- Highly active flash flood and mass wasting sites during 2010-2019 in the Gori Ganga watershed.
- Study of earthquake epicenters occurred during 2011-2019 in and nearby the study area.
- Indiscriminate rock cutting for new road buildings and road induced landslide sites from 2014 to 2019 in the Gori Ganga watershed.
- Heavy anthropogenic pressure on environment and forest fire events in the study area.
- Study of isolated villages due to different disaster events in the Gori Ganga watershed during 2013-2019.
- Mapping of disaster sites and isolated villages in the study area.

Methodology

Mapping for the present study is based on field survey and Global Position System (GPS) prepared by Geographic Information System (GIS) software Arc GIS. Numbers of isolated villages due to different disaster events retrieve from District Disaster Management Office (DDMO), Pithoragarh.

Location and Extent

The study area, *viz*., the Gori Ganga watershed (Kumaun Himalaya) (Figure-1) extends between 29^{0}45’0’’N to 30^{0}35’47’’N latitudes and 79^{0}59’33’’E to 80^{0}29’25’’E longitude, and encompasses an area of about 2191.63 km^2. The altitude of the Gori Ganga watershed varies between 626 m and 6639 m. The Gori Ganga watershed has 168 villages and total population is about 40616 as per 2011cencess (Parihar and Rawat, 2021). Gori Ganga watershed spreads in three Blocks, i.e., Munsyari, Dharchula and Didihat, in three Tehsils, i.e., Munsyari, Dharchula and Didihat, and in one Sub-Tehsil known as Bangapani. Munsyari remains one of the last accessible hill stations by motor road in the region. There are many tribes in this watershed which are Bhotiya, Barpatiya and Anuwal Samuday. Three main valleys i.e., Gori Ganga valley, Ralam valley and Johar valley are famous valleys in the study area.

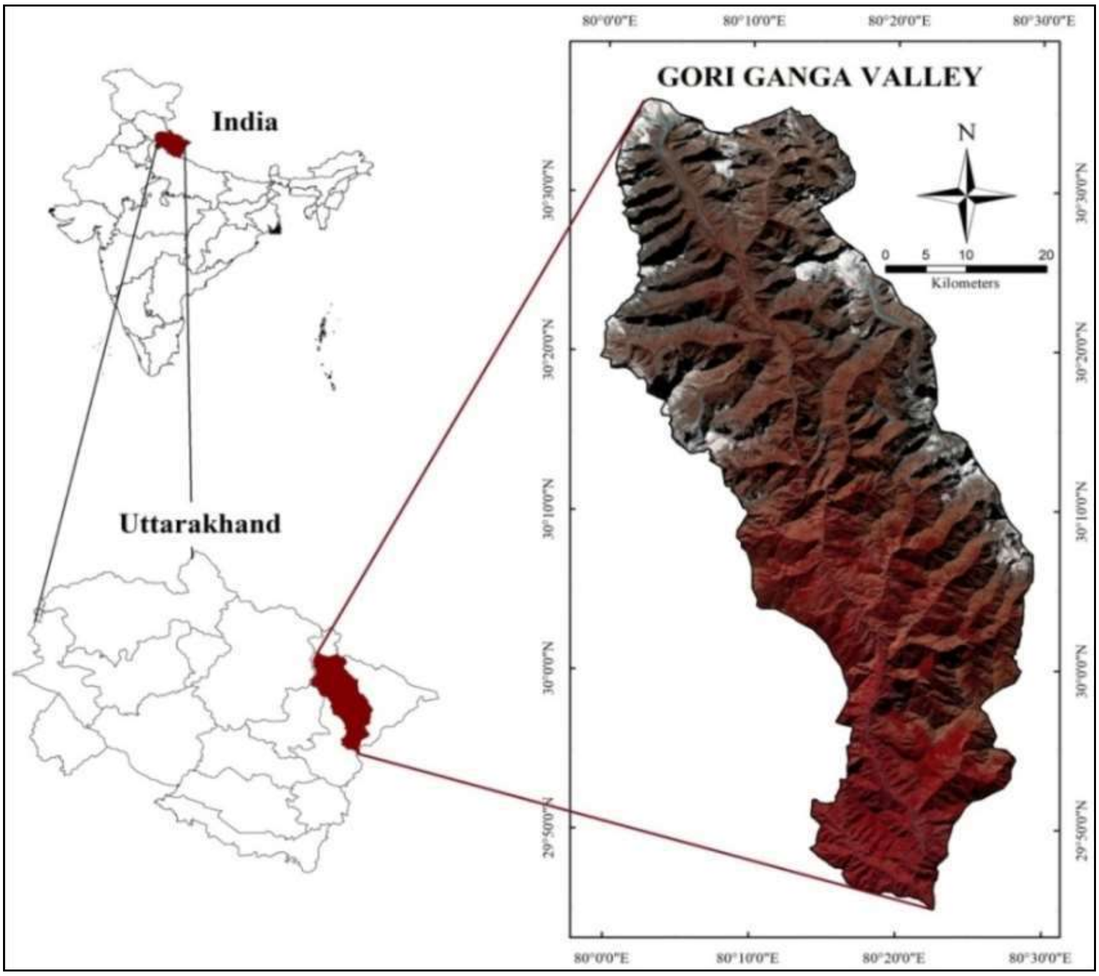

Fig 1: Location map of the Gori Ganga watershed, Kumaun Himalaya (Uttarakhand).

Result and Discussion

The Gori Ganga watershed is constructed of two physiographic regions (Great Himalayan region and Lesser Himalayan region) which is divided by Main Central Thrust (MCT). This is the cause can provide more disaster sensitivity to the study area. In the present study Figure-2 depicts the distribution of sites of highly active natural disasters in the study area which is registered in Table-1. Plate-1 and Plate-2 presented example of disaster events in the study area. Figure-3 depicts the spatial distribution of earthquake epicenters occurred during 2011 to 2019 in and nearby the study area which is registered in Table-2 while Plate-3 presenting example of huge rock fall caused by 2017 earthquake event at Kokila Mandir. Figure-4 depicts development of roads during 2014 to 2019 and details registered in Table-4 while Figure-5 presents road induced landslide events from 2014 to 2019 in the study area which is registered in Table-5 while Plate-4 presenting example of road induced (technologic) landslide events in the Gori Ganga watershed. Plate-5 presenting wild fire events in the Gori Ganga watershed and Figure-6 depicts the geographical distribution of isolated villages during different disaster events during 2013 to 2019 in the Gori Ganga watershed and registered in Table-6. A brief accounts of these results it's discussed in the following paragraphs.

Implication in Disaster Management

The Gori Ganga watershed has been numerous devastating incidents of disaster events claiming huge losses of property, damages to forest wealth, road, agriculture land, infrastructure and livelihood. Major causes for the disaster events in Gori Ganga watershed is the heavy anthropogenic pressure on environment, unprecedented heavy rainfall, flash flood, wild fire and frequently occurring earthquake activities. Frequencies of disaster events are more pronounced during monsoon season. Disaster events are mostly observed on agricultural land, hill slope and near villages in the elevations of between 600 m to 2400 m, on 10°–40° slopes and on either side streams/rivers and roads on either side up to a distance of 500 m. These disaster events suggest that the study area is being affected by global warming and climate change by which the area being triggered different type of disaster events. A brief account frequently occurring disaster in the study such as earthquake, flash flood, mass wasting and road induced landslides is presented in the following paragraphs-

Flash Flood and Mass Wasting

Disaster events are in mountain regions triggered by both natural and anthropogenic disturbances that initiate slope failure. Heavy rainfall, flash flood, landslides mass wasting, land creeping are the most devastating and recurring natural disasters and have deep adverse impacts in the study area. Figure-2 depicts the geographical distribution of 15 natural disaster sites of the last 6 years when occurs from 2006 to 2019 in the Gori Ganga watershed. The details of these disaster events are registered in Table-1. Due to these disaster events, the roads, bridges, houses sometimes entire the villages and hydro projects are damaged. Example of houses damaged by Gori Ganga and its tributaries during disaster events are presented in Plate-1 which shows (A) at Umargada village by Gori Ganga River in 2019, (B) at Balibagar village by Bona Gad in 2019, (C) Primary school building at Madkote town by Gori Ganga River in 2013 and (D) at Madkote town by Gori Ganga River in 2013. Example of hydro power project damaged by Gori Ganga and its tributaries during disaster events are presented in Example of heavy mass wasting by Bona Gad during disaster events in 2016, 2017, 2018 and 2019 at the village Tanga presented in Plate-2.

Plate 1: Damaged houses in Gori Ganga watershed: (A) at Umargada village in 2019, (B) at Balibagar village in 2019, (C) school building at Madkote village in 2013 and (D) at Madkote village in 2013.

Plate 2: Heavy mass wasting at the village Tanga in 2016, 2017, 2018 and 2019 in the Gori Ganga watershed.

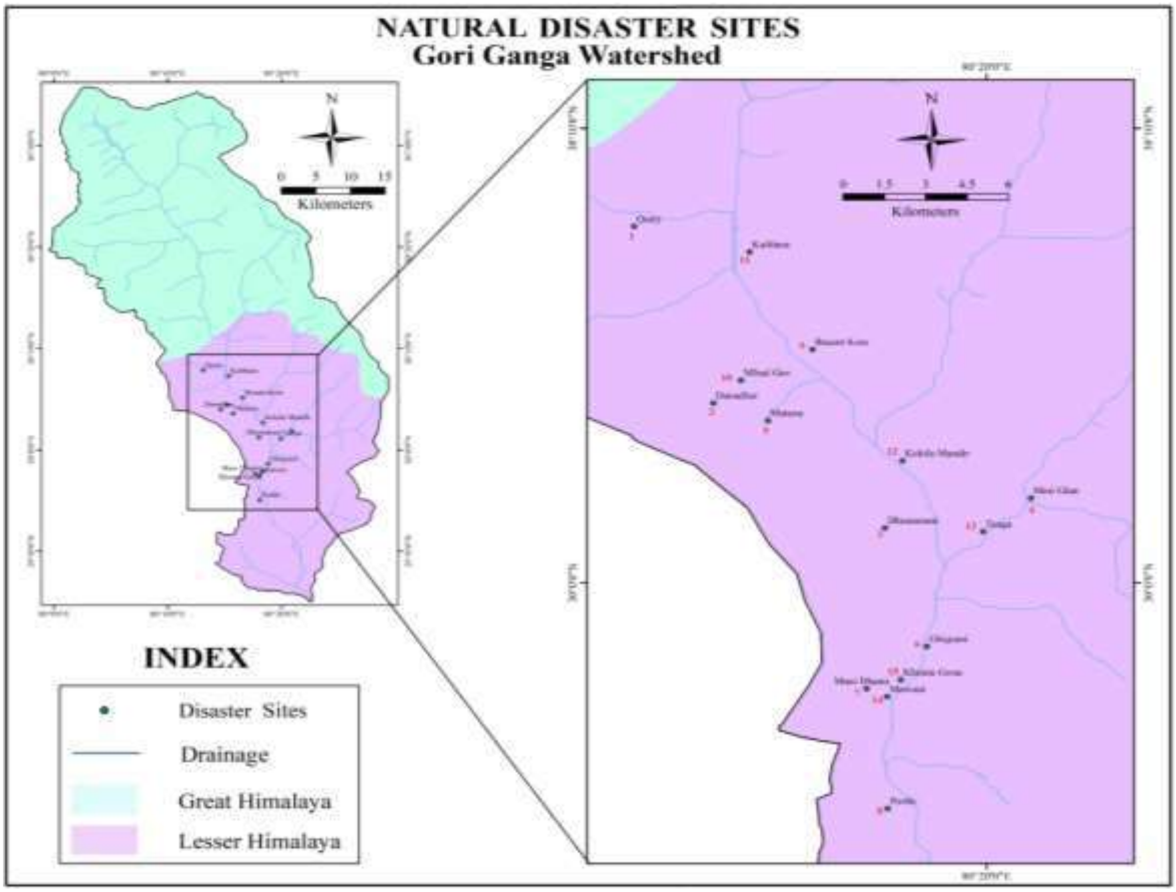

Fig 2: Distribution of sites of highly active natural disaster in the Gori Ganga watershed (based on field survey and GPS).

Earthquake

Entire the study area falls in Earthquake Seismic Zone-V. It means the area has a high degree of susceptibility for earthquakes. Due to recurring earthquake the area is prone for severe mass wasting and landslides. A District Disaster Management Office (DDMO) focused on earthquake-induced landslides reveals that after each earthquake the area damaged by catastrophic landslides. Field observations have indicated that such rock falls and landslide events i.e., Kokila Mandir (Near Fagua) and Ghigrani (near Bangapani) etc. is associated with earthquakes. Figure 3 depicts the geographical distribution of earthquake events from 2011 to 2019 within and nearby the study area and their details are registered in Table 2. Table 3 reveals that during the last 9 years the study area has experiences as many as 23 events of earthquake having Richter scale ranging from 3 to 7.1. On an average the study area is being triggered by earthquake by each year having between 3 to 5 magnitudes. Earthquake of 5 to 6 magnitudes occurs after each 2 years while earthquake of magnitude above 6 occurs once in 10 years (Table 3) and Plate 3 shows the rock fall site at Kokila Mandir caused by the 18-11-2017 earthquake event in the Gori Ganga watershed having a magnitude of 3.3 between Nachani-Banshbagar.

Table 1: Highly active flash flood and mass wasting sites during 2006-2019 in the Gori Ganga watershed (based on field survey and GPS).

S. N.	Disaster sites	Latitude Longitude	Causes of disaster	Years of events
1	Quiry-Jimiya	30°7'50.45"N 80°13'5.65"E	Heavy rainfall, mass wasting, land creeping	2013 and 2018
2	Near Dana Dhar	30°3'57.04"N 80°14'38.78"E	Heavy rainfall, land creeping	2013, 2015, 2018
3	Dhunamani	30°1'12.18"N 80°18'0.64"E	Heavy rainfall, landslides, land creeping	Each year after 2008 continue
4	Moti Ghat	30°1'51.63"N 80°20'52.48"E	Heavy rainfall, flash flood, mass wasting, landslides	2010, 2013, 2017, 2019
5	Matena	30°3'34.02"N 80°15'42.98"E	Heavy rainfall, landslides	2013, 2019
6	Ghigrani	29°58'35.65"N 80°18'50.00"E	Heavy rainfall, rock fall, landslide, land creeping	Each year after 2006 continue
7	Mani Dhami	29°57'39.97"N 80°17'39.24"E	Flash flood, mass wasting	2009, 2013, 2019
8	Porthi	29°55'1.60"N 80°18'3.79"E	Land slide	2013
9	Basantkote	30°5'7.93"N 80°16'35.42"E	Land creeping	2013, 2019
10	Minal Gav	30°4'27.21"N 80°15'11.41"E	Heavy rainfall, mass wasting	2013. 2019
11	Kulthaam	30°7'16.79"N 80°15'21.31"E	Heavy rainfall, landslide, land creeping	Each year after 2010 continue
12	Kokila Mandir	30°2'40.89"N 80°18'21.22"E	Heavy rainfall, rock fall	2017
13	Tanga	30°1'7.46"N 80°19'55.91"E	Heavy rainfall, flash flood, mass wasting, landslides	2017, 2018, 2019, 2020
14	Mawani	29°57'29.57"N 80°18'3.40"E	Flash flood, mass wasting	2010, 2013, 2019
15	Khinnu Gona	29°57'51.67"N 80°18'19.27"E	Flash flood, mass wasting	2013, 2017, 2019

Table 2: Major earthquake epicenters occurred during 2011-2019 in and nearby the study area (Source: DDMO, Pithoragarh from 2020).

Date	Time	Richter scale (m)	Epicenter nearby the study area	Latitude (N)	Longitude (E)
04-04-2011	5:02 PM	5.7	Dharchula	30° 0'22.95"	80°38'1.11"
05-05-2011	7:00 PM	5	India-Nepal Border	30°11'59.82"	80°24'0.01"
15-06-2011	6:29 AM	3.4	Dharchula (Pithoragarh)	30° 6'23.74"	80°36'46.63"
14-07-2011	7:14 AM	3.1	India-Nepal Border	29°59'44.05"	80°42'57.05"
28-07-2012	11:20 AM	4.5	India-Nepal Border	30° 0'53.96"	81° 0'27.94"
02-01-2013	1:20 AM	4	India-Nepal Border	30° 0'43.87"	80°51'59.93"
30-01-2013	1:20 AM	4	Dharchula	30° 0'9.87"	80°43'18.46"
06-03-2013	10:00 AM	3	India-Nepal Border	29°44'46.87"	80°22'40.19"
03-07-2014	5:05 PM	4.1	Between Bogdiyar and Milam	30°20'37.11"	80°11'55.89"
06-07-2014	8:18 PM	4.5	Between Darma and Malla Johar	30°11'58.71"	80°17'59.51"
23-01-2015	10:19 AM	3.2	India-Nepal Border	30° 0'47.55"	80°47'8.50"
27-06-2015	11:34 AM	7.1	Dharchula	29°59'29.70"	80°37'20.21"
26-07-2015	10:29 PM	3.4	Dharchula	30° 0'47.00"	80°45'10.34"
24-10-2015	10:05 AM	3.9	Between Nahar Devi And Rilkote	30°17'59.78"	80°11'59.90"
11-04-2016	4.06 PM	3.7	Between Thal and Berinag	29°47'59.81"	80° 5'60.00"
06.05.2016	11-05 PM	4.1	Near Panchhu village,	30°23'58.18"	80° 5'58.94"
08-06-2016	01.41 AM	3.5	Between Nachani-Banshbagar	29°53'59.73"	80°11'59.81"
17-10-2016	06.01 AM	4	India-Nepal Border	29°57'53.53"	80°41'18.45"
01-12-2016	10.22 PM	5.2	India-Nepal Border	29°57'32.15"	80°48'8.08"
18-11-2017	06.32 PM	3.3	Between Nachani-Banshbagar	29°53'59.48"	80°12'0.03"
24-05-2018	07.55 PM	5	India-Nepal Border	29°42'0.00"	80°36'0.00"
16-09-2019	08.03 PM	4.3	India-Nepal Border	29°35'59.82"	80°41'59.98"
19-11-2019	07.00 AM	5.3	India-Nepal Border	29°41'42.83"	80°25'14.94"

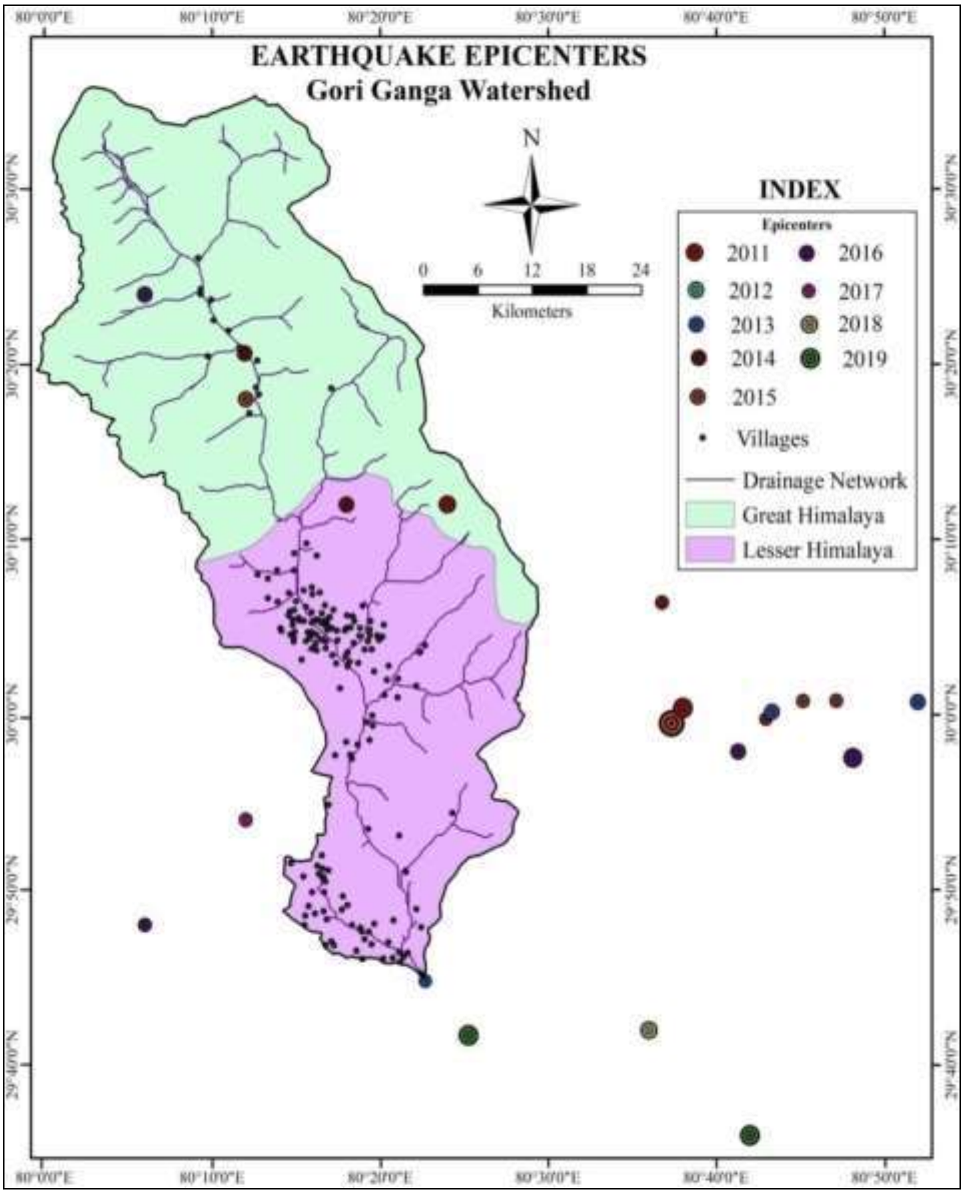

Fig 3: Geographical spatial distribution of earthquake epicenters occurred during 2011 to 2019 in and nearby the study area (based on DDMO, Pithoragarh from 2011-2019).

Table 3: Earthquake's Frequency and rates of earthquake nearby study area from 2011-2019.

S.N.	Richter scale interval (M)	Frequency in last 9 years	Repetition pattern
1	3-4	9	in1 year
2	4-5	8	in 1 year
3	5-6	5	in 2 years
4	>6	1	in 10 years
Total earth quake (2011-2019)		23	

Plate 3: Huge rock fall caused by 2017 earthquake event at Kokila Mandir (Near Fagua) in the Gori Ganga watershed.

Road Induced Landslides

The Gori Ganga watershed is very well connected by National, State, District, Tehsil and block headquarters. The total network of roads in the study area is about 266.15 km having a density of 12.14 km/km^2. The road construction work in the area is growing on very fast. Since 2014, 23 new roads having a total length of 170.46 km (64.05%) has been constructed in the study area during the last 5 years (Table-4 and Figure-4). Large Machines area being used for road construction which generate large amount of vibrations which triggered landslides, land creeping and rock fall incidents. Figure-4 depicts the geographical distribution of new roads development in the Gori Ganga watershed during 2014-2019. Figure-5 depicts the geographical distribution of road induced landslides during 2014-2019 and their details are registered in Table-5. These maps and Tables reveals that in the study area there are almost 11 permanent sites of road induced landslides in the study area. Where landslide occurs each year or after 2 or 3 years these are Gaila road, Madkote-Walthi road, Nirtoli road, Nirtoli village, Jara Jibli road etc. the most important sites of road induced landslides are nearby walthi village (Plate-4, A), nearby Basant Kote village (Plate-4, B), near the Darkote village (Plate-4, C), near Nirtoli village (Plate-4, D) and nearby Gaila village (Plate 4, F). Plate-4 presents road induced (technologic) landslide events in the Gori Ganga watershed.

Table 4: Indiscriminate rock cutting for new road buildings from 2014 to 2019 in the Gori Ganga watershed (based on field survey and PWD Didihat).

S. N.	New roads	Length (in km)	S. N.	New roads	Length (in km)
1	Balibagar to Farvekote	1.09	13	Bindi Road	2.68
2	Seraghat to Lodi	4.78	14	Walthi Bona	25.21
3	Chhori Bagar to Jarajibili	15.71	15	Madkote to Chulkote	7.9
4	Chami to Metali	5.62	16	Baram to Goge	4.45
5	Madkote to Paton	17.39	17	Walthi to Gaila	6.04
6	Madkote to Doonamani	8.16	18	Sera to Sirtola	1.85
7	Josha to Gandhi Nagar	3.62	19	Phalyati	5.23
8	Imla to Chouna	3.56	20	Milam Road	15.94
9	Chouna to Dana Dhar	5.58	21	Sera to Sirtola	1.87
10	Sera Pul to Dana Dhar	7.38	22	Chukotedhar Road	8.09
11	Darati pul to Darkote	5.26	23	Baram to Kanar	10.71
12	Tanga Road	2.34	Total		170.46

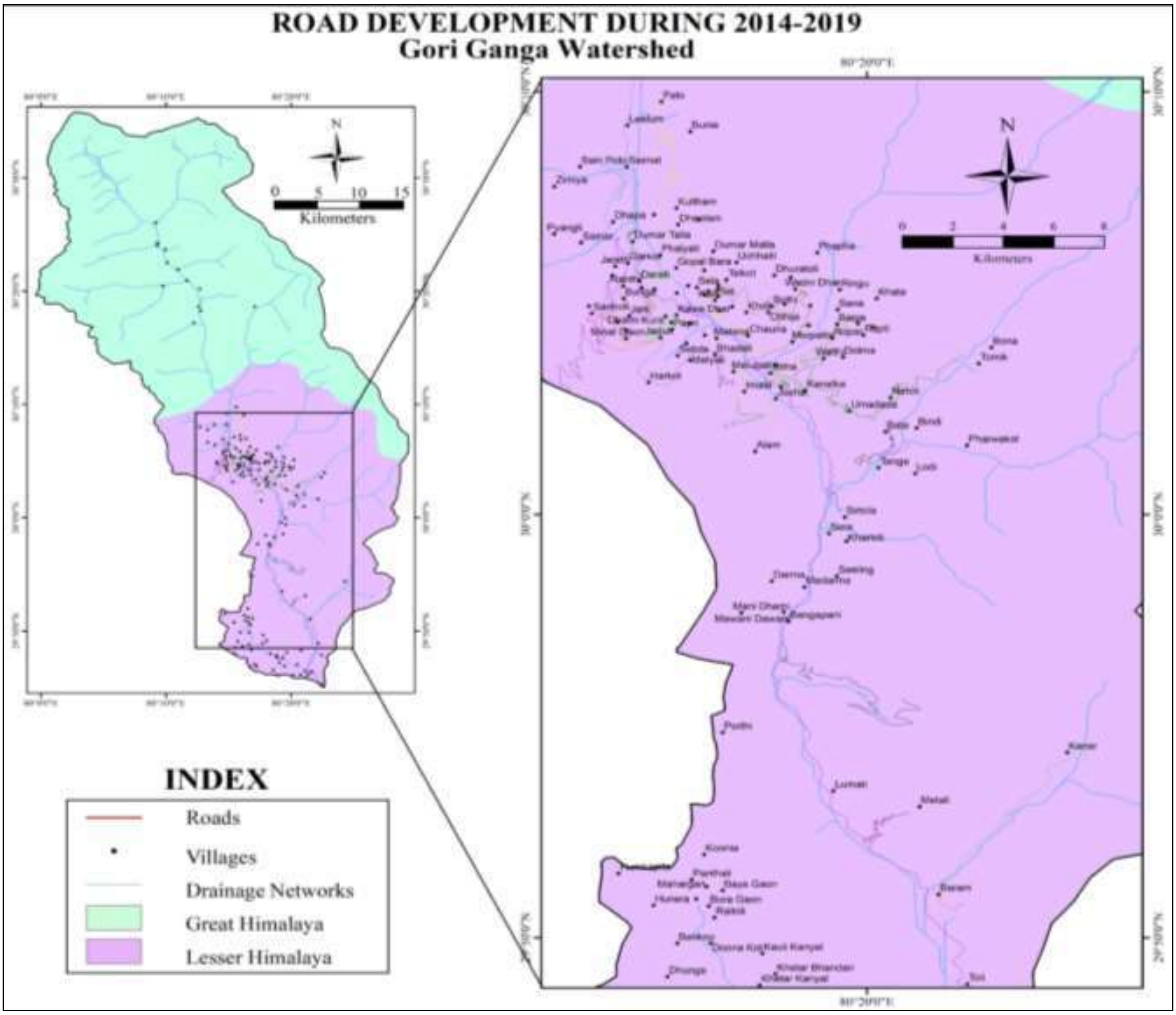

Fig 4: Development of roads during 2014 to 2019 in the Gori Ganga watershed (based on field survey and PWD Didihat)

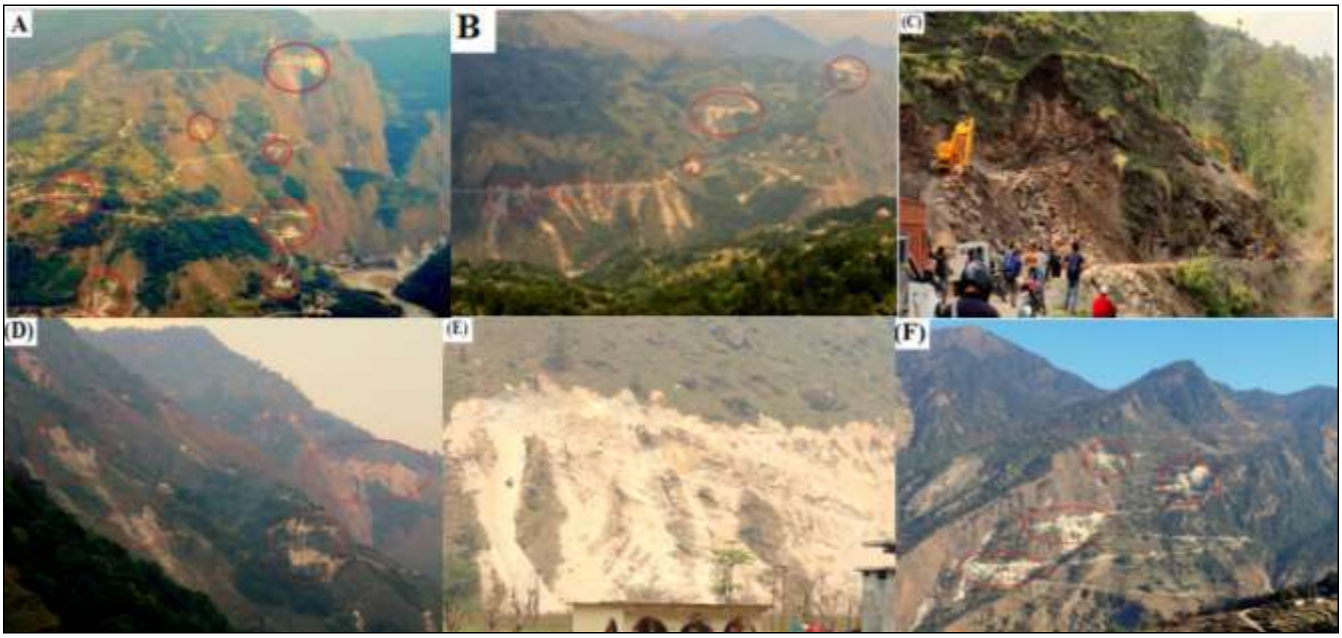

Plate 4: Road induced (technologic) landslide events in the Gori Ganga watershed: (A) nearby village walthi along Madkote to Walthi motor road in 2017, (B) nearby Basant Kote village in 2019, (C) near the Darkote village in 2019, (D) near the Nirtoli Village in 2017, (E) near the Mavani village in 2019 and (F) nearby Gaila village in 2019.

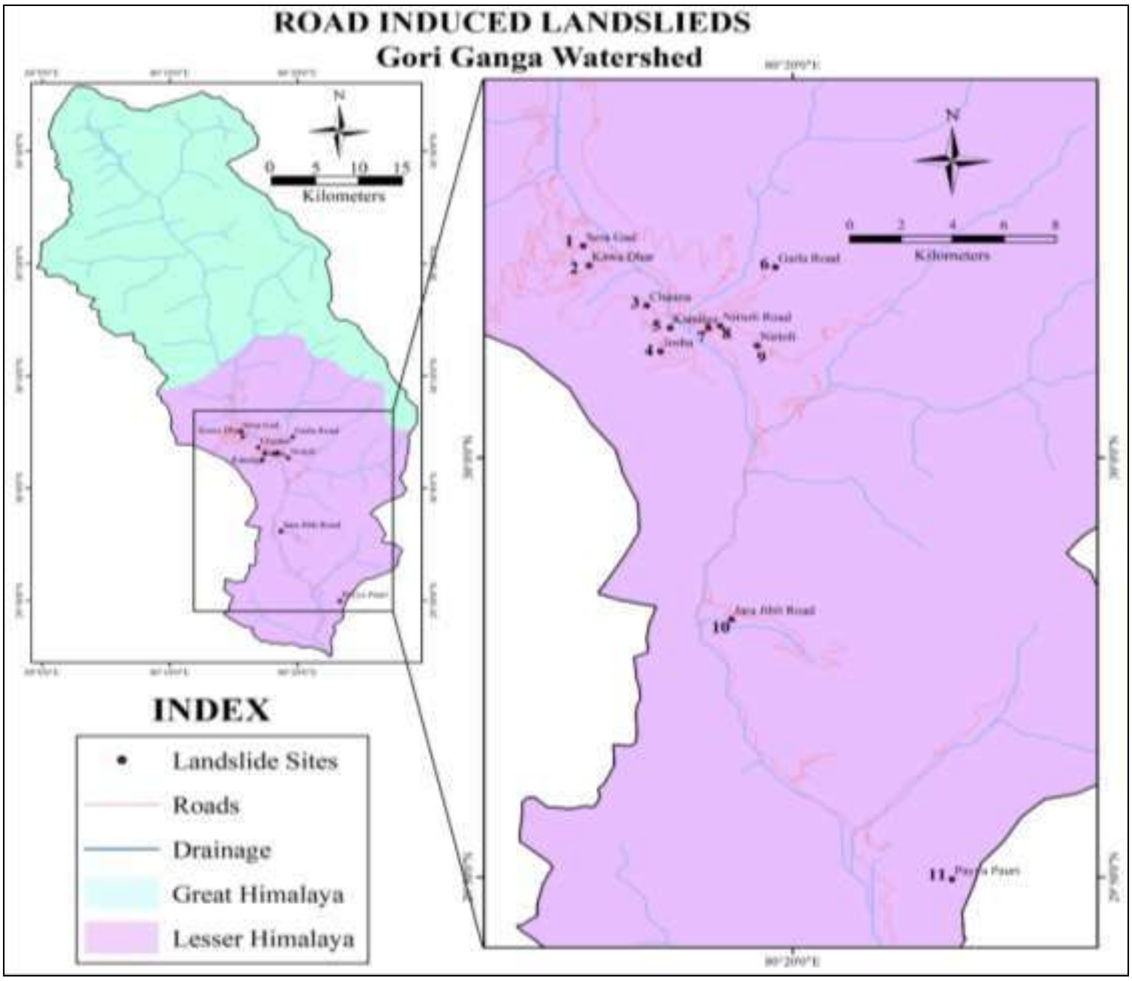

Fig 5: Road induced landslide events from 2014 to 2019 in the Gori Ganga watershed *(based on field survey and GPS).*

Table 5: Road induced landslide sites during the period of 2014-2019 in the Gori Ganga watershed *(based on field survey and GPS).*

S. N.	Landslide site name	Latitude/Longitude	Causes of disaster events	Year
1	Sera Gad	30° 5'2.61"N 80°15'36.07"E	rock cutting, landslide, land creeping	2018
2	Kawa Dhar	30° 4'34.65"N 80°15'43.57"E	rock cutting, landslide	2018
3	Chauna	30° 3'37.39"N 80°16'56.26"E	rock cutting, landslide	2018
4	Josha	30° 2'31.77"N 80°17'13.58"E	rock cutting, landslide, land creeping	2019
5	Kanalga	30° 3'5.70"N 80°17'25.75"E	rock cutting, landslide, land creeping	2018
6	Gaila road	30° 4'32.50"N 80°19'38.10"E	rock cutting, landslide	2014 to 2020
7	Madkote-Walthi road	30° 3'5.41"N 80°18'13.75"E	rock cutting, flash flood, landslide, land creeping	2014, 2016, 2017, 2018, 2019, 2020
8	Nirtoli road	30° 3'8.19"N 80°18'28.62"E	rock cutting, landslide	2014, 2018, 2019
9	Nirtoli village	30° 2'40.19"N 80°19'15.32"E	rock cutting, landslide	2014, 2018, 2019
10	Jara Jibli road	29°56'8.57"N 80°18'42.80"E	rock cutting, flash flood, landslide, land creeping	2018, 2019, 2020
11	Payya Pauri	29°49'56.39"N 0°23'20.20"E	rock cutting, landslide	2019

Heavy Anthropogenic Pressure on Environment

As the pressure of population rapidly growing, more and more human settlements, roads, dams, tunnels, towers and other public utilities are increases in the study area. Beside these lopping of trees for fuel or fodder, overgrazing, increases domestic and industrial consumptions of timber increasing of population in Bugyal for herbal collecting felling and burning of trees and shrubs for cooking and heating including the open burning of biomass, forest open area burning and firing in the alpine region during herbs collecting period. These anthropogenic activities have adverse impact in the environment of the Gori Ganga watershed.

Wild Fire

Gori Ganga watersheds have a rich storehouse of large biodiversity ranging from subtropical evergreen forests and alpine meadows. Now frequently occurring wild fire due to anthropogenic activities i.e. lightening on the agricultural fields, bonfires, burning match stick, lighting a fire in open forest areas to liquefy bitumen for laying bitumen in the road and smoking stick throwing in open forest areas has imposed severe threat for recession of biodiversity, natural regeneration, productive capacity of forests. This has adversely affected the rural economy and ecosystem in the Gori Ganga watershed. Plate-5 presents some of the examples of anthropogenic wild fire events in the different parts of the Gori Ganga watershed.

Isolation of Villages during and After Disaster Events

Due to heavy rainfall frequently occurring cloudburst events caused by the climate change the road network, bridges and footpaths are severely damage, therefore a large number of villages remains isolated for entire the rainy season and sometimes for six months and foe whole year. Figure-6 depicts the distribution of 65 villages were isolated during 2013-2019. The reason of their isolation is presented in Table-6. Table-6 reveals that in 2013 Burfu, Umdada, Lalkote, Jara, Sain, Barna Airo, Ralam, Pachhu, Jimighat, Bhikuriya, Mapa, Buiee, Kolu, Sumdu, Mahargari, Hunera, Madarma, Paton, Jimiya Kooniya, Baya Gaun, Bora Gaun, Porthi, Milam, Humkapita, Marjhali, Darma, Sinnar, Lari, Pyankti, Khet Bharar, Golfa, Martoli, Bata, Bogdyar, Lwa, Alam, Tanga, Nirtoli, Okhali, Rilkote, Dakhim, Tomik, Fagua Bagad, Khelanch, Ghanghura, Gaila, Lodi, Dhoonamani, Raitoli, Doona Kote, Talla Paton, Gangdhar, Lyang, Quirry, Bilju and Leelam villages was isolated for many month due to severe damages of road bridges and foot path caused by flood and mass wasting. In 2014 Porthi, Golfa, Bona and Bhikuriya villages was isolated for two months due to severe damages of bridges, roads and footpaths caused by flash flood and mass wasting. In 2016 Lodi, Tanga, Bhikuriya, Golfa, Bona, Jara, Porthi, Raitoli, Hunera, Mahargari and Kooniya villages was isolated for many months due to severe damages of bridges and footpaths caused by flash flood and mass wasting. In 2018 Metali, Dakhim, Madarma, Darma, Narki, Bora Gaun, Paton, Sain, Buiee, Sinnar, Lari Pyankti and Bogdyar villages was isolated for one month due to severe damages of bridges and footpaths caused by flood and mass wasting. In 2019 Lodi, Tanga, Bhikuriya, Golfa, Bona, Jara, Bora Gaun, Paton, Porthi, Khet Bharar, Dakhim, Raitoli, Hunera, Mahargari and Kooniya villages was isolated for two months due to severe damages of bridges, roads and footpaths caused by flood and mass wasting (Table-6).

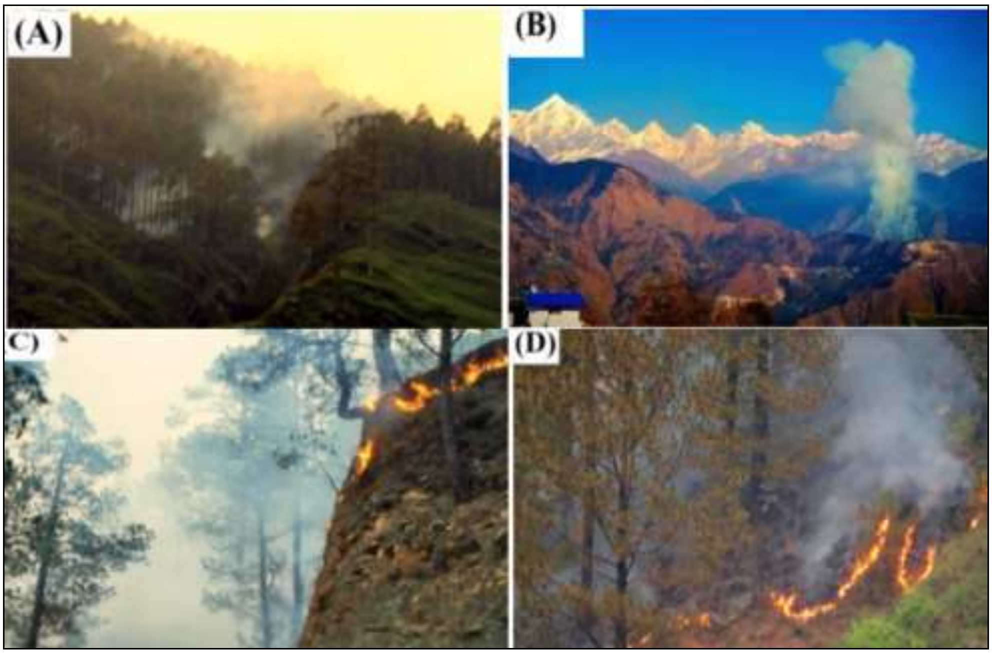

Plate 5: Wild fires in the Gori Ganga watershed: (A) near Dhunamani village in 2019, (B) near the Panchachuli glacier in 2019, (C) near Kanar village in 2019 and (D) near Lodi village in 2019.

Table 6: Details of isolated villages due to different disaster events in the Gori Ganga watershed during 2013-2019 (based on field survey and DDMO, Pithoragarh).

Year	Period of isolation	Cause of isolation	Name of isolated villages
2013	June to September	Damage of bridges, roads, footpaths and telecom connectivity	Burfu, Umdada, Lalkote, Jara, Sain, Barna Airo, Ralam, Pachhu, Jimighat, Bhikuriya, Mapa, Buiee, Kolu, Sumdu, Mahargari, Hunera, Madarma, Paton, Jimiya Kooniya, Baya Gaun, Bora Gaun, Porthi, Milam, Humkapita, Marjhali, Darma, Sinnar, Lari, Pyankti, Khet Bharar, Golfa, Martoli, Bata, Bogdyar , Lwa, Alam, Tanga, Nirtoli, Okhali, Rilkote, Dakhim, Tomik, Fagua Bagad, Khelanch, Ghanghura, Gaila, Lodi, Dhoonamani, Raitoli, Doona Kote, Talla Paton, Gangdhar, Lyang, Quirry, Bilju, Leelam
2014	August and September	Damage of bridges, roads and footpaths	Porthi, Golfa, Bona, Bhikuriya
2016	July to September	Damage of bridges and footpaths	Lodi, Tanga, Bhikuriya, Golfa, Bona, Jara, Porthi, Raitoli, Hunera, Mahargari, Kooniya
2018	August	Damage of bridges and footpaths	Metali, Dakhim, Madarma, Darma, Narki, Bora Gaun, Paton, Sain, Buiee, Sinnar, Lari Pyankti, Bogdyar
2019	July to August	Damage of bridges, roads and footpaths	Lodi, Tanga, Bhikuriya, Golfa, Bona, Jara, Bora Gaun, Paton, Porthi, Khet Bharar, Dakhim, Raitoli, Hunera, Mahargari, Kooniya

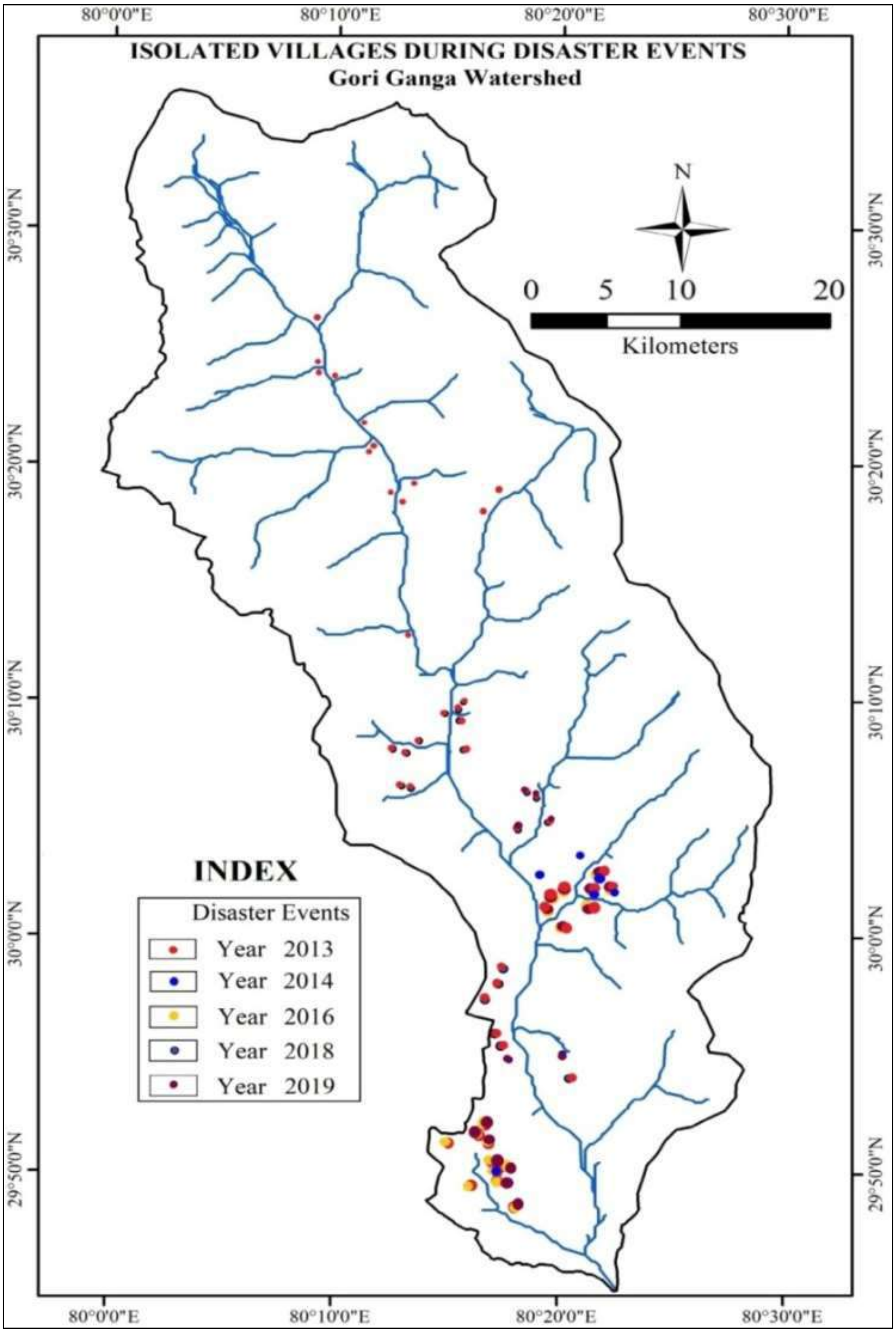

Fig 6: Isolated villages during different disaster events during 2013 to 2019 in the Gori Ganga watershed (based on field survey and DDMO, Pithoragarh).

Conclusion

Global warming and disasters interface with diverse social and natural processes and consequently with the developmental process. The conventional view has been to consider disasters and anthropogenic accelerated global warming as a barrier to development and simultaneously developments as a threat to climate change. However development can be the driving force to overcome challenges and risks of global warming. Disaster, global warming and climate change are increasingly being considered as a development constraint; hence, main streaming them into the development policy is all the more pertinent in the current context. A proactive risk reduction bottom-up driven approach is required and the government should work as a facilitator.

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