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Analysis of Disaster events in District Almora, Kumaun Himalaya, Uttarakhand

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Abstract
The Kumaun Himalaya region is too sensitive to natural disasters. Several natural and human-induced disasters regularly strike the study area almost every year, causing loss of life, agricultural land, forest, settlement, and millions of rupee of property. In the study area, natural disasters, e.g., landslide, cloud burst, earthquake, flood, mass wasting, storm etc occur naturally but human activities have also triggered disaster events, e.g., forest fire, landslide along with construction sites, flood due to deforestation etc. The disaster events affect all the forms of life, e.g., human beings, animals, plants etc. The main purpose of this study is to analyze the disaster events in district Almora, Uttarakhand. For this purpose, the disaster-sensitive zonation maps have been constructed for forest fires, landslides, earthquake and road construction sites mainly based on earlier disaster events using GIS models and techniques. Due to changing climate and human activities, the frequency of disaster events has increased in the study area. In this study, a detailed disaster mitigation strategy has been worked out which may be helpful for the management of disaster events in the future.

Keywords: Climate change, disaster events, disaster zonation, Kumaun Himalaya

1. Introduction
Disaster is an extreme sudden catastrophic event occurred in an area and causes damage to prosperity and the ecosystem. The disaster can be broadly divided into two parts based on the cause of disaster which are natural disasters and anthropogenic disasters (Jha, 2010) [7]. The disaster events are the most common phenomena of the study area, *viz*., Almora district, Kumaun Himalaya. They occur almost every year and strike the agricultural land, roads, settlements, etc of the study area. The disaster events create a significant constraint in the development of the area. Therefore, it is very important to analyze and identify the disaster potential area. So, the effect of potential disasters may be reduced. Remote sensing and geographic information science are very helpful techniques for disaster management and identification of disaster-prone areas (Ahmad and Goparaju, 2018) [7].The study area is too much sensitive for natural disaster events as it lies in earthquake sensitive zone 04 and 05. The forest fire events occur very frequently mostly between March to June and the cloud burst, flood, and landslide events are occurred frequently during the monsoon season from July to September, causing damage to plants, the habitat of wild animals, agricultural land, and construction sites as roads, settlements etc. Several scholars have studied the various aspects of disasters such as flood and its trend (Tripathy, 2015) [20], the trend of forest fire (Kumar and Negi, 2016) [8], landslide susceptibility (Wang, *et al*., 2016, Sarkar., *et al*., 2006, Sujatha*et al*., 2011) [16, 14, 18], disaster management (Verghese and Paul, 2013) [21], climate change and natural disaster (Sauerborn and Ebi, 2012) [15], landslide events causes and mapping (Haigh and Rawat, 2012, Rai P.K., *et al*., 2014) [5, 11], techniques of landslide hazard assessment (Pardeshi, *et al*., 2013) [10], the impact of flood disaster (Sholihah*et al*., 2020) [16], management and mitigation of earthquake disaster (Adnan *et al*., 2015) [1], economy and natural disasters (Hallegatte and Przyluski, 2010) [6] etc.The disaster events affect the development process of a region and the life of the residence. It is not possible to stop the occurrence of disaster but we can mitigate the effects of disaster using the early warning system.

2. Objectives of the study

Different disaster events strike the study area regularly throughout the year. Major disaster types are studied in this research paper. The fundamental objectives of this research paper are presented below:

1. To analyze the disaster events of the study area.
2. To construct maps of the disaster prone areas.

3.Methods and Materials

For the present study, the district Almora has been selected for the study of disaster events. Both natural (i.e., earthquake, flood, landslide etc) and anthropogenic (i.e., forest fire, disaster events along with construction sites) disaster events are analyzed in this research paper. For the completion of this research paper both primary (photographs and field observation) and secondary data (i.e., forest fire, road, earthquake, senses, etc) have been used. Different GIS software (Quantum Geographical Information System and Arc GIS) tools are used to demonstrate the disaster events and potential disaster zones. Disaster zonation maps for earthquakes, floods, landslides, and roads are constructed. The district disaster management authority Almora is approached and consulted for disaster data. The thematic maps of disaster prone areas are prepared with help of the Centre of Excellence for Natural Resource Data Management System (NRDMS), Almora and the weather data is collected from Vivekananda Pravatiya Krishi AnushandhanSansthan (VPKAS), Almora.

4. The study area

The study area is located in the Kumaun Himalaya region of Uttarakhand state, India. It is located between the 29°25`39.5`` N to 29°59`33`` N latitudes and 79°03`03`` E to 79°04`45`` E longitudes which encompasses an area of 3139 km^2 (Fig. 1). The study area varies between the elevations of 478m to 2757m having a mean elevation of 1617m from the mean sea level. The study area is surrounded by district Nainital in the south, district Champawat and Pithoragarh in the east, Bageshwer and Chamoli in the north, and PauriGarhwal in the west. Administratively, the study area is divided into 09 Tehsils (i.e., Almora, Someshwer, Sult, Bhikiyasen, Bhanoli, Chaukhutiya, Dwarahat, Jainti, and Ranikhet) and 11 developmental blocks (i.e., Syalde, Sult, Chaukhutiya, Dwarahat, Bhikiyasen, Tarikhet, Takula, Hawalbag, Bhaisiyachhana, Dhauladevi, and Lamgara). In the study area, there are total 2184 revenue villages, 01 Municipal Council (i.e., Almora) and 04 Nagar Panchayat (i.e., Dwarahat, Ranikhet, Chiliyanaula, and Bhikiyasen) (DSR, 2018) [4].

In 2015, the average maximum and minimum temperature is recorded in June (24 °C) and January (8.7 °C), respectively. In 2015, the total annual rainfall is registered 869.8 mm which varies from 2.4 mm in December to 239.2 mm in July (Table-1). According to census report 2011, the total population of the study area is 622506. Out of the total, 291081 are male and 331425 are female. In the study area, the literacy rate is 80.74%, population density is 198, and Sex ratio is 1139/1000 (DSR, 2011).

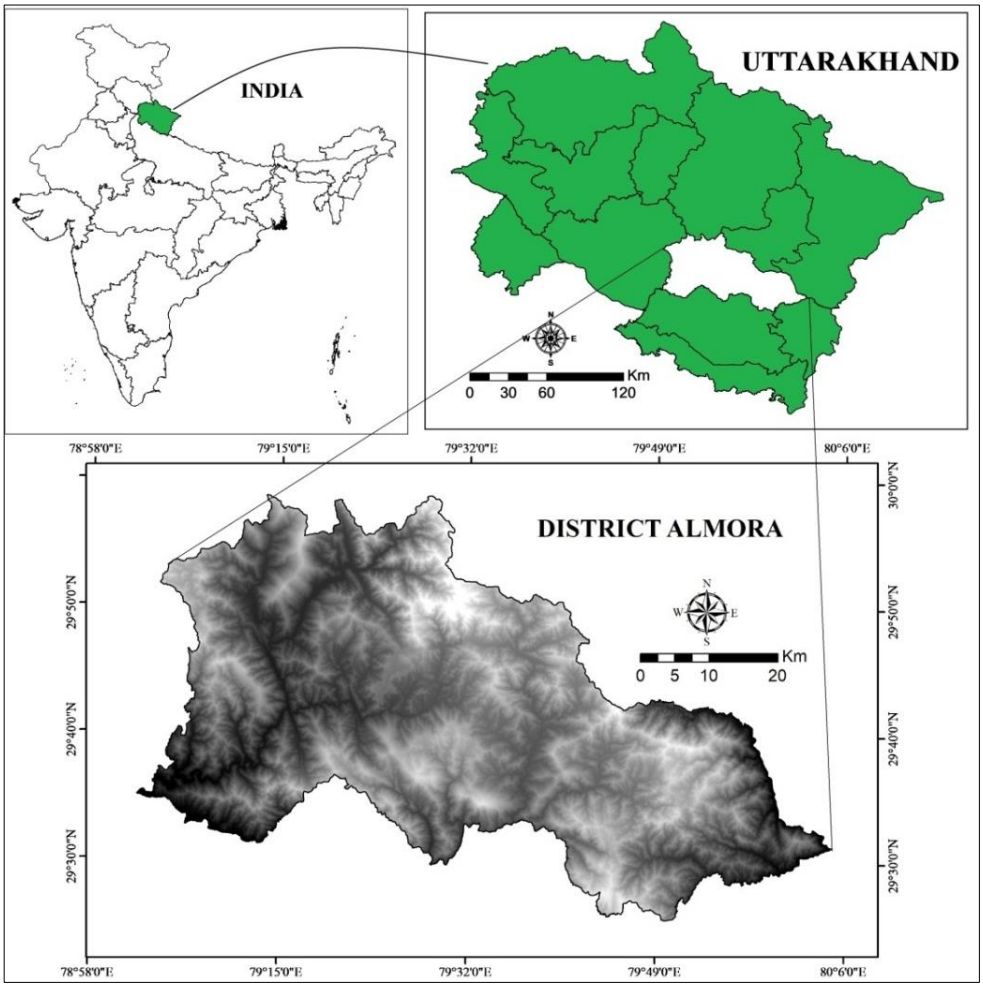

Fig 1: Location map of the study area, *viz*., district Almora.

Table 1: Temperature and rainfall statistics of the study area in 2015 *(Source: VivekanadaPravatiya Krishi AnushandhanSansthan, Almora).*

Months	Temperature °C			Rainfall	
	Max.	Min.	Ave.	Rainfall mm	Rainfall in %
Jan	14.7	2.7	8.7	59.2	6.81
Feb	15.9	5.2	10.55	41.6	4.78
Mar	19.6	7.7	13.65	127.6	14.67
Apr	23.4	12.1	17.75	60.4	6.94
May	28.6	16.7	22.65	17	1.95
Jun	29.5	18.5	24	190.8	21.94
Jul	25.6	17.1	21.35	239.2	27.50
Aug	26.1	18.8	22.45	84.4	9.70
Sep	26.8	17	21.9	4.8	0.55
Oct	23.9	13.1	18.5	40	4.60
Nov	19.7	8.6	14.15	2.4	0.28
Dec	15.6	4.5	10.05	2.4	0.28
Average	22.45	11.83	17.14	869.8	100.00

5. Result and Discussion

District Almora is sensitive for natural and anthropogenic disaster events. Due to uneven relief pattern, human activities, erratic rainfall etc, the study area faces several disaster events such as landslides, floods, forest fires, cloud bursts etc. Flood, cloud burst and landslide disaster events strike the study area probably between July to September, forest fire disaster events took place mostly between March to June, cold wave disastrous events occur in December to January, storm disaster events occur between April to May and earthquake disaster events may occur in any month of the year, i.e., the whole year is sensitive for earthquake disaster events (Table-2). A brief description of these disaster events (i.e., forest fire, flood, road disaster, landslide and earthquake) is presented in the following paragraphs.

Table 2: Probable months for different disaster events in the study area.

S.N.	Type of disaster/hazard	The probable month of disaster/hazard in district Almora											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Flood & cloud burst							■	■	■			
2	Earthquake	■	■	■	■	■	■	■	■	■	■	■	■
3	Landslide							■	■	■			
4	Forest fire			■	■	■	■						
5	Cold wave	■											■
6	Storm				■	■							

5.1 Forest Fire: Forest fire is a one of the dangerous disaster of the study area. Every year, hectares of forested area are damage due to forest fire events (Plate-1). The forest fire events took place in the study area mostly from March to June but in recent the year the forest fire events are also noticed in January and February which shows the effect of climate change and global warming. The detail of forest fire events in the study area is presented in table-3. The last 11 years (2005-2015) forest fire data is analyzed here. The maximum forest fire events are recorded in Chaukhutiya tehsil (148) while minimum forest fire events are recorded in Jainti tehsil (17) during the last 11 years. The maximum forest fire events are recorded in 2012 (307) while the minimum in 2011 (03) (Table-3). The diagrammatic presentation of forest fire events and year is presented in figure 2.

Table 3: Detail of forest fire events in district Almora (Source: district disaster management authority, Almora).

S.N.	Name of Tehsil	Total area(km^2)	Total villages	Forest fire incidence in different years											Total forest fire incidence
				2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
1	Almora	588.5	428	5	2	-	9	45	19	1	56	-	5	1	143
2	Bhanoli	345.8	224	-	-	-	3	7	1	-	6	1	2	1	21
3	Bhikiyasen	437.1	376	-	1	-	5	29	7	1	28	2	15	9	97
4	Chaukhutiya	324.7	164	-	-	2	3	75	12	-	32	3	10	11	148
5	Dwarahat	281.4	206	-	-	-	1	26	12	1	52	-	7	4	103
6	Jainti	165.3	117	-	-	-	-	11	3	-	3	-	-	-	17
7	Ranikhet	379.4	300	-	1	-	4	34	8	-	48	5	15	9	124
8	Salt	392.9	228	-	3	4	8	24	9	-	39	-	16	2	105
9	Someshwer	299.1	141	-	-	-	6	13	29	-	43	-	2	-	93
Total Annual		3139.0	2184	5	7	6	39	264	100	3	307	11	72	37	851

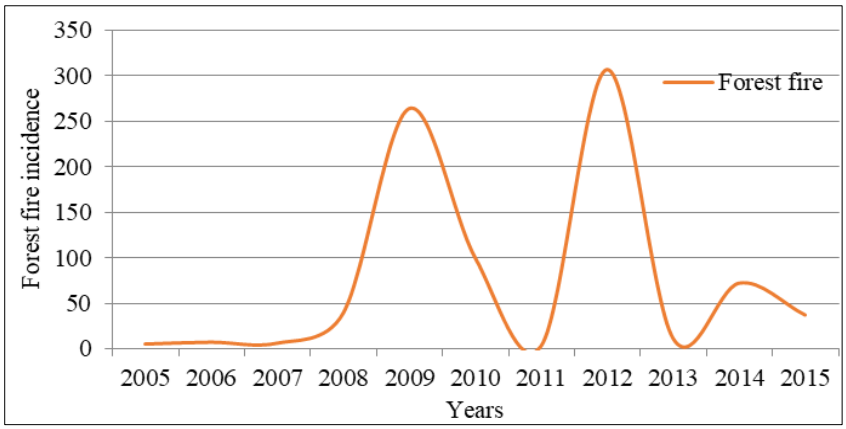

Fig 2: Diagrammatic presentation of forest fire events and years in the study area.

Plate 1: Damage of forest resources due to forest fire in the study area, *viz*., district Almora.

The study area is divisible into three forest fire zones based on total forest fire incidence in the last 11 years. These forest fire zones are; low forest fire zone, medium forest fire zone and high forest fire zone (Table-4). Based on the total forest fire events, the forest fire zonation map is constructed in Arc GIS using spatial analysis tools (Fig. 3). A brief description of these forest fire zones is presented in the following paragraphs.

5.1.1 Low Forest Fire Zone: Tehsils having less than 50 forest fire incidents are classified as a low forest fire zone. In this fire disaster zone, two tehsils are fall which is Bhanoli and Jainti (Fig. 3). The total geographical area of this forest fire disaster zone is 494.4 km^2 which accounts for 15.8% of the total area. There are total 341 villages are fall under this forest fire zone (Table-4).

5.1.2 Medium Forest Fire Zone: Tehsils having forest fire incidents from 50 to 100 are classified as a medium forest fire zone. In this forest fire zone, two tehsils are fall which is Someshwer and Bhikiyasen (Fig. 3). The total geographical area of this forest fire zone is 719.3 km^2 which accounts for 22.9% of the total area. There are total 517 villages are fall under this forest fire zone (Table-4).

5.1.3 High Forest Fire Zone: Tehsils having forest fire events from 100 to 150 are classified as high forest fire zone (Fig. 3). In this forest fire zone, five tehsils are fall which are Almora, Dwarahat, Ranikhet, Salt, and Chaukhutiya. The total geographical area of this forest fire disaster zone is 1925.3 km^2 which accounts for 61.3% of the total area. There are total 1326 villages are fall under this forest fire zone (Table-4).

Table 4: Forest fire zones, area, and total villages in the district Almora.

S.N.	Class intervals forest fire	Number of tehsils	Area in km^2	Area in %	Total Villages	Remark
1	0-50	02	494.4	15.8	341	Low forest fire zone
2	50-100	02	719.3	22.9	517	Medium forest fire zone
3	100-150	05	1925.3	61.3	1326	High forest fire zone
Total		09	3139.0	100.0	2184	-

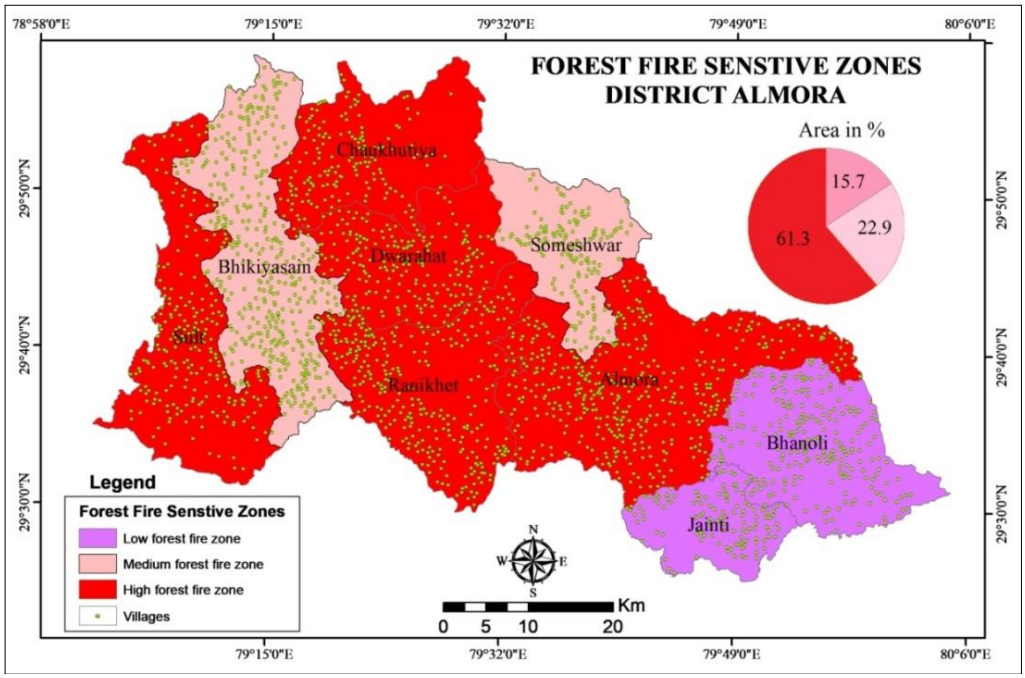

Fig 3: Spatial distribution of forest fire disaster zones in the study area.

5.2 Landslide: Landslide is a natural and man-made disaster in which a mass of soil/rock falls in the presence of water by the force of gravity caused damage to natural and man-made infrastructure (Pardeshi and Pardeshi, 2013) [10]. The slope angle is an important element of a landscape that affects significantly the intensity and process of the landslide (Plate-2). There is a direct correlation between slope angle and landslide events, *viz*., greater the slope angle higher the landslide events and the smaller the slope angle fewer the landslide events (Odhiambo*et al*., 2010) [9]. The study area is divisible into five landslide sensitive zones based on the degree of slope angle. These five landslide sensitive zones are: low sensitive zone, moderately sensitive zone, high moderate sensitive zone, high sensitive zone and very high sensitive zone. The landslide sensitiveness map of the study area is constructed in Arc GIS software using a digital elevation model (DEM) (Fig. 4). The high moderate sensitive zone has the highest area of 909 km^2 which accounts for 29% of the total area and the very high sensitive zone has the lowest area of 653.6 km^2 which accounts for 8.3% of the total area (Table-5). The study reveals that a small part of the study area falls under the high sensitive landslide zone (28%) and a large part falls under the low and moderate sensitive landslide zone (72%).

Table 5: Slope angle, category, area, and landslide sensitiveness in district Almora.

S.N.	Slope angle	Area in km^2	Area in %	Slope category*	Landslidesensitiveness
1	< 5°	453.2	14.4	Gentle slope	Low sensitive
2	5°-10°	861.2	27.4	Moderate slope	Moderate sensitive
3	10°-20°	909.0	29.0	Moderately steep slope	High moderate sensitive
4	20°-30°	653.6	20.8	Steep slope	High sensitive
5	>30°	262.0	8.3	Very steep slope	Very high sensitive
Total		3139.0	100.0	-	-

(*After Singh, 2017)

Plate 2: Landslide events in district Almora during monsoon season.

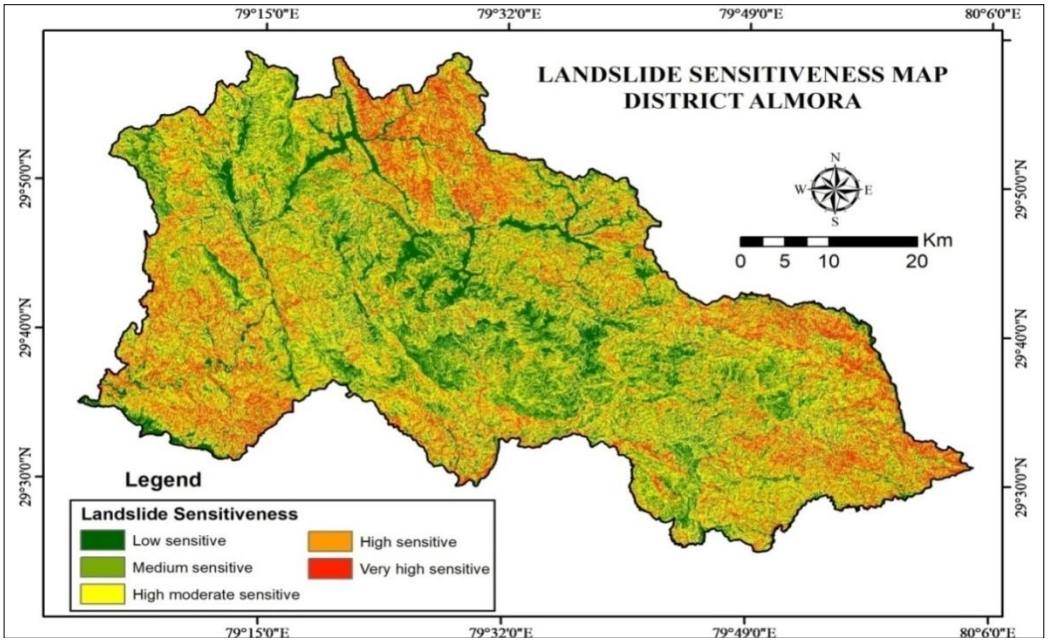

Fig 4: Spatial distribution of landslide sensitiveness zones of the study area (Based on Singh, 2017).

The landslide disaster events are also strongly associated with an infrastructural activity such as road construction especially in the hilly areas. As well known that the study area is completely a hilly region, the roads are constructed here by cutting the mountain rocks which caused of landslide hazard in the rainy season. The study area has a good network of roads. Every year landslide disaster events are noticed along with the road networks in the study area. Due to landslide, the roads are damaged and loss of life and property is also seen. In the study area, there are four types of roads which are National Highway, State Highway, District Highway, and Village roads. There are total 356 roads, out of them, 02 are National Highway, 18 are State Highway, 71 are District Highway and 265 are Village roads (Table-6). All the roads are highly sensitive for landslide events. The spatial distribution of roads of the study area is presented in figure 5. In the rainy season, most roads are closed or damaged due to blocked by debris/landslide (Plate-3).

Table 6: Detail of road networks of the study area *(Source: Dept. of district disaster management Almora).*

S.N.	Type of roads	Number of total roads	Roads in %
1	National Highway	02	0.56
2	State Highway	18	5.06
3	District Highway	71	19.94
4	Village Roads	265	74.44
Total		356	100.00

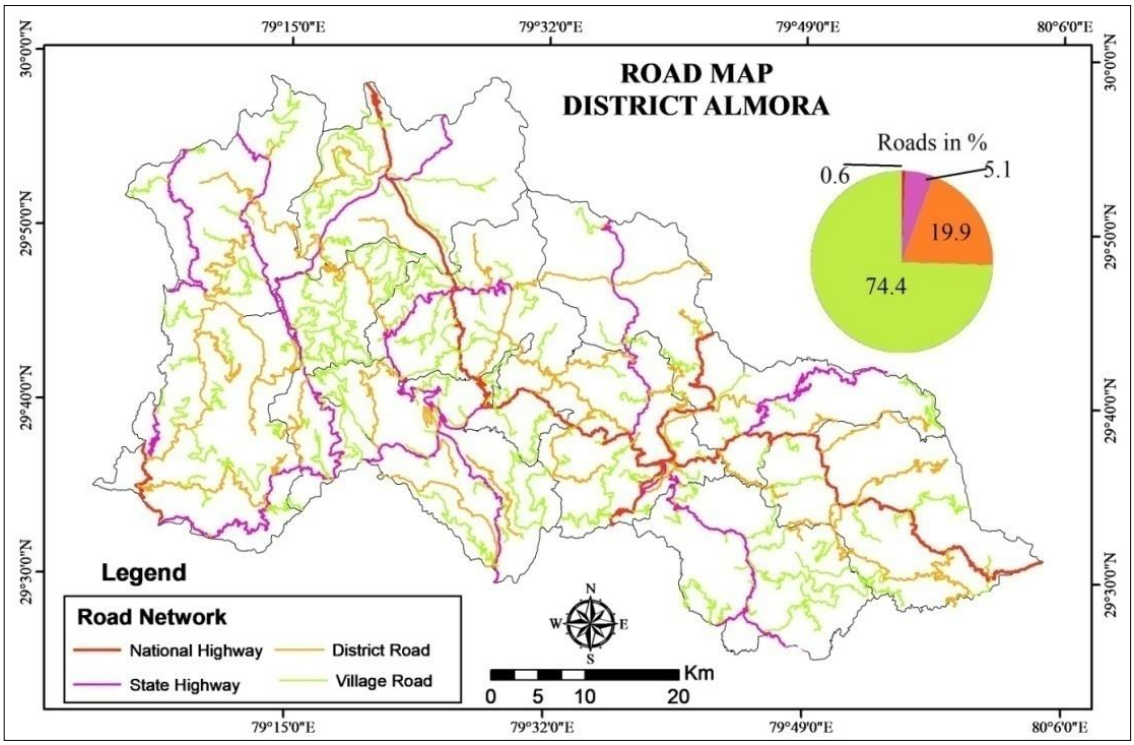

Fig 5: Disaster events along with the road construction sites in district Almora *(Source: Centre of Excellence for NRDMS in Uttarakhand, Soban Singh Jeena University, S.S.J. Campus Almora, Dept. of Geography).*

Plate 3: Landslide events along the road sides in the study area.

5.3 Earthquake: Earthquake is a natural disaster that damages man-made infrastructure and the natural environment. The study area is sensitive for earthquake events because it falls under the earthquake zone 04 and 05. The study area experience mild seismic events. A large part of the study area falls under seismic zone 04 while a small part of the district Almora falls under seismic zone 05 (Fig. 6). The total geographical area of seismic zone 05 is 753.5 km^2 which accounts for 24% of the total area (Table-7). The area of six developmental blocks (i.e., the northernmost part of Syalde development block, Chaukhutiya development block, the northern part of Dwarahat development block, Takula development block, and the northern part of Bhaisiyachhana and Dhauladevi development block) falls under Seismic none 05 (Fig. 6). The total geographical area of seismic zone 04 is 2385.5 km^2 which accounts for 76% of the total area (Table-7). The area of 09 developmental blocks (i.e., the southern part of Syalde development block, Sult development block, Bhikiyasen development block, Tarikhet developmental block, the southern part of Dwarahat development block, Hawalbag development block, the southern part of Bhaisiyachhana development block, Lamgara development block and southern part of Dhauladevi development block (Fig. 6).

Table 7: Details of earthquake zones and their area of the study area (Source: Department of district disaster management authority, 2020, Almora).

S.N.	Seismic zones	Area in km^2	Area in %
1	Zone 04	2385.5	76.0
2	Zone 05	753.5	24.0
Total		3139.0	100.0

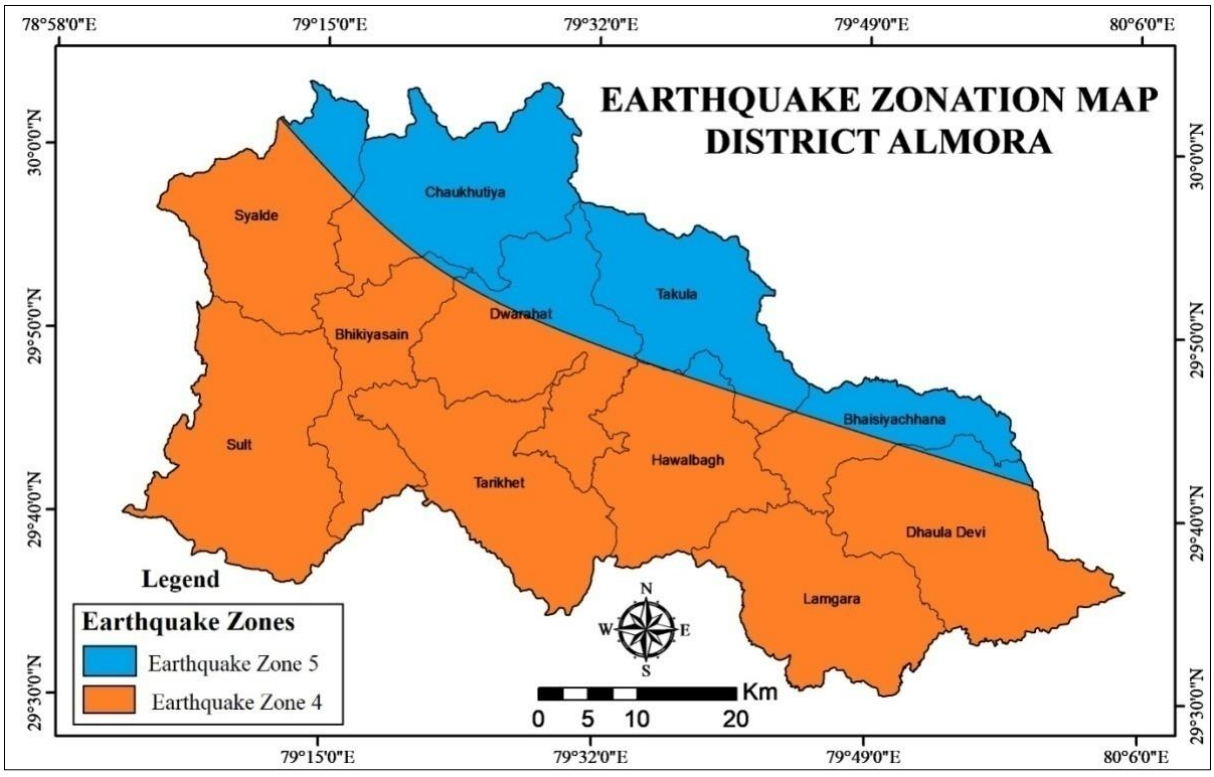

Fig 6: Earthquake disaster zonation map of district Almora *(Based on Department of district disaster management authority, Almora).*

5.4 Flood: Flood is a natural disaster that occurs in the monsoon season or rainy season. The flood events took place in the study area in a very special condition of heavy rainfall or cloud burst. As we know that the district Almora is situated in the hilly region of Kumaun Himalaya which is not sensitive for flood disaster because the river water is flow in shorter volume, i.e., the water does not spread in vast area like plain. Several perennial rivers such as Western Ramganga, Kosi, Suyal, Gagas, Kuchgad, Sarodgad, Kaligad, NaniKosietc drain the study area. Western Ramganga River and Kosi River are the major flood potential river of the study area. The flood zonation map of the study area has constructed using Arc GIS software. For the flood zonation map, the geoprocessing tool buffer has used and 50 m flood buffer zone has drawn along both sides of the river (Fig. 7). A brief description of the Western Ramganga River and Kosi River is presented in this section.

Western Ramganga River is a major river of Kumaun Himalaya which originates from the eastern part of Dudhatoli range and after covering a total length of 155 km it enters in Uttar Pradesh state and in Kannauj it makes confluence with Ganga River (Tripathy and Kumar, 2015) [20]. The total length of the Western Ramganga River in district Almora is 103 km. Gagas is the major tributary of the Ramganga River (Rawat, 2014) [13]. Kosi River is another major river of Kumaun region which originates from the Dharpanidhar forest of Takula development block. In district Almora, it has a total length of about 53 km drains mid part of the study area (Rawat. 2007) [12]. The flood hazard level of Ramganga River is 923.4 m and Kosi barrage is 1135 m. The flood monitoring station is situated in Chaukutiya for the Western Ramganga River and at Kosi barrage for Kosi River (DDMA, 2020) [3]. The valley region of the study area is sensitive for flood disaster.

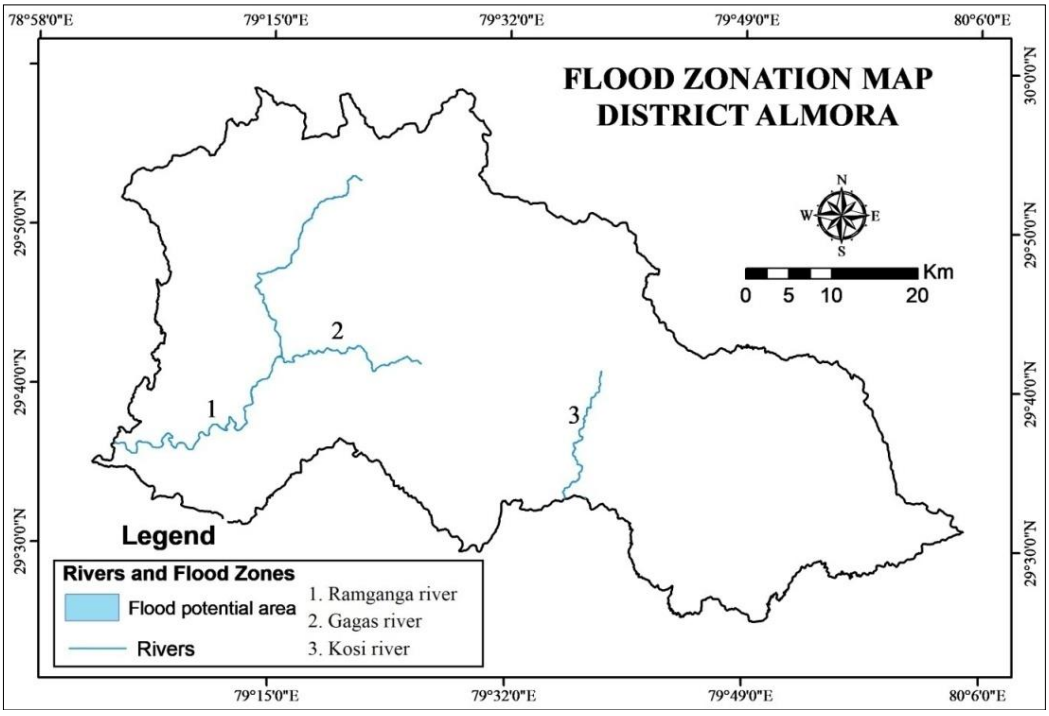

Fig 7: Spatial distribution of major rivers and flood zonation map of the study area.

6. Conclusion

Due to climate change and global warming, the disaster events and their intensity both have been increased. Several disaster events like earthquakes, landslides, floods, forest fire, storms, cold waves etc strike the study area regularly throughout the year. In the study area, most disaster events are influenced by various triggering factors such as human activities, extreme weather conditions, geological processes, etc. It is difficult to identify accurate disaster prone areas because of the unpredictable behavior of nature. In district Almora, the incidence of forest fire has increased and the incidence time has been also shifted to the winter months. The study area lies in earthquake zone 04 and 05. The landslide events that occur frequently in the rainy season affect the socio-economic condition of the affected area. Mostly landslide events occur because of heavy rainfall and human activities. For the mitigation of disaster effects, the probable disaster zonation maps have been prepared. The disaster zonation maps will provide help in the management of disaster events in future.

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8. Conflict of Interest

The authors do not have any conflict of interest.

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