A Study of Extreme Weather Events in Relation to Landslides over India in Recent Years

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ABSTRACT

As per WMO study, a changing climate leads to changes in the frequency, intensity, spatial extent, duration and timing of extreme weather and climate events and could result in huge impact on the environment and society. According to the report of Global Climate Risk Index (GCRI-2019), India is one of the five worst affected countries in the world. A scientific analysis had concluded that climate change had increased the chances of the rainfall that caused the flooding by an estimated 43% (WMO, 2016). The potential for damage from such rainfall extreme events is also increasing, as higher river levels put more properties close to the flood plain at risk from flooding. Landslide is a natural phenomenon which is caused mostly due to heavy rains, floods, earthquakes, unsustainable construction on hill tops etc. In the present study, the frequency and casualties due to landslides have been worked out. The synoptic conditions for these major hazard events have also been analyzed and discussed. It is seen that unsustainable growth, urbanization and deforestation add to losses of lives and property substantially.

Keywords: *Global warming, Anthropogenic, Climate change, Extreme weather events, Floods and Earthquakes.*

1. Introduction

The phenomenon of landslide is large and causes major disaster to mankind. Landslide is an often happening natural hazard in the hilly terrains of India. Many strong earthquakes also lead or cause as trigger for landslide. Regions are marked as critically disposed and unstable slopes defined as the probability of occurrence of a potentially damaging phenomenon or a physical event which has a harmful impact on mankind and their environment. Landslide is the movement of mass of rock, debris or earth down on sloppy section of land which is caused by heavy rainfall, earthquake etc.

Land sliding is a general term applied to all surficial movement of earth material under direct influence of gravity. These are initiated by events such as wave action (low frequency seismic signal received at the time of earthquake), earthquake, heavy rains, artificial excavations, etc. When a landslide occurs, it results in sudden translocation of earth materials from a higher to a lower elevation. Human activities such as disturbance of vegetative cover, excavations for buildings, highways and appurtenances, gravel pits and washing plants, mining and other activities may cause serious disturbance of natural conditions and provide an important source for destabilizing the earth cover on slope. In India, most of the landslides occur during the rainy season of the southwest monsoon. The passage of rainwater increases the soil porosity and sufficient amounts of soil particles are washed out. This creates unbalancing along the slopes, which subsequently culminates in landslides. A huge landslide occurred at village Gona on river Birehi Ganga on September 22, 1893 and at Reni on the bank of river Rishi Ganga on Feb 4th 1968. (Ray et al. 2001). About 50% of the occurrences of the landslide are found associated with loss of human lives. The heavy rains on Jun 15th, 2017, have triggered a series of landslides and floods in Bangladesh and Northeast India, killing at least 156 people in two days. Landslides are a common natural hazard in different countries. For example landslides are quite frequent in north coastal ranges of Venezuela lying close to the Caribbean Sea similar to the coastal belt facing the Arabian Sea in India. During past 200 years many landslides have occurred in this area of Venezuela. In the Himalayas alone, one could find landslides of every fame, name and description – big and small, quick and creeping, ancient and new. Similarly most of the northeastern region is bristling with landslides of a bewildering variety. Then, there are landslides in the Western Ghats in the south, along the steep slopes overlooking the Konkan coast. Landslides are also very common in the Nilgiris, characterized by a lateritic cap, which is very sensitive to mass movement. Landslides are often the cause of dislocation of traffic and casualty over inaccessible areas in the Northwestern and Northeast parts of the country. Landslides associated with heavy rains cause extensive damage to crops, road/rail and communication get disrupted.

2. Some Findings over Meghalaya Hills

Natural disasters like floods, tornadoes, tropical cyclones, heat and cold waves and landslides cause tremendous loss of property all over the world. Nearly 80% of these natural disasters are related to weather directly or indirectly and damage from this is of meteorological and hydrological origin (Obasi 2001). De et al. (2004) based on the worldwide data for the period 1967 to 1991 reported 238 events of landslides due to which 41,992 persons were killed. According to them landslides comes under the category of natural disasters indirectly related to weather events. In India, about 1,500 human lives are lost annually due to floods and heavy rains of which landslides contribute a significant percentage. As per recent World Meteorological Organisation (WMO) review, the total global losses (economical) as a result of natural disasters are about US $ 50-100 billion per year with loss of life about 2,50,000 (De et al. 2005a). During the period 1977-2001, India suffered significant loss of property and human lives each year due to weather related hazards such as floods, droughts, tropical storms, heat and cold waves (De et al. 2005b, Tongdi et al. 2008).

According to Singh et al. (2011), landslides are slippery masses of rock, earth or debris, which move by force of their own weight down mountain slopes or riverbanks under gravity. They are due to meteorological or geological causes such as erosion, intense rainfall, human excavation; earthquake shaking, volcanic eruption etc. The Indian subcontinent, with diverse physiographic, seismotectonic and climotological conditions is subjected to varying degrees of landslide hazards. Removal of vegetation and toe erosion has also triggered landslides. Torrential monsoon rain on the vegetation cover removed on slopes was the main causative factors in the Peninsular India namely in Western Ghats and Niligiris. Human intervention by way of slope modification has added to this effect. Singh and Kumar (2013) observed that, flood-related human fatalities in India were found to be more dominant in the flood plains of Uttar Pradesh, Bihar, Orissa and West Bengal. It is assumed that there will be more human fatalities in the flood plains of these states because this region reels under a very high incidence of severe floods, high-population density, limited resources and tardy economic development. In addition, this region suffers from the high velocity surging water streams originating from the Himalayas. However, when standardized data were incorporated, mountainous states were found to be more vulnerable in terms of flood fatalities. Prokop and Walanus (2015) based on the analysis of daily rainfall data for the period 1901–2000 over the Meghalaya Hills found that,

(i) In the pre- and post-monsoon seasons at Cherrapunji, the changes in the frequency of rainfall pattern remain those of the monsoon season, though without propagation northwards across the Meghalaya Hills.

(ii) A statistically significant increase in the frequency of extreme rain events and a significant reduction in low and moderate events appear during the summer monsoon at all the three stations viz. Cherrapunji, Shillong and Gauhati. In view of this effect, the contribution of the increase in heavy events is balanced by a reduction in moderate events and the monsoon mean rainfall does not show a statistically significant trend.

(iii) The interaction between large-scale monsoon circulation and the local topography plays a crucial role in determining the spatial and temporal variability of the rainfall over the Meghalaya Hills.

The location of the Cherrapunji station, on the highest elevated edge of the first barrier for the summer monsoon winds, makes the place very sensitive to a moisture influx from the adjacent Bay of Bengal. The modification of rainfall amount and spatial pattern by topography can be very strong over short distances. As a result, stations which are located leeward, especially, do not always exhibit the long-term monsoon variability over this area strongly. The above was also confirmed by their observation that the positive correlation between the stations' rainfall levels was not maintained for the highest daily rainfall.

(iv) There was no abrupt increase in the extreme rainfall over the Meghalaya Hills around 1950. However, it was a statistically significant fact that, generally, in the second half of the twentieth century, they observed a greater number of individual years with perceptible extreme rainfall events and more pronounced quasi-periodicity of 10–20 and 30–60 days. Detection of the 30–60-day rainfall periodicity, especially visible during extreme monsoon years, indicates that the northward propagating component of the MJO can favour the generating of extreme rainfall events over the Meghalaya Hills. Thus, the source of deep convection located in the equatorial ocean can influence atmospheric processes more northward than it was shown in previous studies. The present study aims to bring out an essential pattern and features of hazards associated with landslide and their impact on society.

3. Data and Methodology

Data on the incidence of landslides were obtained from the Annual Reports of Disastrous weather Events published by India Meteorological Department (IMD), Pune for the years 1981 to 2017. The associated synoptic systems were obtained from Indian Daily Weather Reports. Data from the annual reports of disastrous weather events have also been collected and analysed in this study to examine weather situation causing the landslides.

Further, state wise, month wise and yearly data series have been prepared. Trends in the number of incidences of deaths/frequency have been determined using standard statistical methods and the results are discussed.

4. Results and Discussion

4.1 Landslide Hazard in India

The major areas affected by landslides in India (Figure 1) are identified below based on the landslide hazard zonation.

(i) The Western Himalayas (in states of Uttar Pradesh, Uttarakhand, Himachal Pradesh and Jammu & Kashmir)

(ii) The Eastern & North-eastern Himalayas (in states of West Bengal, Sikkim and Arunachal Pradesh)

(iii) The Naga-Arakkan Mountain belt (in states of Nagaland, Manipur, Mizoram and Tripura)

(v) The Western Ghats region including Nilgiris (in states of Maharashtra, Goa, Karnataka, Kerala & Tamil Nadu)

(ivi) The Plateau margins of the Peninsular India and Meghalaya plateau in North-east India. Mountain being tall elevated landform having peaked so has got steep slope whereas plateau being elevated table top land has both gentle and steep slope. Moreover it is highly eroded surface because of highest rainfall received (e.g Cherapunji) displays bare rocky surface. High rain, continuous tectonic uplift and lithology plays major role in landslides to happen in this area. According to Highland (2008), regions historically prone to seismic tremors, heavy rainfall amount saturating over the slopes and increase in human activities due to increase in population cause landslides.

The causes due to human activities include,

- Excavation of slope or its toe
- Use of unstable earth fills, for construction
- Loading of slope or its crest, such as placing earth fill at the top of a slope
- Drawdown and filling (of reservoirs)
- Deforestation—cutting down trees/logging and (or) clearing land for crops; unstable logging roads

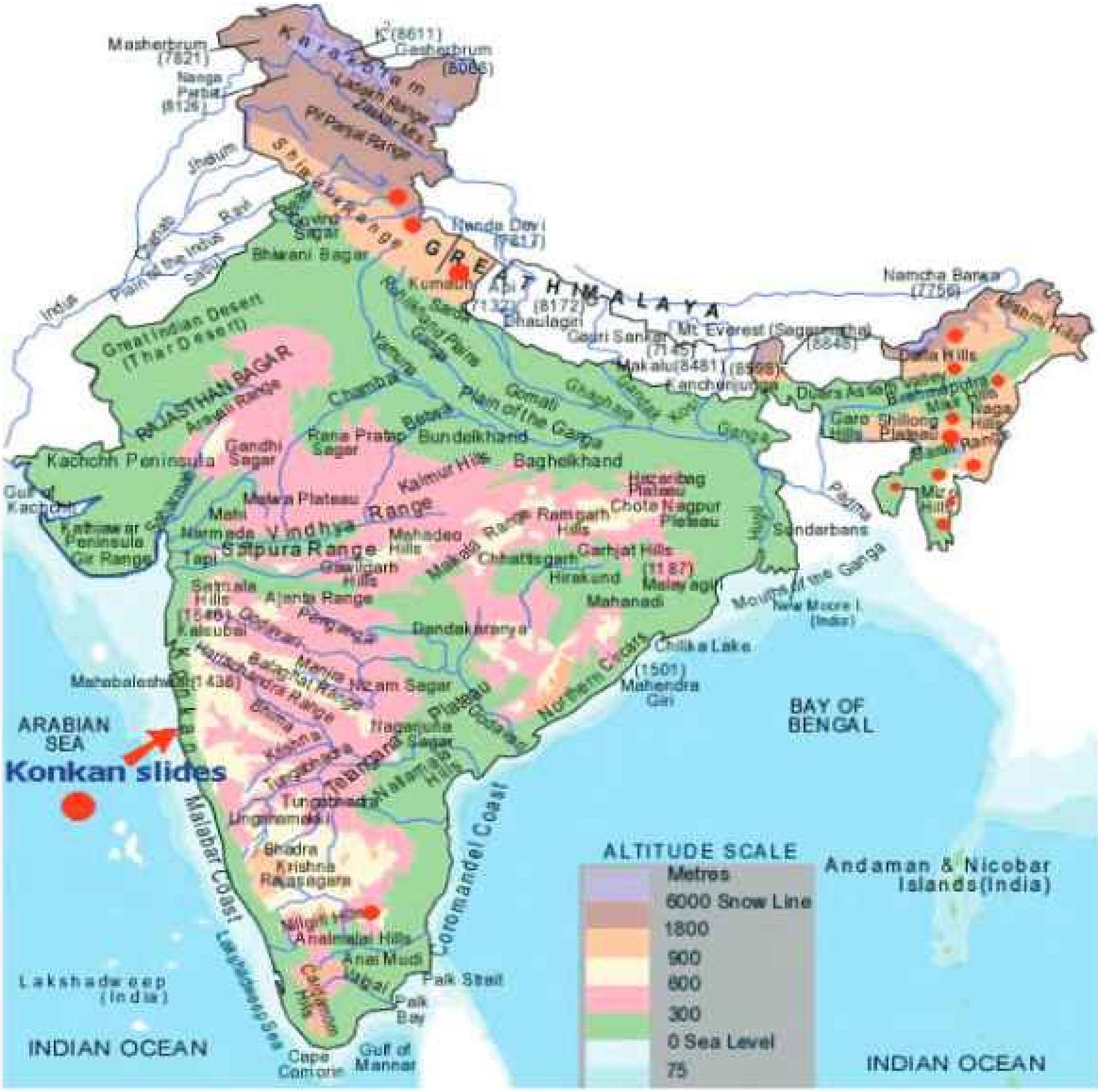

Figure 1: Map of landslide prone areas in India (gsi.gov.in).

- Irrigation and (or) lawn watering
- Mining/mine waste containment
- Artificial vibration such as pile driving, explosions or other strong ground vibrations
- Water leakage from utilities, such as water or sewer lines
- Diversion (planned or unplanned) of a river current or longshore current by construction of piers, dikes, weirs, etc.

4.2 Case studies of recent Landslides in India

We now present some cases of major landslides in recent years:

4.2.1 Landslide in Malin (Pune, 2014)

A major landslide was witnessed on 30th July 2014 in the village of Malin in the AmbegaonTaluka; 19°9'N and 73°41'E of the Pune district in Maharashtra, India. Fig.2 shows the landslide in Malin. This hazardous landslide struck up and wiped out the complete village of Malin, located close to Bhimashankar in Western Ghats. The landslide which hits early in the morning while residents were asleep, was believed to have been caused by a burst of heavy rainfall, and killed at least about 134 people. More than 40 houses were buried with an analysis suggested which the landslide meant which its course near to river bed and happened aftermath of heavy rainfall and it would be a major calamity.

Figure 2: Landslide at Malin, 2014 (Pune).

Synoptic situations from 28th July to 30th July 2014

(a) An Off Shore trough lay extended from North Maharashtra coast to Karnataka coast on 28th July 2014. It lay extended from Gujarat coast to Karnataka coast on 29th and it persisted on 30th July 2014.

(b) A low pressure area formed over Northwest Bay of Bengal and neighbourhood on 27th. It persisted on 28th and 29th and got intensified into a well marked low pressure area over the same area on 30th.

(c) An upper air cyclonic circulation lay over Northeast Rajasthan between 1.5 km and 3.1 km above sea level on 27th.

(d) An upper air cyclonic circulation lay over West Madhya Pradesh and neighborhood extended up to 3.1 km above sea level on 30th.

(e) An intense convection over Maharashtra was observed on 30th.

4.2.2 Landslide in Meghalaya (2014)

An amount of 203 mm rainfall was observed in 24 hours between 21 and 22 September 2014. 59 persons lost their lives, mostly in the Garo Hills region, and properties including road, houses, livestock and agriculture worth about Rs 2,000 crore got damaged. Many houses had been washed away and some affected villages remained cut off. National Highway number 51 connecting Tura town that connects National Highway number 37 at Paikan in Assam's Goalpara district has been damaged at several locations, massive landslides disrupting road links and hampering relief and rescue work. Official sources said 17 deaths due to landslides were reported in Kharkutta block in the worst-hit North Garo Hills district. In west Garo hills, seven persons were missing while seven died in south west Garo hills district.

Figure 3: Landslide in Meghalaya (2014).

Synoptic situations from 21st September to 22nd September 2014

(a) A low pressure area over northeast Jharkhand and adjoining Gangetic West Bengal and Bihar. Associated cyclonic circulation extends up to 4.5 kms a.s.l.

(b) The western disturbance as a trough in mid and upper tropospheric westerlies with its axis at 5.8 kms a.s.l. was roughly along Long.78°E to the north of Lat.28°N and moving away east northeastwards.

(c) The axis of monsoon trough at mean sea level became un-important.

(d) A cyclonic circulation extending between 4.5 & 5.8 kms a.s.l. led over Lakshadweep area and neighbourhood.

(e) The southwest Monsoon was vigorous over Assam & Meghalaya and Sub-Himalayan West Bengal & Sikkim and active over Arunachal Pradesh, Gangetic West Bengal and Jharkhand.

4.2.3 Landslides in Uttarakhand (2013)

The Himalayan State of India, Uttarakhand on 16th June 2013 faced one of the worst disasters like landslides and flash floods. Figures 4-6 show various landslides in Uttarakhand observed in the year 2013. There were also reports that huge loss was caused by torrential rains in the Mandakini and Saraswati river basin in Kedarnath valley of the state, (Dobhal et al., 2013).

Synoptic situations on 15thJune 2013

(a) The Western Disturbance (WD) as an upper air system laid over north Pakistan and adjoining J&K with anticipated movement in east-north- eastward direction.

(b) An upper air cyclonic circulation lay over northwest Rajasthan and adjoining Pakistan, extending up to 0.9 km above sea level.

(c) The monsoon trough at mean sea level was passing through northwest Rajasthan, Madhya Pradesh and thence south-eastwards on morning and persisted there till the evening with the mean position of monsoon trough.

Figure 4: Landslide in Uttarakhand after a heavy rainfall (2013).

Figure 5: Landslide in Uttarakhand on a locality (2013).

Figure 6: Landslide in Uttarakhand on a high way road (2013).

4.2.4 Landslide in Mumbai (2000)

On July 12, 2000, 67 people were killed when a landslide occurred in Ghatkopar area of Mumbai due to heavy rains. Most of the victims were the residents of slums. The landslide occurred on around 100 hutments of Chiragnagar-Azadnagar locality due to land erosion, caused by heavy rains in Mumbai during the Monsoon season. In the 24-hour-period before the landslide, more than 350 mm rainfall recorded in the suburbs of Mumbai. Figure 7 shows landslide in Ghatkopar (Mumbai) on 12th July 2000.

Figure 7: Landslide in Ghatkopar (Mumbai) on 12th July 2000.

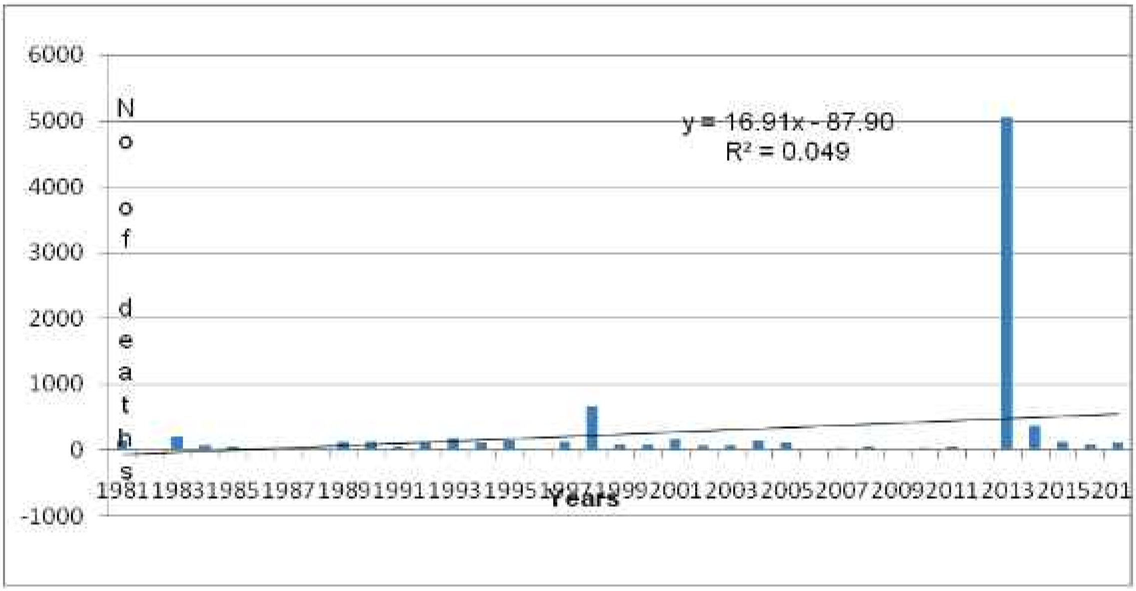

Figure 8: Year wise deaths due to landslides.

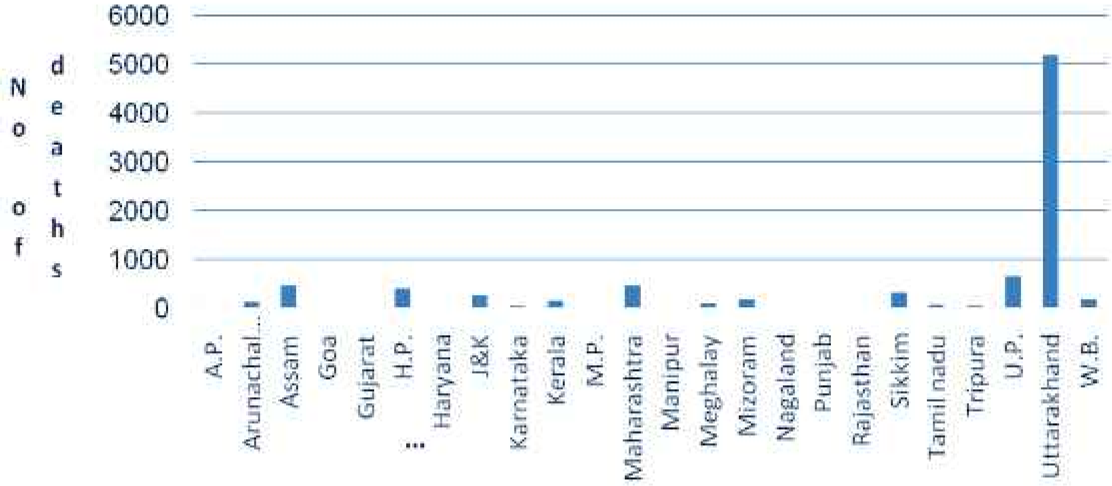

Figure 9: State wise deaths due to landslides.

4.3 Analysis of data

From the analysis of data sample (1981-2017), it was observed that, there were 733 cases of landslides due to heavy rainfall. The total number of deaths was observed as 8638 during the same period. From Figure 8, it is noticed that during the study period, maximum deaths due to landslides were 5054, out of which 5000 from Uttarakhand alone and 54 were reported from other places in the year 2013, followed by the year 1998 (659). It was also observed that during the period for which the data have been analyzed, the deaths over India due to landslides show increasing trend, though it is not statistically significant.

Flood-related fatalities are distributed all over the country with highest fatalities in Uttar Pradesh (17%), Maharashtra (13%), and Bihar and Gujarat (10 % each). Most fatalities occurred during the summer season monsoon months of August (30 %) followed by July (29%) and September (20 %), Singh and Kumar (2013). Figure 9 reveals that the maximum deaths related to landslides were reported from the state of Uttarakhand (5180), followed by Uttar Pradesh (660), Maharashtra (458) etc.

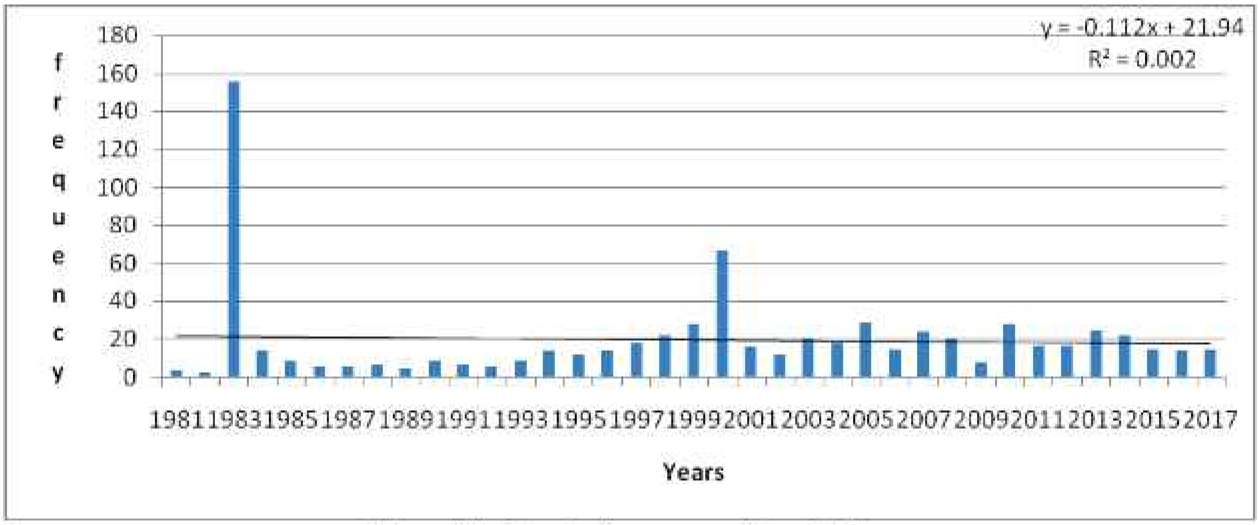

Figure 10: Yearly frequency of landslides.

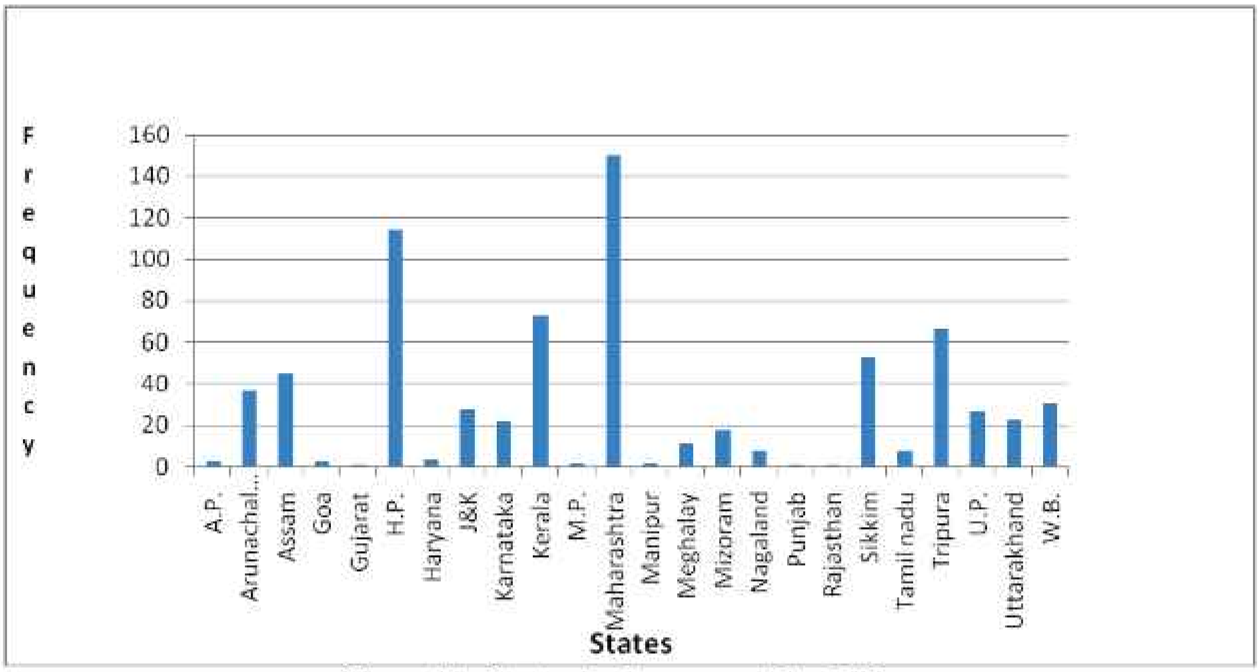

Figure 11: State wise frequency of landslides.

It is seen from Figure 10 that the maximum yearly frequency of landslides was observed in the year 1983 (156) followed by the year 2000 (67).

Figure 11 shows that, maximum frequency of landslides was observed in Maharashtra (150) followed by, Himachal Pradesh (114). The Western Ghats is most vulnerable to landslides. Several evidences indicating anthropogenic causes during recent years were responsible for bringing slopes into in-equilibrium. These include blasting during laying of the Konkan railway and construction of the tunnel, widening of roads, leveling on rolling spurs for horticulture, playground or other purposes, deforestation, etc. (Thigale and Umrikar , 2007). Theses may be the cause for higher peak in recent years in Mahatashtra.

5. Conclusions

The following conclusions emerge from the analysis:

(i) The deaths due landslides over India during the study period show increasing trend, though it is not statistically significant.
(ii) The deaths due to landslides are the highest in Uttarakhand followed by Uttar Pradesh, Maharashtra etc.

(iii) The frequency of landslides is the highest in Maharashtra followed by Himachal Pradesh during the study period.

(iv) Presence of favourable synoptic situations like depression or low-pressure area near the location are mainly responsible for causing heavy to very heavy rainfall which causes landslides.

As people move into new areas of hilly or mountainous terrains, it is important to understand the nature of their potential exposure to landslide hazards, and how cities, towns, and countries can plan for land-use, engineering of new construction and infrastructure, and other measures which will reduce the costs of living with landslides. Although the physical causes of many landslides cannot be eliminated, geologic investigations, good engineering practices, and effective enforcement of land-use management regulations can reduce landslide hazards.

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