Government of Jammu & Kashmir
Higher Education Department

E-CONTENT

A Gateway to all Under Graduate Courses

Subject	Environmental Sciences
Paper Title	Environmental Studies
Course Name	Environmental Hazards: Concept and Management
Course Code	PSESTE 601
Module/Unit No	Understanding Disasters and Their Characteristics; Unit-II (2.4)
Title	**Geological Disasters: Landslides**
Affiliated Institution: GDC Kishtwar	University of Jammu
Content Developer Name: **Dr. Sehrish Gazal** Designation: Assistant Professor Email: sehrishgazal@gmail.com	**Reviewer** Name: Designation:

TABLE OF CONTENTS

2.4.3 LANDSLIDES

I. INTRODUCTION

Landslides constitute a major natural hazard in our country, which accounts for considerable loss of life and damage to communication routes, human settlements, agricultural fields and forest lands. Based on the general experience with landslides, a rough estimate of monetary loss is of the order of 100 crore to 150 crore per annum at the current prices for the country as a whole.

Landslides mainly affect the Himalayan region and the Western Ghats of India. Landslides are also common in the Nilgiri range. It is estimated that 30% of the world's landslides occur in the Himalayas. The Himalayan Mountains, which constitute the youngest and most dominating mountain system in the world, are not a single long landmass but comprises a series of seven curvilinear parallel folds running along a grand arc for a total of 3400 kilometers. Due to its unique nature, the Himalayas have a history of landslides that has no comparison with any other mountain range in the world.

Landslides are also common in western Ghat. In the Nilgiris, in 1978 alone, unprecedented rains in the region triggered about one hundred landslides which caused severe damage to communication lines, tea gardens and other cultivated crops. A valley in Nilgiris is called **"Avalanches Valley".** Scientific observation in north Sikkim and Garhwal regions in the Himalayas clearly reveal that there is an average of two landslides per sq. km. The mean rate of land loss is to the tune of 120 meter per km per year and annual soil loss is about 2500 tonnes per sq km.

Definition:

- Landslides are simply defined as down slope movement of rock, debris and/or earth under the influence of gravity.

- In other words landslide is defined as the movement of a mass of rock, debris or earth down the slope, when the shear stress exceeds the shear strength of the material.

- Landslide is *"the movement of a mass of rock, debris or earth down the slope"* (Cruden, 1991).

This sudden movement of material causes extensive damage to life, economy and environment. It is the most common and universally accepted collective term for most slope movements of the massive nature. The term has sometimes been considered unsuitable as the active part of the word denotes sliding, whereas it connotes even movements without sliding like fall, topple, flow etc.

II. Landslide Vulnerability Zones in India

Disasters due to landslides are in general far less dramatic than due to earthquakes, volcanic eruptions, tsunamis and cyclones but their impact on the natural environment and national economy is in no way less severe. Unlike other disasters that are sudden, unpredictable and are largely controlled by macro or regional factors, landslides are largely controlled by highly localised factors. Hence, gathering information and monitoring the possibilities of landslide is not only difficult but also immensely cost-intensive. It is always difficult to define in a precise statement and generalise the occurrence and behaviour of a landslide. However, on the basis of past experiences, frequency and certain causal relationships with the controlling factors like geology, geomorphic agents, slope, land-use, vegetation cover and human activities, India has been divided into a number of zones.

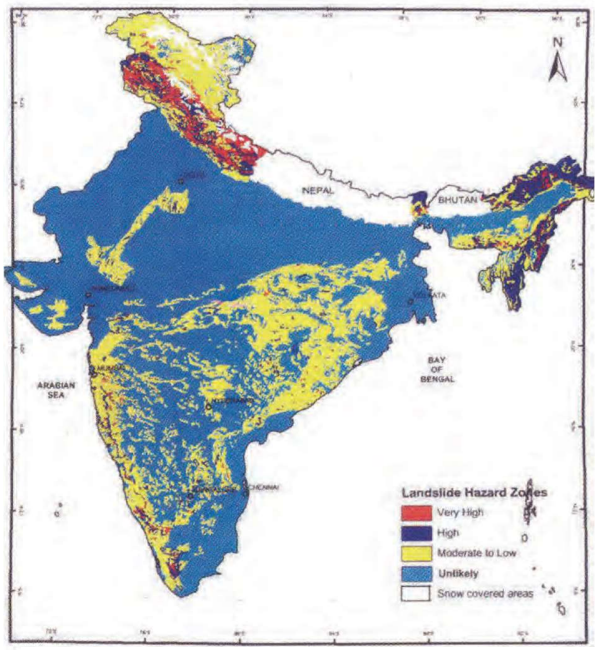


Figure 1: Landslide hazard zones in India

Landslide Vulnerability Zones:

A. **Very High Vulnerability Zone:** Highly unstable, relatively young mountainous areas in the Himalayas and Andaman and Nicobar, high rainfall regions with steep slopes in the Western Ghats and Nilgiris, the north-eastern regions, along with areas that experience frequent ground-shaking due to earthquakes, etc. And areas of intense human activities, particularly those related to construction of roads, dams, etc. are included in this zone.

B. **High Vulnerability Zone:** Areas that have almost similar conditions to those included in the very high vulnerability zone are also included in this category. The only difference between these two is the combination, intensity and frequency of the controlling factors. All the Himalayan states and the states from the north-eastern regions except the plains of Assam are included in the high vulnerability zones

C. **Moderate to Low Vulnerability Zone:** Areas that receive less precipitation such as Trans-Himalayan areas of Ladakh and Spiti (Himachal Pradesh), undulated yet stable relief and low precipitation areas in the Aravali, rain shadow areas in the Western and Eastern Ghats and Deccan plateau also experience occasional landslides. Landslides due to mining and subsidence are most common in states like Jharkhand, Orissa, Chhattisgarh, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Goa and Kerala.

D. **Other Areas:** The remaining parts of India, particularly states like Rajasthan, Haryana, Uttar Pradesh, Bihar, West Bengal (except district Darjiling), Assam (except district Karbi Anglong) and Coastal regions of the southern States are safe as far as landslides are concerned.

III. MORPHOLOGY OF LANDSLIDES

Parts of Landslides – Description of Features

Accumulation - The volume of the displaced material, which lies above the original ground surface
Crown – The practically undisplaced material still in place and adjacent to the highest parts of the main scarp
Depletion – The volume bounded by the main scarp, the depleted mass and the original ground surface
Depleted mass – The volume of the displaced material, which overlies the rupture surface but underlies the original ground surface

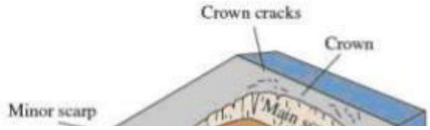
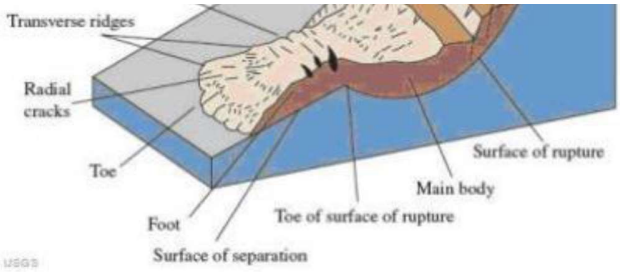


Figure 2: Source: USGS Components of landslides



Displaced material – Material displaced from its original position on the slope by movement in the landslide. It forms both the depleted mass and the accumulation.
Flank – The undisplaced material adjacent to the sides of the rupture surface. Compass directions are preferable in describing the flanks, but if left and right are used, they refer to the flanks as viewed from the crown.
Foot – The portion of the landslide that has moved beyond the toe of the surface of rupture and overlies the original ground surface.
Head – The upper parts of the landslide along the contact between the displaced material and the main scarp.
Main body – The part of the displaced material of the landslide that overlies the surface of rupture between the main scarp and toe of the surface of rupture.
Main scarp – A steep surface on the undisturbed ground at the upper edge of the landslide, caused by movement of the displaced material away from undisturbed ground. It is the visible part of the surface of rupture.
Minor scarp – A steep surface on the displaced material of the landslide produced by the differential movement within the displaced material.
Original ground surface – the surface of the slope that existed before the landslide took place. ***Surface of separation*** – The part of the original ground surface overlain by the foot of the landslide ***Surface of rupture*** – The surface that forms the lower boundary of the displaced material below the original ground surface.
Tip – The point of toe farthest from the top of the landslide.
Toe – The lower, usually curved margin of the displaced material of a landslide, it is the most distant part from the main scarp.
Top – The highest point of contact between the displaced material and the main scarp.
Toe of surface of rupture – The intersection (usually buried) between the lower part of the surface of rupture of a landslide and the original ground surface.
Zone of accumulation – The area of landslide within which the displaced material lies above the original ground surface.
Zone of depletion – The area of the landslide within which the displaced material lies below the original ground surface.

IV. CAUSES OF LANDSLIDES

A landslide occurs when stability conditions of the slope is disturbed either by the increase of stress imposed on the slope and / or by the decrease in strength of the earth material building up the slope and it involves downward movement of earth material under the influence of gravity. Thus, the occurrence of landslides is the consequence of a complexes of forces (stress is a force per unit area) which is active on a mass of rock or soil on the slope. Basically, the two main determinative parameters are:

A. Increase in shear strength	B. Reduction of material strength
• Removal of lateral and underlying support (erosion, previous slides, road cuts and quarries) • Increase of load (weight of rain/snow, fills, vegetation) • Increase of lateral pressures (hydraulic pressures, roots, crystallisation, swelling of clay) • Transitory stresses (earthquakes, vibrations of trucks, machinery, blasting) • Regional tilting (geological movements).	• Decrease of material strength (weathering, • Change in state of consistency) • Changes in intergranular forces (pore water pressure, solution) • Changes in structure (decrease strength in failure plane, fracturing due to unloading)

CAUSES OF LANDSLIDES: Many of the landslides are natural phenomenon that occurs independently of any human actions. There are also landslides that have been induced by the very actions taken to make land suitable for some human purposes. Landslides can be triggered due to external causes or internal causes.

External Causes

1. Undercutting of the foot of the hill slope due to river erosion, quarrying, excavation for canals and roads, etc.
2. External loads such as buildings, reservoirs, highway traffic, stockpiles of rocks, accumulation of alluvium on slopes, etc.
3. Increase in unit weight of slope material due to increased water content.
4. Vibrations due to earthquakes, blasting, traffic, etc., causing increase in shearing stresses.
5. Authropic changes caused by deforestation
6. Undermining caused by tunneling, collapse of underground caverns, seepage erosion, etc.

Internal Causes

1. Increase in pore water pressure.
2. Reduction in cohesive strength caused by progressive laterization.
3. Hair cracks due to alternate swelling and shrinkage from tension.
4. Presence of faults, joints, bedding planes, cleavage etc., and their orientation.
5. Freezing and thawing of rocks and soils.
6. Material properties such as compressive strength, shearing strength, etc., of earth material.

Causal Factors for Landslides

There can be several different causative factors for the occurrence of landslides which may work individually or collectively to cause a landslide. Broadly these factors can categorize into **ground conditions, geomorphological processes, physical processes** and **man-made processes.** A brief list of these causal factors is given below.

A. Ground Conditions

- Plastic weak material
- Sensitive material
- Collapsible material
- Weathered material
- Sheared material
- Jointed or fissured material
- Adversely oriented structural discontinuities including faults, unconformities, flexural shears, sedimentary contacts
- Adversely oriented mass discontinuities (including bedding, schistosity, cleavage)
- Contrasts in permeability and its effects on ground water
- Contrasts in stiffness (stiff, dense material over plastic material)

B. Geomorphological Processes

- Tectonic uplift
- Volcanic uplift
- Glacial Rebound
- Fluvial erosion of the slope toe
- Wave erosion of the slope toe
- Glacial erosion of the slope toe
- Erosion of the lateral margin
- Subterranean erosion (solution, piping)
- Deposition loading of slope at its crest
- Vegetation removal (by erosion, forest fire, drought)
- Ground Cracks
- Subsidence

C. Physical Processes

- Intense rainfall over a short period
- Rapid melt of deep snow
- Prolonged heavy precipitation
- Rapid drawdown following floods, high tides or breaching of natural dam
- Earthquake
- Volcanic eruption
- Breaching of crater lake
- Thawing of permafrost
- Freeze and thaw weathering
- Shrink and swell weathering of expansive soils

D. Man-Made Processes

- Excavation of the slope or its toe
- Loading of the slope or its crest
- Drawdown of reservoir
- Irrigation
- Defective maintenance of drainage system
- Water leakage from services like water supplies, sewage, storm water drains
- Vegetation removal (deforestation)
- Mining and quarrying in open pits or underground galleries
- Creation of dumps of very loose waste
- Artificial vibration including traffic, pile driving, heavy machinery,blasting and explosion
- Poor maintenance of remedial measures

V. TYPES OF LANDSLIDES

Classification of Landslides					
Type of movement			**Type of material**		
			Rock	**Soils**	**Debris**
				Predominantly fine	Predominantly coarse
1. Falls			Rockfall	Earth fall	Debris fall
2. Topples			Rock topples	Earth topples	Debris topples
3. Slides	Rotational		Rock slump	Earth slumps	Debris slump
	Translational	Few units	Rock block slide	Earth block slide	Debris block slide
		Many units	Rock slide	Earth slide	Debris slide
4. Lateral spreads			Rock spread	Earth spread	Debris spread
5. Flows			Rock flow	Earth flow	Debris flow
			Rock avalanche		Debris avalanche
			(Deep creep)	(Soil creep)	
6. Complex			Nature of movement varies with time		
7. Compound			Nature of movement varies in different parts of the failed slopes		

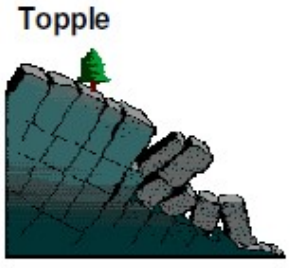
Landslide types based on process of failure:

Based on process types, there are five types of landslides i.e. Fall, Topple, Slide, Spread, Flow and Subsidence.

1. **Fall:** is a very rapid to an extremely rapid movement which starts with a detachment of material from steep slopes such as cliffs, along a surface on which little or no shear displacement takes place. The material then descends through the air by free falling, bouncing or rolling onto the slopes below.
   - The detachment of soil or rock from a steep slope along a surface on which little or no shear displacement takes place.
   - Movement very rapid to extremely rapid.
   - Free fall if slope angle exceeds 76 degrees and rolling at or below 45 degrees.

Figure 3: Fall

2. **Topple:** involves overturning of material. It is the forward rotation of the slope mass about a point or axis below the centre of gravity of the displaced mass. Topples range from extremely slow to extremely rapid movements.
   - The forward rotation out of the slope of a mass or a rock about a point or axis below the centre of gravity of the displaced mass.
   - Movement varies from extremely slow to extremely rapid.



- Driven by gravity and sometimes by water or ice in cracks in mass.

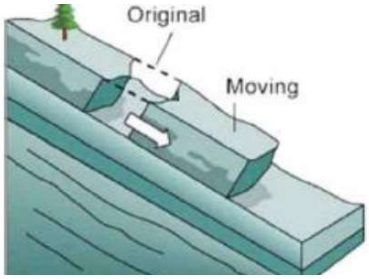


Figure 4: Topple

3. **Slide:** movement of material along a recognizable shear surface e.g. translational and rotational slides.
   - Down slope movement of a soil or mass occurring dominantly on surfaces of or on relatively thin zones of intense shear strain.
   - The sign of ground movement are cracks of the original ground.

   Modes of Sliding:
   - Translational / planar slides
   - Wedge slides
   - Rotational slide

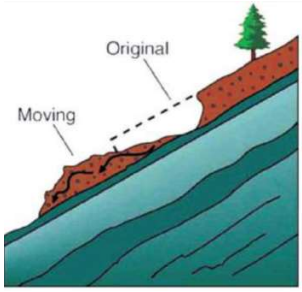


Figure 5: Slide

4. **Flow:** is a landslide in which the individual particles travel separately within a moving mass. Spatially continuous movement, in which surfaces of shear are shortlived, closely spaced and usually not preserved. Flows are differentiated from slides, on the basis of water content, mobility and evolution of the movement.

Spread

5. **Spread**
   - Sudden movement on water- bearing seams of sand or silt overlain by homogeneous clays or loaded by fills.
   - May result from liquefaction or flow of softer material.

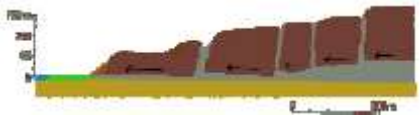


Figure 7: Spread

***Slump*:** It is a type of rotational failure on the slopes. The trees bend or fall backwards on towards the slope.

Creep: Very slow rates of slope movements, usually a few millimeter per year, that is imperceptible in nature) is covered under this category. However, one may find landslides that do not fall directly under any of these typical singular types of slope failures. Such landslides may be composite, complex or multi-tier.

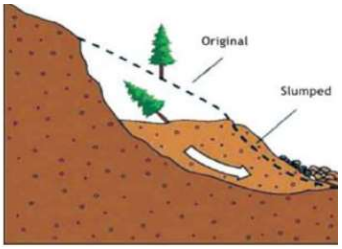


Figure 8: Slump type failure

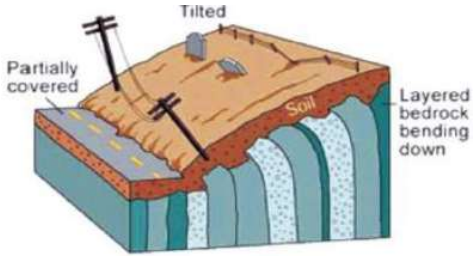


Figure 9: movement during creep

Multi-tier/Multi-rotational landslides:

When more than one main scars appears in a landslide site and slope mass has more than one slip surface along which movement takes place.

Complex Landslides:

Those landslides where the nature of failure process is not consistent but changes with time are called complex landslides. For example, a landslide that begins with rock sliding changes its nature to a rockfall due to a steepening of slopes during a failure may again result into a debris flow due to the formation of a channel during the process of past failures. Thus, it becomes, often very difficult to prevent and control such complex landslides. It requires a persistent study to understand the causes of such landslides properly. These landslides are also found to be chronic and recurring in nature. For example, Kaliasaur landslide in Alaknanda valley, Uttarakhand has displayed complex failure.

Composite Landslides:

The slopes which fail in different manners simultaneously at the same site are termed as composite landslides. These landslides display a composite nature as different parts of the landslide indicate a different process type. The types of failure vary due to changes in slope aspect, gradient, heterogeneity in slope mass, landcover, structural / tectonic controls etc. For example, Matli landslide in Bhagirathi valley, Uttarakhand is an example of composite landslide.

VI. IMPACTS OF LANDSLIDES

Landslides have relatively small and localised area of direct influence, but roadblock, destruction of railway lines and channel blocking due to rock-falls have far-reaching consequences. Diversion of river courses due to landslides can also lead to flood and loss of life and property. It also makes spatial interaction difficult, risky as well as a costly affair, which, in turn, adversely affects the developmental activities in these areas.

A. Direct losses:

1) **Loss of life:** Landslides can result in death and injury of people and animals. The moving mass can bury people and animals under debris.
2) **Loss of property and asset:** The force and speed of debris, mud or earth mass generated due to mass movement may destroy houses, buildings and other properties on its way.
3) **Loss of infrastructure and lifeline facility**: Earth mass can block or damage infrastructures such as roads, railway, bridges, telecommunication, electrical supply lines, etc.
4) **Loss of Resources:** Earth mass can effect water recourses in the area by blocking rivers, diverting water ways, blocking irrigation channels, reducing storage capacity of tanks, reservoirs, ponds, etc. it can cause production losses to open cast mines, rock quarries.
5) **Loss of farmland:** Productive land area may be covered with debris or blocked from access.
6) Loss of places of cultural importance

B. Indirect losses:

1) **Loss in productivity of agricultural or forest lands**: Due to being buried by debris, lack of access or being under flood.
2) **Reduced property values:** Due to unwillingness of people to purchase disaster prone land.
3) **Loss of revenue:** Due to loss of productivity, transport breakdown, etc.
4) **Increased cost:** Due to investments in preventing or mitigating future landslide damage.
5) **Adverse effect on water quality:** Occur in water storage facilities such as streams, reservoirs, storage tanks etc.
6) **Secondary physical effects:** Such as flooding which in turn generates both direct and indirect costs.
7) **Loss of human productivity:** Due to death and injury.
8) **Reduction in quality of life:** Due to the deaths of family members and the destruction of personal belongings, which may also have great sentimental value.
9) **Impact on emotional wellbeing:** Any disaster can have a profound impact on people's emotional wellbeing affecting their feelings, thoughts, actions, and relationships. The sudden overwhelming disruption and danger to life and property can put tremendous psychological at the time of the crisis. The impact a disaster can have on a person also depends on his/her past experiences of crises, how well he/she has been prepared for such events both physically and mentally and his/her attitude or level of resilience.

VII. Mitigation Measures

It is always advisable to adopt area-specific measures to deal with landslides. Restriction on the construction and other developmental activities such as roads and dams, limiting agriculture to valleys and areas with moderate slopes, and control on the development of large settlements in the high vulnerability zones, should be enforced. This should be supplemented by some positive actions like promoting large-scale afforestation programmes and construction of bunds to reduce the flow of water. Terrace farming should be encouraged in the north-eastern hill states where *Jhumming* (Slash and Burn/Shifting Cultivation) is still prevalent.

a) **Drainage Corrections:** The most important triggering mechanism for mass movements is the water infiltrating into the overburden during heavy rains and consequent increase in pore pressure within the overburden**.** Hence the natural way of preventing this situation is by reducing infiltration and allowing excess water to move down without hindrance. As such, the first and foremost mitigation measure is drainage correction. This involves maintenance of natural drainage channels, both micro and macro in vulnerable slopes.

b) **Proper land use measures:** Adopt effective land-use regulations and building codes based on scientific research. Through land-use planning, discourage new construction or development in identifying hazard areas without first implementing appropriate remedial measures.

c) **Structural measures:** Adopt remedial techniques (i.e., buttresses, shear keys, sub-drains, soil reinforcement, retaining walls, etc.) of existing landslides that are in close proximity to public structures.

d) **Afforestation:** Afforestation program should be properly planned so the little slope modification is done in the process. Bounding of any sort using boulders, etc. has to be avoided. The selection of suitable plant species should be such that can with stand the existing stress conditions of the terrain.

e) **Awareness generation**: Educate the public about signs that a landslide is imminent so that personal safety measures may be taken. Some of these signs include:

i. Springs, seeps, or saturated ground in areas that have not typically been wet before.
ii. New cracks or unusual bulges in the ground, street pavements or sidewalks.
iii. Soil moving away from foundations, and ancillary structures such as decks and patios tilting and/or moving relative to the house.
iv. Sticking doors and windows, and visible open spaces.
v. Broken water lines and other underground utilities.
vi. Leaning telephone poles, trees, retaining walls or fences.
vii. Sunken or dropped-down road beds.
viii. Rapid increase in a stream or creek water levels, possibly accompanied by increased turbidity (soil content).
ix. Sudden decrease in creek water levels even though rain is still falling or just recently stopped.

Post-Landslide Measures:

- Clear the blocked drainage channels.
- Clear the debries, especially the huge rock boulders and tree trunks on the slopes.
- Stabilise the depositional area (characterized by loose soil, small rock boulders, etc.) by fast growing trees/plants.
- Rehabilitate the affected people.

VIII. ASSESSMENTS-SHORT QUESTIONS

1) Discuss various causative agents of landslides
2) Explain different types of landslides.
3) Give various negative impacts of landslides.
4) What mitigation measures should be taken to reduce risk of landslides?

IX. References

- *NCERT, 2005. INDIA: PHYSICAL ENVIRONMENT. Chapter:IV Natural Hazards And Disasters: Causes, Consequences And Management*
- Ministry of home affairs, govt. Of india.Disaster management in india: disasters in india an overview. http://mha.nic.in
- National Institute of Disaster Management, Ministry of Home Affairs, Govt. of India, (2012):Training Module on Comprehensive Landslides Risk Management.
- http://www.saarc-sadkn.org/landslide.aspx
- http://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html
- http://geology.isu.edu/wapi/envgeo/EG4_mass_wasting/EG_module_4.htm 5National Institute of Disaster Management, Ministry of Home Affairs, Govt. of India, Do‟s & Don‟ts for Common Disasters
- Narasimha, N.B. Prasad Landslides-Causes & Mitigation. Centre for Water Resources Development and Management Technical Report · January 1995.
- Learning to live with LANDSLIDES Natural Hazards and Disasters. 2006. Ministry of Education and National Institute of Education Education for Social Cohesion, Disaster Risk Management and Psycho-social Care. Sri Lankan-German Development Cooperation