Landslide Hazard Assessment & Mitigation

DML – 502 Lecture - 4

Subject Code: DMN-502
Course Title: Landslide Hazard Assessment & Mitigation

"To understand mapping and hazard assessment techniques of landslides and protection against landslide."

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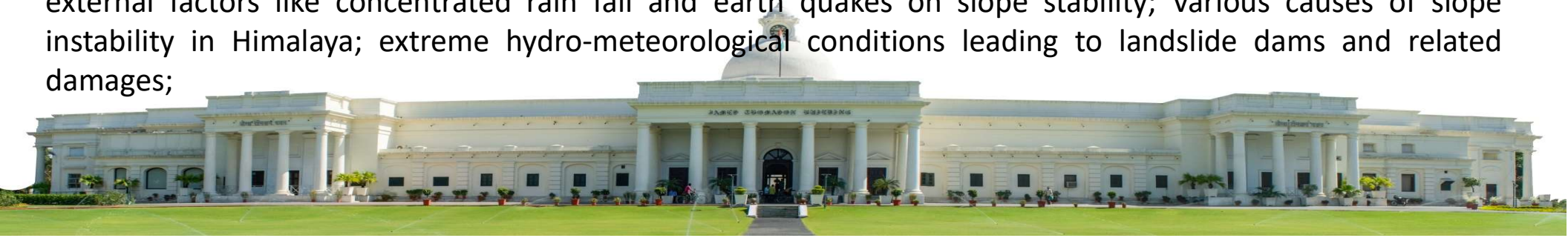
Causative factors of landslides – natural including inherent factors and external factors as well as anthropogenic factors; Impacts of natural causative factors like lithology, structure, slope morphometry, relative relief, hydrogeological conditions and land use and land cover on stability of slopes ; Impacts of external factors like concentrated rain fall and earth quakes on slope stability; Various causes of slope instability in Himalaya; extreme hydro-meteorological conditions leading to landslide dams and related damages;



What Causes Landslides?

There are two primary categories of causes of landslides: natural and human-caused. Sometimes, landslides are caused, or made worse, by a combination of the two factors.

Natural Occurrences

This category has three major triggering mechanisms that can occur either singly or in combination

(1) water,

(2) seismic activity, and

(3) volcanic activity.

Effects of all of these causes vary widely and depend on factors such as steepness of slope, morphology or shape of terrain, soil type, underlying geology, and whether there are people or structures on the affected areas.

The Landslide Handbook—A Guide to Understanding Landslides

Landslides and Water

- Slope saturation by water is a primary cause of landslides.
- Saturation can occur in the form of intense rainfall, snowmelt, changes in ground-water levels, and surface-water level changes along coastlines, earth dams, and in the banks of lakes, reservoirs, canals, and rivers.
- Landslides and flooding are closely associated because both are related to precipitation, runoff, and the saturation of ground by water.
- Flooding may cause landslides by undercutting banks of streams and rivers and by saturation of slopes by surface water (overland flow).
- In addition, debris flows and mudflows usually occur in small, steep stream channels and commonly are mistaken for floods; in fact, these two events often occur simultaneously in the same area.

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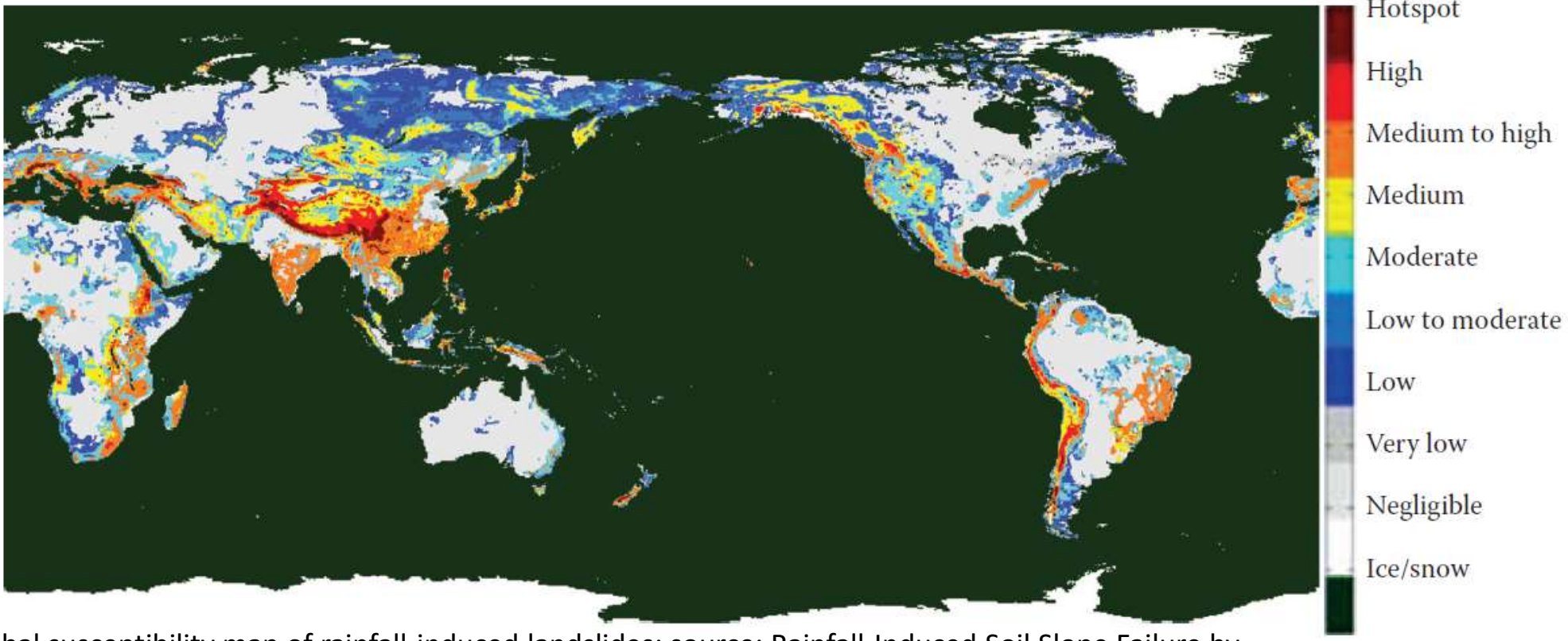
Landslides and Water



Global susceptibility map of rainfall-induced landslides: source: Rainfall-Induced Soil Slope Failure by Zhang et al. 2016, CRC Press. Taylor and Francis https://www.routledge.com/Rainfall-Induced-Soil-Slope-Failure-Stability-Analysis-and-Probabilistic/Zhang-Li-Li-Zhang-Zhu/p/book/9780367139018

Landslides and Water

The Mameyes, Puerto Rico, landslide, 1985. This landslide destroyed 120 houses and killed at least 129 people. The catastrophic slide was triggered by a tropical storm that produced extremely heavy rainfall.

Contributing factors could also have included sewage saturating the ground in the densely populated area, and a leaking water pipe at the top of the landslide.

(Photograph by Randall Jibson, U.S. Geological Survey.)

Landslides and Seismic Activity

Many mountainous areas that are vulnerable to landslides have also experienced at least moderate rates of earthquake activity in recorded times.

Earthquakes in steep landslide-prone areas greatly increase the likelihood that landslides will occur, due to ground shaking alone, liquefaction of susceptible sediments, or shaking-caused dilation of soil materials, which allows rapid infiltration of water.

For instance, the 1964 Great Alaska earthquake in the United States caused widespread landsliding and other ground failure. Canada, have experienced landslides, lateral spreading, and other types of ground failure classified as landslides, due to moderate to large earthquakes.

Rockfalls and rock topples can also be caused by loosening of rocks or rocky formations as a result of earthquake ground shaking.

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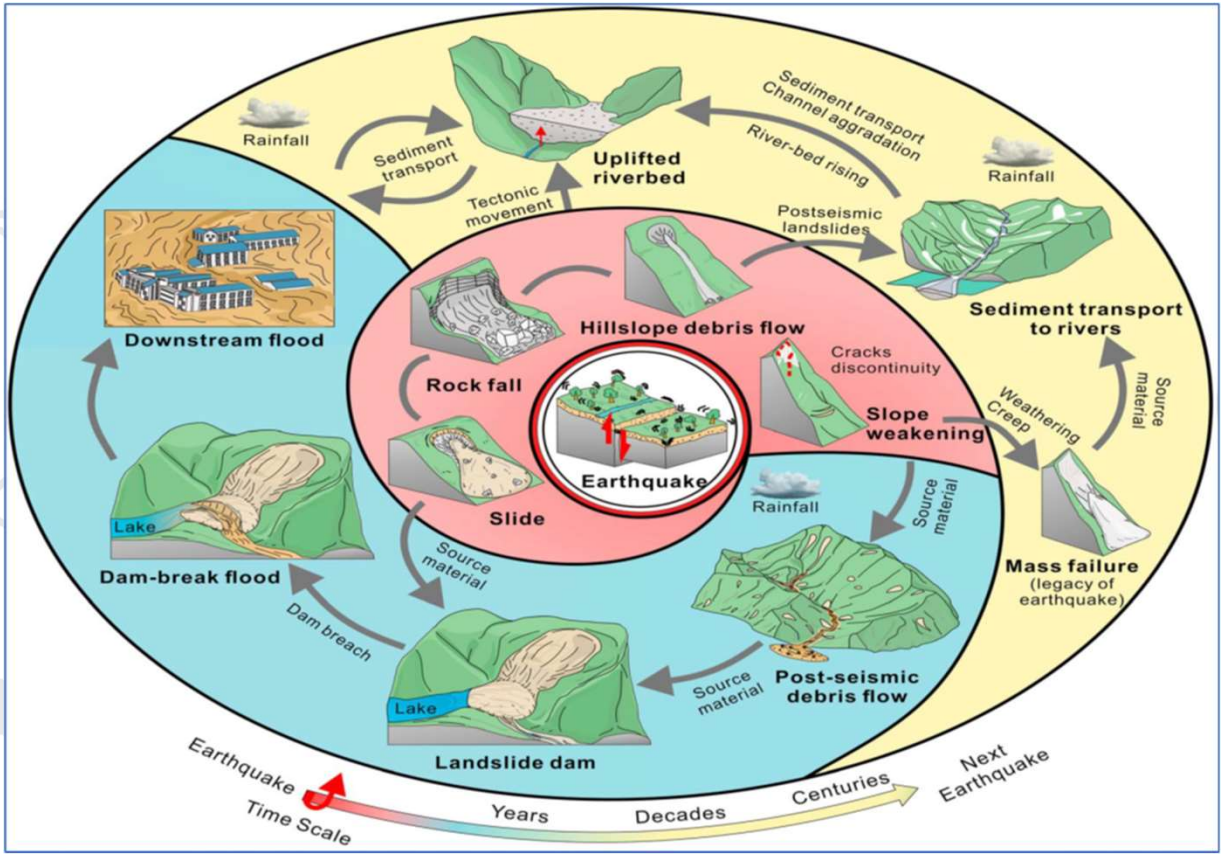
Landslides and Seismic Activity

- Large earthquakes initiate chains of surface processes that last much longer than the brief moments of strong shaking.
- Most moderate- and large-magnitude earthquakes trigger landslides, ranging from small failures in the soil cover to massive, devastating rock avalanches. Some landslides dam rivers and impound lakes, which can collapse days to centuries later, and flood mountain valleys for hundreds of kilometers downstream.
- Landslide deposits on slopes can remobilize during heavy rainfall and evolve into debris flows.



Fan et al., 2019, *Review of geophysics, 57*

Landslides and Seismic Activity

- Earthquake-induced landslide damage to a house built on artificial fill, after the 2004 Niigata Prefecture earthquake in Japan. (Photograph by Professor Kamai, Kyoto University, Japan.)

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Landslides and Seismic Activity

- The Slumgullion landslide, Colorado, USA. This landslide (formally referred to also as an earthflow) dammed the Lake Fork of the Gunnison River, which flooded the valley and formed Lake Cristobal. (Photograph by Jeff Coe, U.S. Geological Survey.)

Landslides and Seismic Activity

- The Thistle landslide in Utah, USA, 1983. This landslide dammed a river, which formed a lake (called "Thistle Lake") behind the dam, flooding the town of Thistle. (Photograph by Robert L. Schuster, U.S. Geological Survey.)

Landslides and Volcanic Activity

Landslides due to volcanic activity represent some of the most devastating types of failures.

Volcanic lava may melt snow rapidly, which can form a deluge of rock, soil, ash, and water that accelerates rapidly on the steep slopes of volcanoes, devastating anything in its path.

These volcanic debris flows (also known as lahars, an Indonesian term) can reach great distances after they leave the flanks of the volcano and can damage structures in flat areas surrounding the volcanoes.

Volcanic edifices are young, unconsolidated, and geologically weak structures that in many cases can collapse and cause rockslides, landslides, and debris avalanches.

Many islands of volcanic origin experience periodic failure of their perimeter areas (due to the weak volcanic surface deposits), and masses of soil and rock slide into the ocean or other water bodies, such as inlets. Such collapses may create massive sub-marine landslide

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Landslides and Volcanic Activity

- The side of Casita Volcano in Nicaragua, Central America, collapsed on October 30, 1998, the day of peak rainfall as Hurricane Mitch moved across Central America. This lahar killed more than 2,000 people as it swept over the towns of El Porvenir and Rolando Rodriguez. (Photograph by K.M. Smith, U.S. Geological Survey.)

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Landslides and Human Activity

Populations expanding onto new land and creating neighborhoods, towns, and cities is the primary means by which humans contribute to the occurrence of landslides.

Disturbing or changing drainage patterns, destabilizing slopes, and removing vegetation are common human-induced factors that may initiate landslides.

Other examples include oversteepening of slopes by undercutting the bottom and loading the top of a slope to exceed the bearing strength of the soil or other component material.

However, landslides may also occur in once-stable areas due to other human activities such as irrigation, lawn watering, draining of reservoirs (or creating them), leaking pipes, and improper excavating or grading on slopes.

Causative factors of landslides

Physical Causes—Triggers

- Intense rainfall
- Rapid snowmelt
- Prolonged intense precipitation
- Rapid drawdown (of floods and tides) or filling
- Earthquake
- Volcanic eruption
- Thawing
- Freeze-and-thaw weathering
- Shrink-and-swell weathering
- Flooding

Natural Causes

Geological causes

- Weak materials, such as some volcanic slopes or unconsolidated marine sediments, for example
- Susceptible materials
- Weathered materials
- Sheared materials
- Jointed or fissured materials
- Adversely oriented mass discontinuity (bedding, schistosity, and so forth)
- Adversely oriented structural discontinuity (fault, unconformity, contact, and so forth)
- Contrast in permeability
- Contrast in stiffness (stiff, dense material over plastic materials)

Morphological causes

- Tectonic or volcanic uplift
- Glacial rebound
- Glacial meltwater outburst
- Fluvial erosion of slope toe
- Wave erosion of slope toe
- Glacial erosion of slope toe
- Erosion of lateral margins
- Subterranean erosion (solution, piping)
- Deposition loading slope or its crest
- Vegetation removal (by forest fire, drought)

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Causative factors of landslides

Human Causes

- 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
- 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, and so forth

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Thank you very much for your kind attention and time!

Question time