Journal of Environmental Hazards

Research Article Open Access

# Flash Flood and its Mitigation: A Case Study of Almora, Uttarakhand, India

**Pankaj G* and Anand S**

*Department of Geography, University of Delhi, Delhi, India*

## Abstract

Himalaya is the life of millions of living being and rivers are the backbone. Flash flood is frequent disaster in Himalaya. Flash flood is the result of hydro-meteorological disturbance. Most of the Himalayan districts are the victim of flash flood disaster. Almora is experiencing this disaster for a long time, but the intensity is varied. The worst year was 2013, in which 12 out of 13 districts of Uttarakhand had faced the flash flood. The paper aims to analyze the role of hydro-climatic activities in an occurrence of flash flood in Almora and its impact and mitigation. The climatic and river discharge data have been used to study this issue. The projection of water discharge has been calculated for next few years with least square method. The dependency of water discharge on rainfall has also been calculated. Mapping techniques such as Arc, GIS and ERDAS have been used for mapping the features. The mitigation measures of the flash flood have also been discussed in this paper.

**Keywords:** Flash flood; Hydro-meteorological; Himalaya; Human life; Disaster; Mitigation

## Introduction

Flash flood is the disastrous result of hydrological disturbance. Flash flood is described as the flow of water catastrophically in a very short time span. Flash flood defines as incorporate high velocity flows that occur in a short period [1]. Flash flood is important hydrological phenomena which took place at the same spatial and temporal scales, as a result of intense precipitation [2]. The flash flood becomes cause for concern after human intervention in hilly areas. The human intervention, development activities and change in environment are responsible for disaster. It is increasingly recognized as a serious and growing problem because vegetation has been removed from urban environment [2]. Flash flood is very dynamic issue which receives concern from all side of the world. Therefore, major initiatives have taken for moderation against the hydrological disaster. The flash flood was triggered by heavy rainfall, or cloudburst in Uttarakhand in mid of June in 2013, which affected the 12 out of 13 districts of this state [3].

The flash flood in Uttarakhand brought the death of thousands of people in 2013 in which almost more than 2000 people have been declared dead and almost 12000 people have disappeared and there the loss of 50 billion dollars has been taking place in this state. The mountains comprise steep slope which enhances the power of river during the rainfall. In this process, huge amount of water has generated in very short or limited period. This excessive amount of water rapidly flows towards the ground slope with high intensity and this process is known as the flash flood. Flash floods are not caused uniquely by meteorological phenomena alone; it is a result of supportive meteorological and hydrological circumstances coexist [4].

The mountainous region is more prone to disasters like flash flood, earthquake, landslide, avalanche, etc. This region is more susceptible than the other, and there is uneven land structure, improper soil cover, and presence of animal grazing. Vulnerability can be used to empirically link the susceptibility of foundations at risk to the magnitude of the impacting hazardous process [5]. The active slopes are responsible for all hydro-meteorological disaster in Himalayan districts. Therefore, the hydrological vulnerability is visible in the Uttarakhand state of India.

The flash flood in Himalaya during 2012 occurred at midnight on 3 August. All the Himalayan states in India were affected by the same. The cloudburst claimed the lives of 31 people and also led flash flood as well as landslides across the entire region (MOI, 2017). The disaster such as flash flood is common phenomena in the mountains like Himalaya. It is because Himalayan range provides supportive conditions for flash flood with their uneven land structure. Flash flood becomes yearly phenomena in Uttarakhand during the monsoon season. In last few years, the intensity of rainfall has manifolds. Therefore, the loss of property and life also manifolds. Almora has experienced one of the most devastating flash floods during the monsoon season in the year of 2010. It was the worst flash flood experienced by Almora in last twenty years which brought the toll of deaths. This flash flood has damaged villages, towns, etc. and the number had been washed out with the water and mud of river Kosi. The aim of the paper is to analyze the role of hydro-climatic phenomena in occurrence of flash flood in Almora and its impact and mitigation in Himalayan region.

## Study Area

The study area, Almora is situated in the foothills of Himalaya in Southern-Central part of Uttarakhand state in northern part of India. The Almora region is located at 29°81'50" North latitude and 79°29'02" East longitude. Almora has only 3697 sq. km area which is bounded by Nainital from the south and Bageshwar in north. The Pithoragarh district lies in North-East of Almora, Garhwal in West and Champawat in South-East (Figure 1). This is bounded by thick forest of pine and fir trees from all sides. It shape presents the horse saddle shaped hillock. Almora lies on the lesser part of youngest mountain in the world. The lifeline of this region is river Kosi which originated from Dharpani Dhar in North of Almora at the height of 2500 m [6].

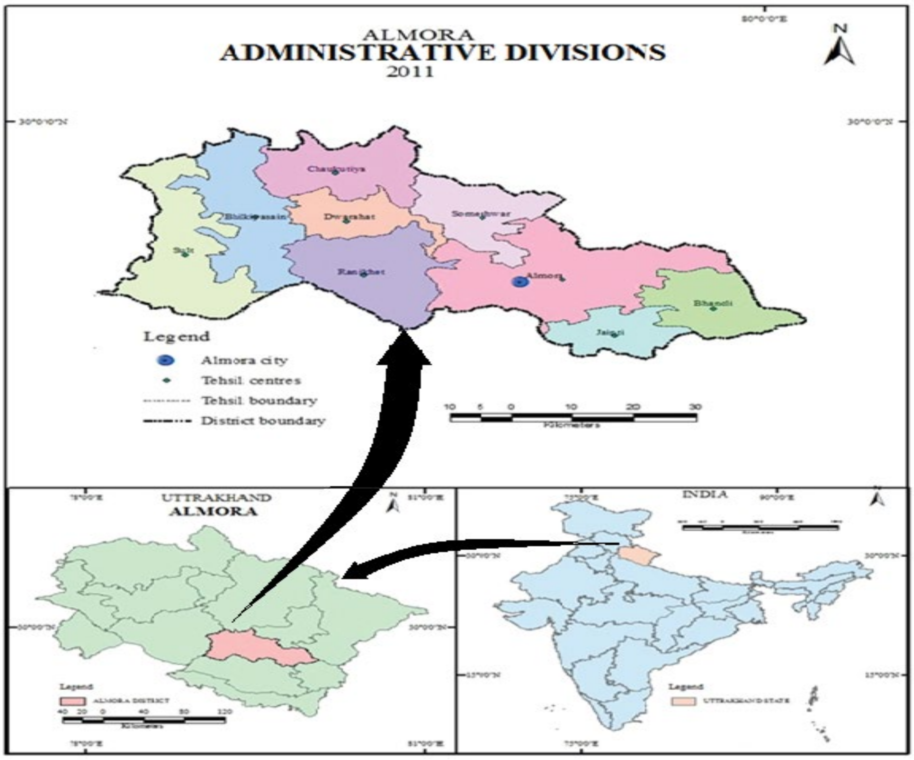
## Data Sources and Methodology

The present study determines the whole process of occurrence of flash flood under the influence of hydro-climatic elements and its mitigation measures. The primary survey with structured questionnaire

***Corresponding author:** Pankaj G, Department of Geography, University of Delhi, Delhi, India, Tel: 9958352026; E-mail: pankajgwahg0202@gmail.com

**Received** December 15, 2017; **Accepted** February 22, 2018; **Published** February 28, 2018

**Citation:** Pankaj G, Anand S (2018) Flash Flood and its Mitigation: A Case Study of Almora, Uttarakhand, India. J Environ Hazard 1: 104.




*Source: Survey of India, 2011*

**Figure 1:** Location of study area.

has been conducted using random sampling method. With the help of survey, people's perception has drawn about the problem of flash flood and its mitigation practices. In the study area, 120 respondents have been taken for questionnaire survey. This survey has been conducted during December 2016 and this questionnaire comprises various section related to flash flood and its causes and impact and mitigation. The secondary data have been collected related to temperature, rainfall and water discharge from India Meteorological Department (IMD) and Central Water Commission (CWC) respectively. The data of human death and other damages during disaster have been collected from Districts Disaster Management Office (DDMO) of Almora district. The data related to destruction in sources like electricity, water, road and its rehabilitation have been collected from Public Works Department (PWD), Almora. The data like human death and financial compensation have been obtained from Public Health Department (PHD), Almora. Collected data have been processed and analyzed by various statistical methods. The ANOVA method has been used for describing the interdependency between rainfall and fluctuation in water discharge in river Kosi and least square method used for analysis of trend of water discharge in river Kosi and projection of next few years water discharge in river. Mapping software's such as Arc GIS and ERDAS has been used for making maps.

## Results and Discussions

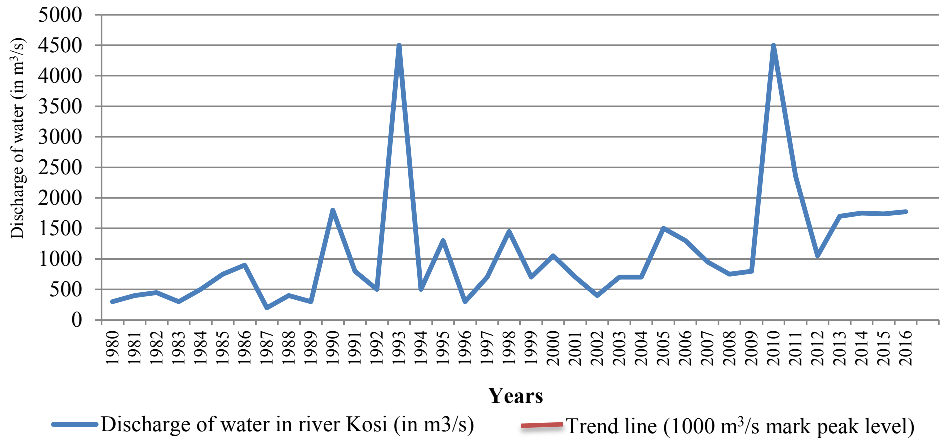
### Pattern of flash flood

The pattern of flash flood depends on discharge of water in river. The river Kosi is very dynamic which is catastrophically changes their flow under the influence of heavy rainfall. The Almora experiences the worst flash flood in the year of 1993 as same as 2010. There is interrelationship between heavy rainfall and occurrence of flash flood. The continuous rainfall has increased the capacity of river flow and amount of water into river catchment. The water discharge is controlled by natural process such as rainfall. Therefore, following diagram reveals the fluctuation in amount of water discharge which is very high in river Kosi (Figure 2). This figure is showing water discharge level in river Kosi from 1980 to 2016 which represents fluctuation character of river. The peak trend line of 1000 $m^3/s$ differentiates between the normal flow and peak or danger flow in river Kosi. During the time span of 37 years, it is observed that this river has crossed the danger level (1000 $m^3/s$) 12 times in the last 37 years (Figure 2).

### Relationship between rainfall and water discharge in river

Flash flood is quick surface water retorts to rainfall from strong cloudburst or sudden release of water from dam, which results in short lead time and enough potential for destruction due to extreme velocities [7]. The regularity and continuation of flash flood are dependent on climatic phenomena like heavy rainfalls which provide energy to flash flood. Other than rainfall, it could be occurring only in one condition when natural or human-built dam or reservoirs get damaged or breached by any disaster. The calculation of dependency of river water discharge on rainfall by ANOVA reveals that water discharge is highly dependent on rainfall with high degree of regression residual (0.84) (Table 1) [8].

The calculation of rainfall and water discharge data has revealed that the rainfall and water discharge has very positive relationship. The linear segment of both the graph is representing the close relationship



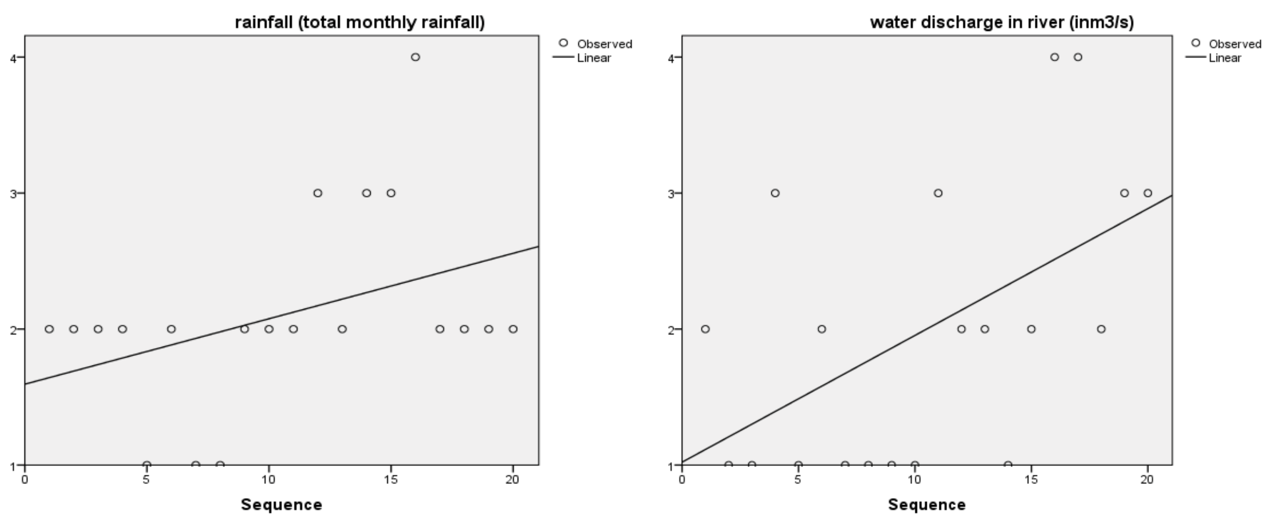

*Source: Central Water Commission, 2016*

**Figure 2:** Pattern of water discharge in river Kosi.

| ANOVA | | | | | |
|---|---|---|---|---|---|
| | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| **Regression** | 1.540 | 1 | 1.540 | 3.356 | 0.084 |
| **Residual** | 8.260 | 18 | 0.459 | - | - |
| **Total** | 9.800 | 19 | - | - | - |

*Source: Calculation by scholars with the help of rainfall and water discharge data in SPSS*

**Table 1:** Calculation of dependency of river water discharge on rainfall by ANOVA method.




*Source: Prepared by scholars with the help of SPSS*

**Figure 3:** A. Rainfall in Almora. B. Water Discharge in River Kosi.

between both the phenomena, and if both of them will be overlapped to each other, the line will lies to each other for a long period (Figure 3A and B). Therefore, direct relationship found between the rainfall and peak water discharge in river and this becomes the cause of the occurrence of flash flood in Almora during rainy season [9].

## Trend analysis of flash flood

The trend analysis of water discharge data reveals that there is very high fluctuation in water discharge in river. The analysis of water discharge data of last 37 years (1980-2016) has been done. With the help of least square method, the projection of water discharge for next four years of 2017, 2018, 2019 and 2020 has been calculated (Table 2) [10].

Figure 4 representing the calculation of last 37 years trend analysis of water discharge data of river Kosi along with the value of combination of XY, $X^2$ and X.

| Year | Discharge of water in river (Y) | X(t-A) | $X^2$ | XY |
|---|---|---|---|---|
| 1980 | 300 | -18 | 324 | -5400 |
| 1981 | 400 | -17 | 289 | -6800 |
| 1982 | 450 | -16 | 256 | -7200 |
| 1983 | 300 | -15 | 225 | -4500 |
| 1984 | 500 | -14 | 196 | -7000 |
| 1985 | 750 | -13 | 169 | -9750 |
| 1986 | 900 | -12 | 144 | -10800 |
| 1987 | 200 | -11 | 122 | -2200 |
| 1988 | 400 | -10 | 100 | -4000 |
| 1989 | 300 | -9 | 81 | -2700 |
| 1990 | 1800 | -8 | 64 | -14400 |
| 1991 | 800 | -7 | 49 | -5600 |
| 1992 | 500 | -6 | 36 | -3000 |
| 1993 | 4500 | -5 | 25 | -22500 |
| 1994 | 500 | -4 | 16 | -2000 |
| 1995 | 1300 | -3 | 9 | -3900 |
| 1996 | 300 | -2 | 4 | -600 |
| 1997 | 700 | -1 | 1 | -700 |
| **A= 1998** | 1450 | 0 | 0 | 0 |
| 1999 | 700 | 1 | 1 | 700 |
| 2000 | 1050 | 2 | 4 | 2100 |
| 2001 | 700 | 3 | 9 | 2100 |
| 2002 | 400 | 4 | 16 | 1600 |
| 2003 | 700 | 5 | 25 | 3500 |
| 2004 | 700 | 6 | 36 | 4200 |
| 2005 | 1500 | 7 | 49 | 10500 |
| 2006 | 1300 | 8 | 64 | 10400 |
| 2007 | 950 | 9 | 81 | 8550 |
| 2008 | 750 | 10 | 100 | 7500 |
| 2009 | 800 | 11 | 122 | 8800 |
| 2010 | 4500 | 12 | 144 | 54000 |
| 2011 | 2350 | 13 | 169 | 30550 |
| 2012 | 1050 | 14 | 196 | 14700 |
| 2013 | 1700 | 15 | 225 | 25500 |
| 2014 | 1750 | 16 | 256 | 28000 |
| 2015 | 1740 | 17 | 289 | 29580 |
| 2016 | 1775 | 18 | 324 | 31950 |
| **TOTAL** | **40765** | **0** | **4220** | **161180** |

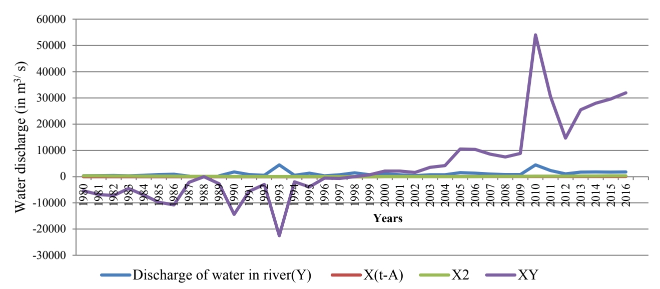
**Table 2:** Calculation of trend analysis through least square method.

**Solution:-**

| **FORMULA'S** | |
|---|---|
| **X= t-A , Yi=a+bX** | |
| **for a:- Y=Na+bx** | **for b:- XY=ax+bX²** |
| **Solution :-** | **Solution :-** |
| **a=Y=Na+bx** | **b=XY=ax+bX²** |
| 40765=37 × a+b × 0 | 161180= a × 0+b × 4220 |
| 40765=37 × a+0 | 161180=0+b × 4220 |
| 40765/37= a | 161180/4220=b |
| **a=1101.7** | **b= 38.2** |

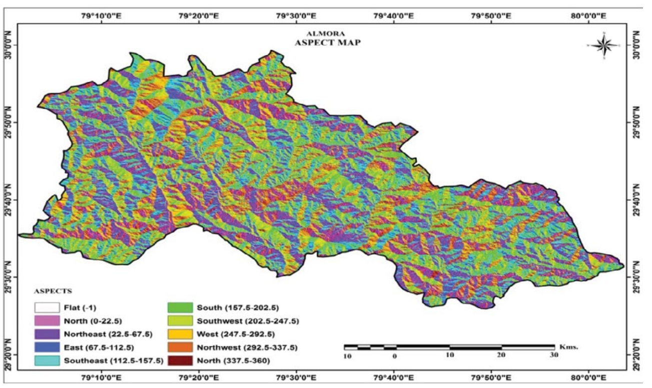
| **Projection of Water Discharge in next few years** | |
|---|---|
| **For Year 2017** | **For Year 2018** |
| **Yi= a+bX** | **Yi=a+bX** |
| Yi=1101.7+38.2 × 19 | Yi=1101.7+38.2 × 20 |
| Yi=1101.7+725.8 | Yi=1101.7+764 |
| **Yi=1827.5** | **Yi=1865.7** |
| **For Year 2019** | **For Year 2020** |
| **Yi=a+bX** | **Yi=a+bX** |
| Yi=1101.7+38.2 × 21 | Yi=1101.7+38.2 × 22 |
| Yi=1101.7+802.2 | Yi=1101.7+840.4 |
| **Yi=1903.9** | **Yi=1942.1** |

*Source: Calculation by Scholars*




*Source: Calculation by scholars with help water discharge of Kosi River, 2016*

**Figure 4:** Trend analysis of water discharge into river Kosi during flash flood events.



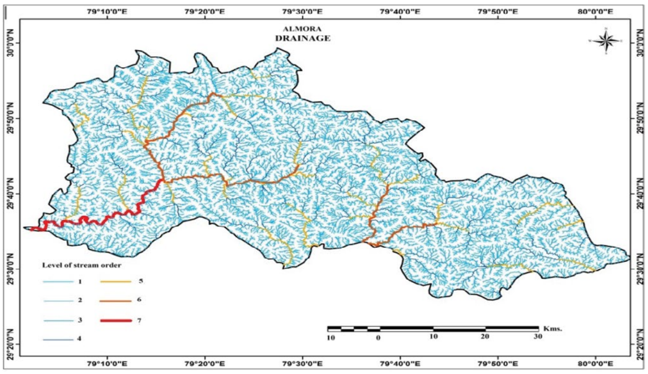

*Source: Bhuvan, 2011*

**Figure 5:** Aspect map of Almora.

## Role of physiography in occurrence of flash flood

Physiography provides checks and advantages for the occurrence of flash flood in Himalayan region. The southern part is lower with average height of 1000 meter and the northern part is higher with the average height of 2000 meter.

Himalayan physiography comprises various sedimentary rocky structure, steep slopes, high flowing drainage, deep valleys, hills, etc. These features always control the occurrence of flash flood. The aspect map of Almora is described that the direction of slope and sunshine side and shadow side of Himalaya. It also determines the climate of this region [11]. The direction of slope is inclined towards the South (Figure 5). The drainage is most probably controlled by slope in mountain and the Northern part is higher than southern part. Therefore, the direction of flow is from north to south (Figure 6).




*Source: Bhuvan, 2011*

**Figure 6:** Drainage map of Almora.

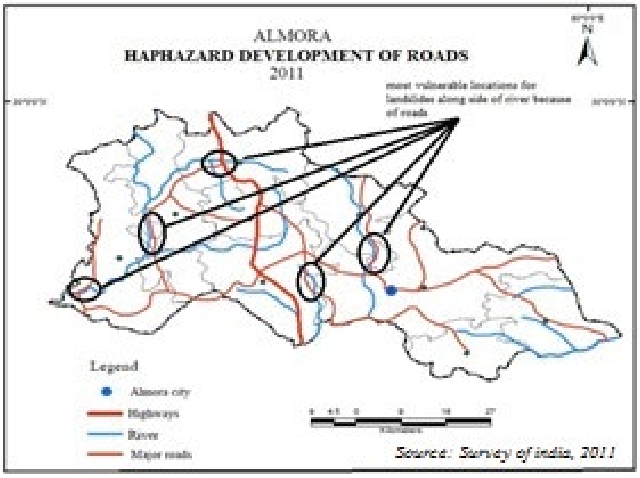



**Figure 7:** Haphazard development.

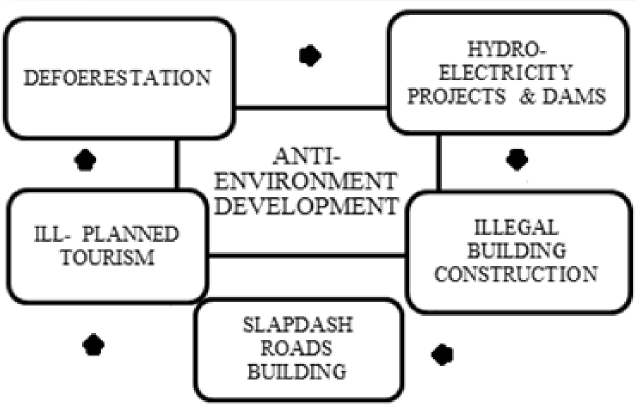



**Figure 8:** Haphazard developments of roads.

The river Kosi is flowing from north to South direction and Almora comprises the number of minor tributaries of Kosi River. There is 128 flowing direction according to slope which followed by rivulets to form the major tributaries.

## Causes of Flash Flood in Almora

### Haphazard development

The development without concern and importance of natural phenomena always leads towards the disaster. Various development processes or activities like deforestation, dam construction, transportation, and construction of buildings, etc. falls under haphazard development (Figure 7). The following figure is also described the haphazard development of roads in Almora, in which most of them are developed on the river banks or alongside the river [12]. This is the major cause of the huge toll of death during the flash flood events (Figure 8).

The slapdash roads, hotels and resorts which built on river banks have been increasing the burden on river catchment and increasing the intensity of disaster in river catchment (Figure 9).

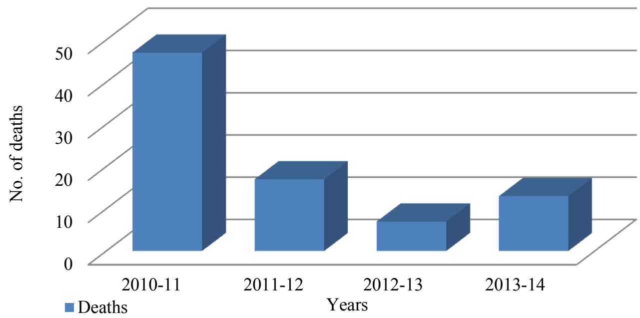
### Impact of flash flood in Almora

The flash flood brings various losses for human being as well as nature. Almora has been affected by flash flood every year and it also represents the evidence of its impact in the form of destroyed property, loss of life and change in land use pattern. Almost every year number of people died because of catastrophic occurrence of flash flood. As per the official information from last six years, every year 15 to 20 people killed by monsoon rainfall-induced flash flood [13].

### Impact on human life

Every year flash flood brings death for the people of Almora. The


**Figure 9:** Illegal encroachment alongside the catchment area of river Kosi.




*Source: Primary Survey, 2016*

**Figure 10:** Death of human being in last five years.

highest casualty was in 2010 because it was worst flash flood for the people of this region. As per the primary information was given by government offices of Almora, it can say that 47 people dead during the flash flood of 2010, followed by 17 people in 2011, 13 people in 2013 and seven people in the year of 2012 in Almora (Figure 10).

## Mitigation Measures

In the mountainous region, traditionally, people have avoided those places which were affected by any disaster in history. They are trying to prevent the natural disaster because they are well aware of the consequences of a disaster. The flash flood often occurs in rural areas and affected the most. Because they cannot get same level of awareness at urban level about river floods [14]. Therefore, it is difficult to inspire local communities in flash flood-prone areas to undertake precautionary measures [15]. Except for all these, local authority initiated for local in this region. During the rainy season, authorities informed or told the people to leave their homes which are in the catchment. It is because these are affected most during flash flood. Authorities has done well in monitoring, assessing, and warning at their level. But as I previously discussed that this is catastrophic event. Therefore, authorities can not reach every person in the district. The rural people are affected the most by flash flood because they have found themselves far from public awareness programme functioned by local authorities.

### Strategies to prevent the flash flood

The various approaches can help in prevention from flash flood. The strategies such as ecological restorations afforestation, sensitive development, sustainable infrastructure development, safe tourism and nature supportive roads and habitats can help in prevention and mitigation of flash flood disaster (Figure 11).

Environment hazards are the product of combined interaction between geographical and anthropogenic processes which lies at the interface between the natural ecosystems and the human use system [16-19].

**Afforestation:** Forest is the mainstay of a mountainous ecosystem because forest protects the rocks from exposing and keep these rocks strong through their root system. Forest canopy intercept the 60% of rainfall which falls over the forest.

**Ecological sensitive development:** Environmental friendly development should be allowed to complete. The ecological processes and flora and fauna of that region should be allowed to complete.

**Nature supportive roads and habitats:** The connectivity is dependent on the presence of roads. Therefore, roads should be environmental friendly also, and it should not be on margins of hills. Roads should be constructed according to natural aspect of the region.


**Figure 11:** Strategies for prevention of flash flood.

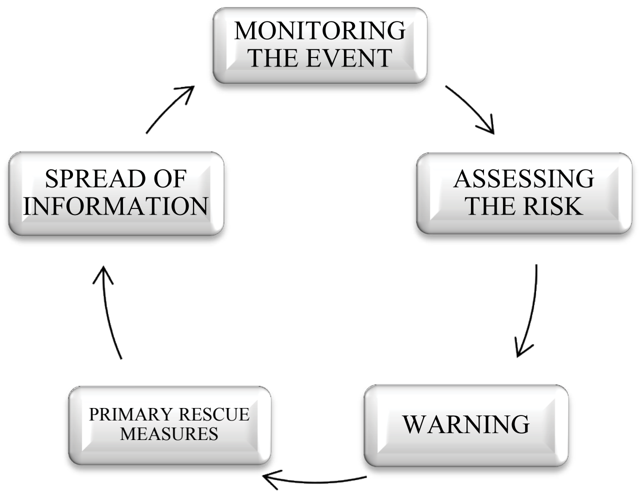



**Figure 12:** Cycle of pre-management for flash flood.

**Flash flood risk assessment:** The flash flood risk assessment comprises the area, intensity of flash floods, assessing of damage, etc. The process of post-disaster mitigation, relief, rehabilitation are more expensive than the preparedness.

## Preparedness for Flash Flood

The readiness is described as pre-arrangement for coping with disaster that has been adopted for minimizing the impact of disaster on human and their property. It includes various measures of coping with the disaster.

These measures are following:

- Spread the awareness among the people for flash flood disaster in Almora district.
- Complete planning for flash flood and it's the mitigation in the region,
- Increase individual participation through teachings about the methods of coping and
- Promote the community participation in the coping mechanisms with the disaster.
- The supply of emergency food, supply of water, medicines and shelters for affected peoples.

Figure 12 described the various stages for pre-management against the flash flood disaster and it comprises five steps such as monitoring the event, assessing the risk, warning, primary rescue measures and spread of information.

## Conclusion

Mountains are one of the disaster-prone areas because of their geology, climate, vegetation, glaciers, high flowing river and less development. The hydrological disturbances are creating problem in the mountainous region. The most of the environmental problem in the mountains are result of human-induced activities that exposed the nature of these mountains. During the flash flood of 1993-94, only four people were dead and that time peak water discharge in river Kosi was 4500 $m^3$/s. This peak water discharge in river Kosi was same in 2010 when another disastrous flash flood has taken place, but the number of causalities was 48 people. Ecological restoration, afforestation, sustainable infrastructure development, nature supportive roads and habitats should be promoted for the sustainable future of mountains. This study reveals that the flash flood is result of natural phenomena but loss of human and its property is because of human shifting toward hills. The shifting of human population towards the mountain is cause of increase in the number of disastrous events. Human activities and presence in river basin is cause of disaster. The statistical inquiry provides us a broad scenario which reveals that rainfall is primary cause of occurrence of flash flood. But uncertainties in rainfall have increased in recent years.

## References

1. Census of India (2011) Map of Uttarakhand State, Census of India, Government of India.
2. CWC (2016) Regional Central Water Commission, Central Water Commission, Ram Nagar Barrage, Almora, Uttarakhand, India (part of field work).
3. Gruntfest, Eve, Handmer, John (2000) Detecting flash floods in small urban watersheds. Preprints, 15th Conference on Hydrology, American Meteorological Society, Long Beach, CA, Coping With Flash Floods pp. 233–236.
4. DDMO (2016) District Disaster Management Office, Almora Town, Almora, Uttarakhand, India (part of field work).
5. District Census Handbook (2011 to 2014) Directorate of Economics and Statistics, Government of Uttarakhand, Almora, Uttrakhand, India.
6. District Census Handbook (2016) Directorate of Economics and Statistics, Government of Uttarakhand, Almora, Uttrakhand, India.
7. Federal Emergency Management Agency (1987) Reducing Losses in High-Risk Flood Hazard Areas. Government Printing Office, U.S. pp: 224.
8. Fuchs S, Heiss K, Hubl J (2007) Towards an empirical vulnerability function for use in debris flow risk assessment. National hazards earth system science 7: pp: 495-506.
9. Gruntfest E, Huber CJ (1991) Toward a comprehensive national assessment of flash flooding in the United States. Episodes 14: pp: 26–34.
10. Hong Y, Adhikari P, Gourley JJ (2012) Flash flood. In Bobrowsky, Peter T (ed.) Encyclopedia of natural hazards. Springer pp: 324-325.
11. IMD (2016) India Meteorological Department, Pune, Maharashtra, India.
12. Indian Red Cross Society (2013) Uttarakhand flash flood – A report, New Delhi, India.
13. Kelsch M, Caporali E, Lanza LG (2001) Hydrometeorology of Flash Floods, Coping **w**ith Flash Floods, Kluwer academic publisher, Netherland pp: 19-35.
14. Kundzewicz ZW, Szamalek K, Kowalczak P (1999) The Great Flood of 1997 in Poland. Hydrological science journal 44: pp: 855-870.
15. Maps of India (2017) Major floods in India.
16. Montz BE, Gruntfest E (2002) Flash flood mitigation: Recommendations for research and applications. Global Environmental Change 4: pp: 15-22.
17. National Disaster Report (2011) Disaster Map on India, National Institute of Disaster Management, Delhi, India.
18. Oliver-Smith A (1996) Anthropological research on hazards and disaster. Annual review of anthropology *25*: pp: 303-328.
19. https://www.internationalrivers.org/blogs/257/india%E2%80%99s-himalayan-floods-a-man-made-disaster