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Landslide Disaster: Cause Effect and Protective Measures in India

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Abstract—*Landslide, a natural hazard in mountain areas, can cause extensive damage to life and property. India has areas which are prone to landslides. The most affected area are J & K, H.P., Garhwal Himalayas, North East Himalayas, western Ghats and Nilgiri Hills. So, it is essential to take up detailed investigations to explore the origin and cause of landslides and to find out the mechanisms for prevention and monitoring on a national level from time to time.*

1. INTRODUCTION

The term' landslide' includes all varieties of mass movements of hill slopes and can be defined as the downward and outward movement of slope forming materials composed of rocks, soils, artificial fills or combination of all these materials along surfaces of separation by falling, sliding and flowing, either slowly or quickly from one place to another. Although the landslides are primarily associated with mountainous terrains, these can also occur in areas where an activity such as surface excavations for highways, buildings and open pit mines takes place. Landslide is a general term for a wide variety of downslope movements of earth materials that result in the perceptible downward and outward movement of soil, rock, and vegetation under the influence of gravity. The materials may move by falling, toppling, Sliding, spreading, or flowing. Some landslides are rapid, occurring in seconds, whereas others may take hours, weeks, or even longer to develop.

Mudflows (or debris flows) are fluid mass of rock, earth, and other debris saturated with water. Mudflows are characteristics of steep, scanty vegetated slopes on which heavy rainfall initiates movement in a thick layer of weathered material. They develop when water rapidly accumulates in the ground, such as during heavy rainfall or rapid snowmelt, changing the earth into a flowing river of mud or slurry. Slurry can flow rapidly down slopes or through channels, and can strike with little or no warning at avalanche speeds. Slurry can travel several miles from its source, growing in size as it picks up trees, cars, and other materials along the way.

1.1. Objective

The purpose of the paper is as follow:

i. To analyze the different types of landslides in India.

ii. To attempt at the identification of some major constraints to landslides in India.

iii. To examine the adverse effect on living being and resources.

iv. To put forward some policy, suggestions for mitigating landslide hazards in India.

1.2. Methodology

The paper is a descriptive survey, which involves the collection of data for the purpose of describing the cause, effects and mitigation of landslides in India. .A descriptive methodology, based on secondary data derived from books of eminent authors, research thesis and articles of published and unpublished works and from various sources is adopted for the purpose.

2. CAUSES OF LANDSLIDES

Many factors contribute to slides, including geology, gravity, weather, groundwater, wave action, and human actions. Although landslides usually occur on steep slopes, they also can occur in areas of low relief. Landslides can occur as ground failure of river bluffs, cut and-fill failures that may accompany highway and building excavations, collapse of mine-waste piles, and slope failures associated with quarries and open-pit mines. Underwater landslides usually involve areas of low relief and small slope gradients in lakes and reservoirs or in offshore marine settings. Typically, a landslide occurs when several of these factors converge.

2.1 Natural Factors

2.1.1 Gravity

Gravity works more effectively on steeper slopes, but more gradual slopes may also be vulnerable.

2.1.2 Geological factors

Many slides occur in a geologic setting that places permeable sands and gravels above impermeable layers of silt and clay, or bedrock. Water seeps downward through the upper materials and accumulates on the top of the underlying units, forming a zone of weakness.

2.1.3 Heavy and prolonged rainfall

Water is commonly the primary factor triggering a landslide. Slides often occur following intense rainfall, when storm water runoff saturates soils on steep slopes or when infiltration causes a rapid rise in groundwater levels. Groundwater may rise as a result of heavy rains or a prolonged wet spell. As water tables rise, some slopes become unstable.

2.1.4 Earthquakes

Seismic activities have always been a main cause of landslides throughout the world. Any time plate tectonics move the soil that covers moves with it. When earthquakes occur on areas with steep slopes, many times the soil slips causing landslides. Furthermore, ashen debris flows caused by earthquakes can also trigger mass movement of soil.

2.1.5 Forest fire

Fires cause soil erosion and induce floods and landslides due to the destruction of the natural vegetation. (eg. ridges of Manipur-Nagaland border).

2.1.6 Volcanoes

Strata volcanoes are prone to sudden collapse, especially during wet conditions. (E.g. May 18, 1980, magma moved high into the cone of Mount St. Helens and shoved the volcano's north side outward by at least 150 m. Within minutes of a magnitude 5.1 earthquake at 8:32 a.m., a huge landslide completely removed the bulge, the summit, and inner core of Mount St. Helens, and triggered a series of massive explosions.)

The conditions commonly prevail after volcanic eruptions that kill vegetation over extensive areas and spread loose volcanic rocks over the landscape. During subsequent rainy seasons, swollen rivers will erode the new deposits and sometimes generate lahars that are dangerous to people downstream. (E.g. lahars at Mount Pinatubo, Philippines in 1990)

2.1.7 Waves

Wave action can erode the beach or the toe of a bluff, cutting into the slope, and setting the stage for future slides.

2.2 Anthropogenic Factors

Human actions most notably those that affect drainage or groundwater, can trigger landslides e.g. are Inappropriate drainage system, change in slope/land use pattern, deforestation, agricultural practices on steep slopes, cutting & deep excavations on slopes for buildings, roads, canals & mining ,inappropriate disposal of debris after excavations are examples.

2.2.1 Inappropriate drainage system

Natural drainage lines on slopes are blocked by terracing/ contour bounding adopted to prevent soil erosion and to enhance percolation during dry season for cultivation, without adequate provision for surface drainage of excess storm water during high intensity rains increase the landslide vulnerability.

2.2.2 Cutting & deep excavations on slopes for buildings, roads, canals & mining

Developmental activities like construction of buildings, road cutting, embankments, cut and fill structures causes modification of natural slopes, blocking of surface drainage, loading of critical slopes and withdrawal to toe support promoting vulnerability of critical slopes.

2.2.3 Change in slope/land use pattern, deforestation, agricultural practices on steep slopes

Deforestation and cultivation of seasonal crops and increase in settlements. Improper land use practices such as heavy tilling, agricultural practices and settlement patterns have contributed to creep and withdrawal of toe support in many cases

3. TYPES OF LANDSLIDES

The common types of landslides are described below. These definitions are based mainly on the work of Varnes (Varnes, D.J., 1978)

3.1 Falls

Abrupt movements of materials that become detached from steep slopes or cliffs, moving by free-fall, bouncing, and rolling.

3.2 Flows

General term including many types of mass movement, such as creep, debris flow, debris avalanche, lahar, and mudflow.

3.3 Creep

Slow, steady downslope movement of soil or rock, often indicated by curved tree trunks, bent fences or retaining walls, tilted poles or fences.

3.4 Debris flow

Rapid mass movement in which loose soils, rocks, and organic matter combine with entrained air and water to form slurry that then flows downslope, usually associated with steep gullies.

3.5 Debris avalanche

A variety of very rapid to extremely rapid debris flow.

3.6 Lahar

Mudflow or debris flow that originates on the slope of a volcano, usually triggered by heavy rainfall eroding volcanic deposits, sudden melting of snow and ice due to heat from volcanic vents, or the breakout of water from glaciers, crater lakes, or lakes dammed by volcanic eruptions

3.7 Mudflow

Rapidly flowing mass of wet material that contains at least 50 percent sand-, silt-, and clay-sized particles.

3.8 Lateral spreads

Often occur on very gentle slopes and result in nearly horizontal movement of earth materials. Lateral spreads usually are caused by liquefaction, where saturated sediments (usually sands and silts) are transformed from a solid into a liquefied state, usually triggered by an earthquake.

3.9 Slides

Many types of mass movement are included in the general term "landslide." The two major types of landslides are rotational slides and translational landslides.

3.9.1 Rotational landslide

The surface of rupture is curved concavely upward (spoon shaped), and the slide movement is more or less rotational. A slump is an example of a small rotational landslide.

3.9.2 Translational landslide

The mass of soil and rock moves out or down and outward with little rotational movement or backward tilting. Translational landslide material may range from loose, unconsolidated soils to extensive slabs of rock and may progress over great distances under certain conditions.

3.9.3 Topple

A block of rock that tilts or rotates forward and falls, bounces, or rolls down the slope

4. WHERE DOES LANDSLIDES MOSTLY OCCUR?

Large, deep-seated slides tend to be a reactivation of existing landslide complexes. Slope stability maps can provide an excellent indication of unstable areas. A competent geological analysis can usually provide an estimate of stability of problem areas on a site. It cannot reliably provide a probability of failure or an exact map of the area to be affected.

4.1 On steep slopes

Steep slopes are typically found along shorelines where centuries of wave or river currents have eroded the toe of the slope. Most steep slopes experience sliding.

4.2 On benches

Relatively level benches on an otherwise steep slope often indicate areas of past slope movement.

5. WHERE DRAINAGE IS CAUSING A PROBLEM

Landslides are often triggered by the failure of drainage systems. Large amounts of water flowing from driveways, roof areas, roads and other impermeable surfaces can cause slides.

6. WHERE CERTAIN GEOLOGIC CONDITIONS EXIST

Landslides occur where certain combinations of soils are present. When layers of sand and gravel lie above less permeable silt and clay layers, groundwater can accumulate and zones of weakness can develop.

7. HOW DO LANDSLIDES AFFECT US?

In hilly terrains of India, Himalayan Mountains, Western Ghats and northeastern part, landslides have been major natural disasters that strike life and property almost perennially. These landslides, year after year, bring about untold misery to human settlements apart from causing devastating damages to transportation and communication network.

7.1 Landslides cause property damage

Injury and death and adversely affect a variety of resources. For example, water supplies, fisheries, sewage disposal systems, forests, dams and roadways can be affected for years after a slide event.

7.2 The negative economic effects of landslides

Include the cost to repair structures, loss of property value, disruption of transportation routes, medical costs in the event of injury, and indirect costs such as lost timber and lost fish stocks.

Water availability, quantity and quality can be affected by landslides. Geotechnical studies and engineering projects to assess and stabilize potentially dangerous sites can be costly. Large, infrequent landslides contribute less to personal and property losses than do the smaller, more frequent slides and debris torrents in populated areas. Often in India in mountain regions like Himalaya landslides damage many houses and cause millions of rupees damage to buildings, roads, railways, pipelines, agricultural land and crops.

8. SOME OF THE MAJOR LANDSLIDES IN INDIA (1990-2005)

i. October 1990 Nilgris 36 people killed and several injured. Several buildings and communication network damaged.

ii. July 1991 Assam 300 people killed, road and buildings damaged, Millions of rupees.

iii. November 1992 Nilgiris Road network and buildings damaged, Rs.5 million damage estimate.

iv. June 1993 Aizawal 4 persons were buried.

v. July 1993 Itanagar 25 people buried alive 2 km road damaged.

vi. August 1993 Kalimpong, West Bengal 40 people killed heavy loss of property.

vii. August 1993 Kohima, Nagaland 200 houses destroyed, 500 people died, about 5km road stretch was damaged. **viii.** November 1993 Nilgris 40 people killed, property worth several lakhs damaged.

ix. January 1994 Kashmir National Highway 1A severely damaged.

x. June 1994 Varundh ghat, Konkan Coast 20 people killed, breaching of ghat road damaged to the extent of 1km. at several places.

xi. May 1995 Aizwal Mizoram 25 people killed road severely damaged.

xii. June 1995 Malori Jammu 6 persons killed, NH 1A damaged.

xiii. September 1995 Kullu, HP 22 persons killed and several injured about 1 km road destroyed.

xiv. 14, August 1998 Okhimath 69 people killed. **xv.** 18, August 1998 Malpa,Kali river 205 people killed road network to Mansarovar disrupted.

xvi. August 2003 Uttarkashi Heavy loss of infrastructures.

xvii. July 2004 Joshimath – Badrinath Heavy landslides hit Lambagarh area washed away nearly 300 meter long road between Joshimath and Badrinath, 17 killed.

xviii. August 03, 2004 Landslide at Tehri dam project; 9 killed.

9. REVIEW OF THE LITERATURE

The NLIC publishes in various venues such as USGS fact sheets, books, pamphlets, and posters, and will provide personnel to present landslide information in schools, civic organizations, and other interested governmental entities. International Landslide Research Group (ILRG) is an informal group of individuals concerned about sharing information on landslide research and promoting regional landslide analyses. The Federal Emergency Management Agency (FEMA) provides "fact sheets" - including preparedness tips - concerning most natural and technological hazards. The Washington State Department of Ecology recently launched this excellent site on landslides in the Puget Sound region. Geological Survey of India. Centre for earth Science Studies.

10. PREPAREDNESS FOR MITIGATING LANDSLIDE HAZARD

10.1 During a Landslide

1. Stay alert and awake. Many debris-flow fatalities occur when people are sleeping. Listen to a Weather Radio or portable, battery powered Radio or television for warnings of intense rainfall. Be aware that intense, short bursts of rain may be particularly dangerous, especially after longer periods of heavy rainfall and damp weather.

2. If you are in susceptible to landslides and debris-flows, consider leaving if it is safe to do so. Remember that driving during an intense storm can be hazardous. If you remain at home, move to a second story if possible. Staying out of the path of a landslide or debris-flow saves lives.

3. Listen for any unusual sounds that might indicate moving debris, such as trees cracking or boulders knocking together. A trickle of flowing or falling mud or debris may precede larger landslides. Moving debris can flow quickly and sometimes without warning.

4. If you are near of stream or channel, be alert for any sudden increase or decrease in water flow and for a change from clear to muddy water Such changes may indicate landslide activity upstream, so be prepared to move quickly. Do not delay! Save yourself, not your belongings.

5. Be specially alert when driving. Embankments along roadsides are particularly susceptible to landslides. Watch the road for collapsed pavement, mud, fallen rocks, and other indications of possible debris flows.

10.2 What to do if you suspect imminent landslide

1. Contact your local fire, police or public works department. Local officials are the best persons able to assess potential danger.

2. Inform affected neighbors. Your neighbors may not be aware of potential hazards. Advising them of a potential threat may help save lives. Help neighbors who may need assistance to evacuate.

Getting out of the path of a landslide or debris flow is your best protection.

10.3 After the landslide

1. Stay away from the landslide area. There may be danger of additional slides.

2. Check for injured and trapped persons near the slide, without entering the direct slide area.

3. Help a neighbor who may require special assistance – infants, elderly people, and people with disabilities. Elderly people and people with disabilities may require additional assistance. A people who care for them or who

have large families may need additional assistance in emergency situations.

4. Listen to local radio or television stations for the latest emergency information.
5. Watch for flooding, which may occur after a landslide or debris flow. Foods sometimes follow landslides and debris flow because they may both be started by the same event.
6. Look for an report broken utility lines to appropriate authorities. Reporting potential hazards will get the utilities turned off as quickly as possible, preventing further hazard and injury.
7. Check the building foundation, chimney, and surrounding land for damage. Damage to foundations, chimneys, or surrounding land may help you assess the safety of the area.
8. Replant damaged ground as soon as possible since erosion caused by loss of ground cover can lead to flash flooding.
9. Seek the advice of a geotechnical expert for evaluating landslide hazards or designing corrective techniques to reduce landslide risk. A professional will be able to advise you of the best ways to prevent or reduce landslide risk, without creating further hazard**.**

10.4 Before a Landslide: How to Plan

1. Develop a family disaster landslide specific planning. Learn about landslide risk in your area. Contact local officials, state geological surveys or departments of natural resources, and university department of geology. Landslides occur where they have before, and in identifiable hazard locations. Ask for information on landslides in your area, specific information on areas vulnerable to landslides, and request a professional referral for a very detailed site analysis of your property, and corrective measures you can take, if necessary**.**

10.5 If you are at risk from landslides

1. Talk to your insurance agent. 2. Develop an evacuation plan. Discuss landslides and debris flow with your family. Everyone should know what to do in case all family members aren't together. Discussing disaster ahead of time helps reduce fear and lets everyone know how to respond during a landslide or debris flow.

10.6 Media and Community Education Ideas

1. In an area prone to landslides, publish a special newspaper section with emergency information on landslides and debris flows. Localize the information by including the phone numbers of local emergency service offices, the American Red Cross chapter and hospitals.
2. Report on what city and county governments are doing to reduce the possibility of landslides.
3. Regarding the National Flood Insurance Program. Find out if debris flow is covered by flood insurance policies from the National Flood Insurance Program and contact your local emergency management office to learn more about the program.
4. Work with local emergency to prepare special reports for people with mobility impairments on what to do if evacuation is ordered.
5. Support your local government in efforts to develop and enforce land-use and building ordinance that regulate construction in areas susceptible to landslides and debris flows. Building should be located away from steep slopes, streams and rivers, intermittent-stream channels, and the mouths of mountain channels.

11. FUTURE PLANS

Drawing upon the Kerala study in parts of Western Ghats (referred to earlier), it has been felt that while permanent settlement should be avoided in high-risk zones, site selection even in moderately safe zones, especially in plateau edge regions should be made with caution. Diversion of stream channels in upper slopes, especially above settlement should strictly disallow. Adequate provision should made to ensure drainage of storm water away from the high sloping terrain so as to reduce over saturation, Any contour bounding, or terracing adopted for seasonal cultivation or initiation of plantations in slopes of >160 above settlement should have sufficient provision for storm water drainage. Further, in such areas the existing natural drainage channels and hallows are to be meticulously maintained without any attempt at blocking, division or modification.

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