Fundamentals of Earth Sciences (ESO 213A)

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Landslides

Previous Class: Earthquake

LANDSLIDES

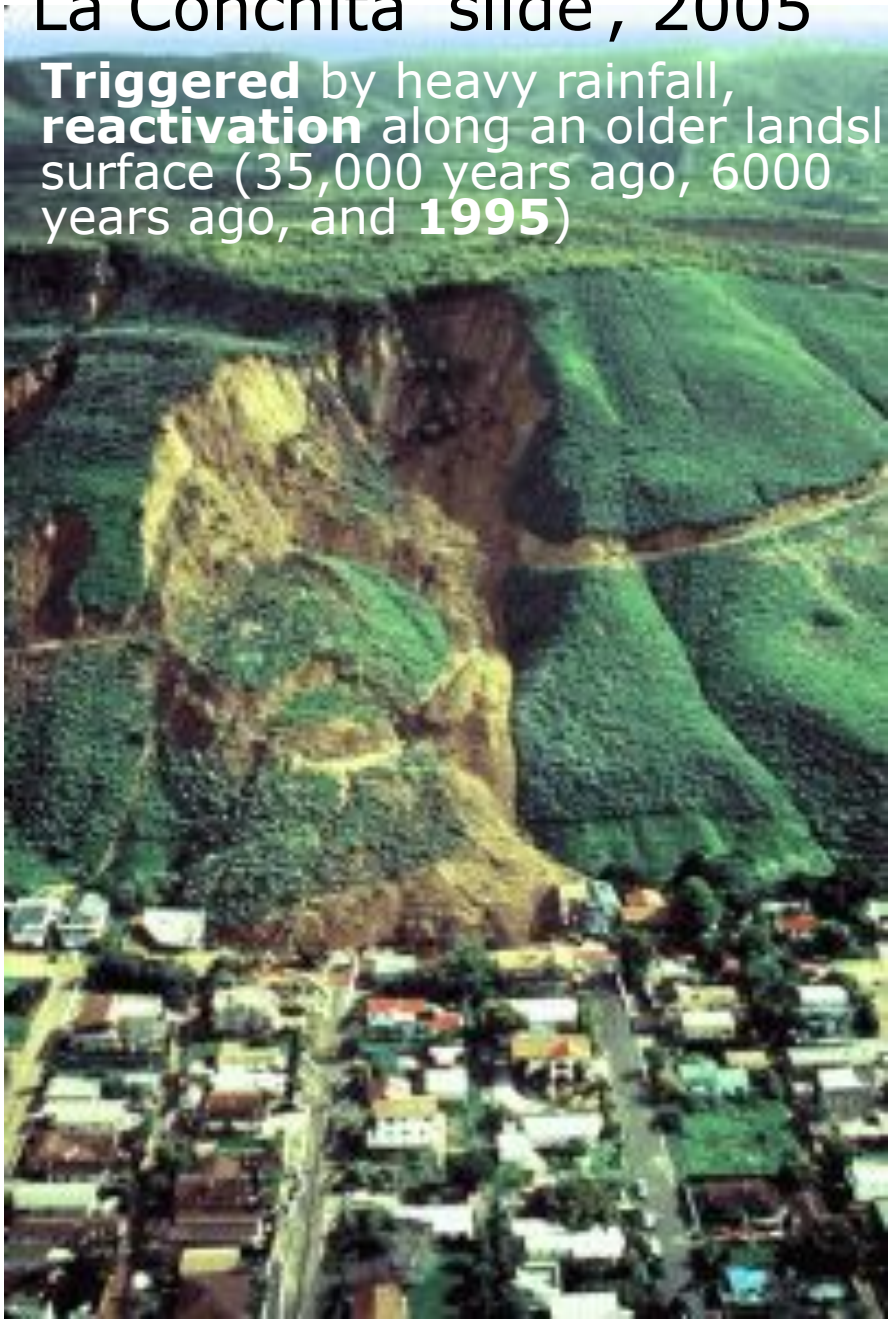
Landslide: refers to the downward sliding of huge quantities of land mass which occur along steep slopes of hills or mountains and may be sudden or slow. It encompasses all categories of gravity-related slope failures in Earth materials.

For convenience, definition of *landslide* includes all forms of ***mass-wasting*** movements

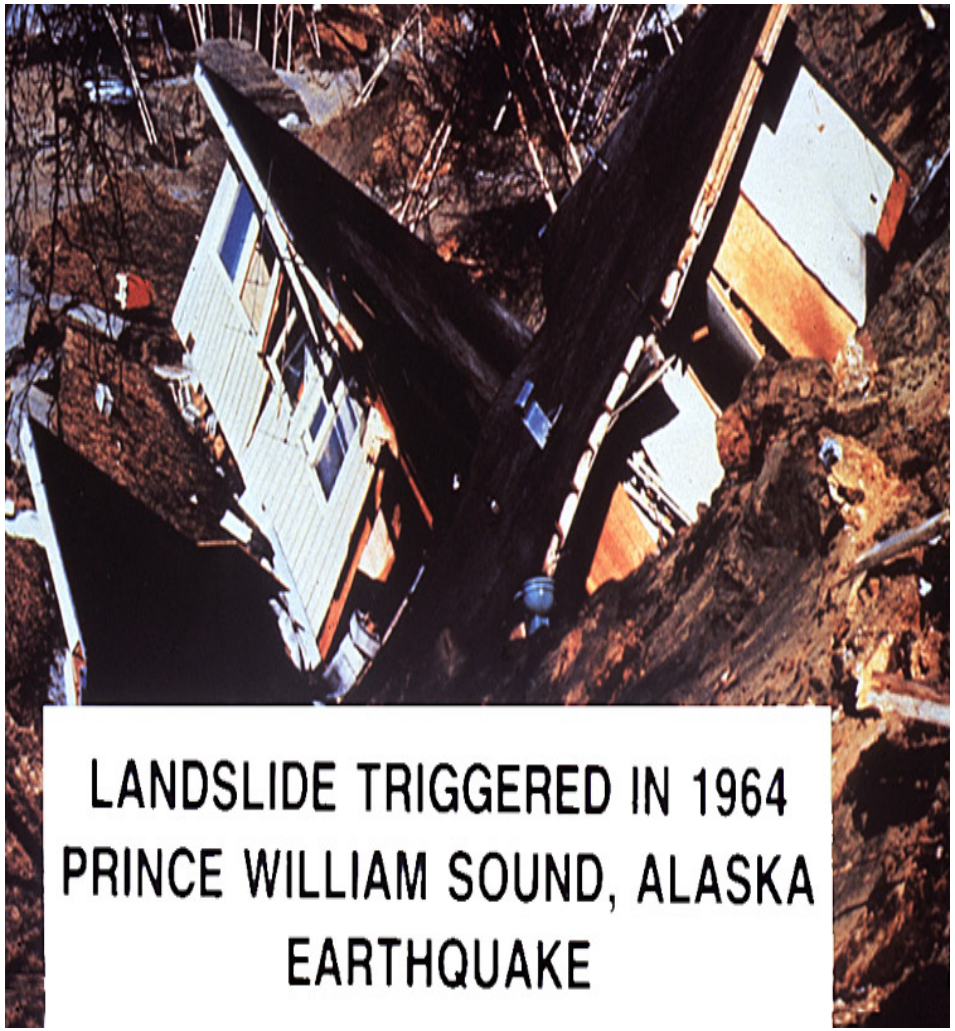
Natural phenomena that occur with or without human activity

Essential knowledge for societal sustainability

La Conchita 'slide', 2005



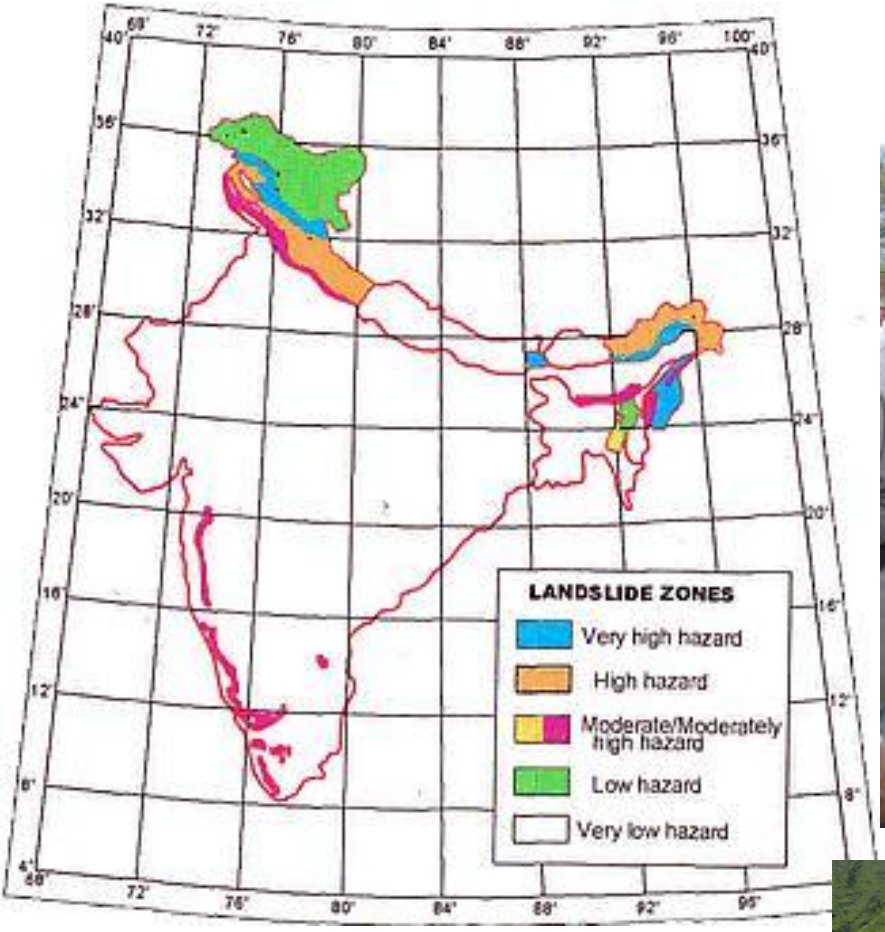
LANDSLIDE HAZARD: ALASKA



- The 1964 prince william sound earthquake triggered a large volume landslide at turnagain heights.
- Millions of cubic meters of soil and rock moved down slope.
- Slope failure was induced by ground shaking of “Quick Clay.”

LANDSLIDE HAZARD: JAPAN

Landslides in NE India

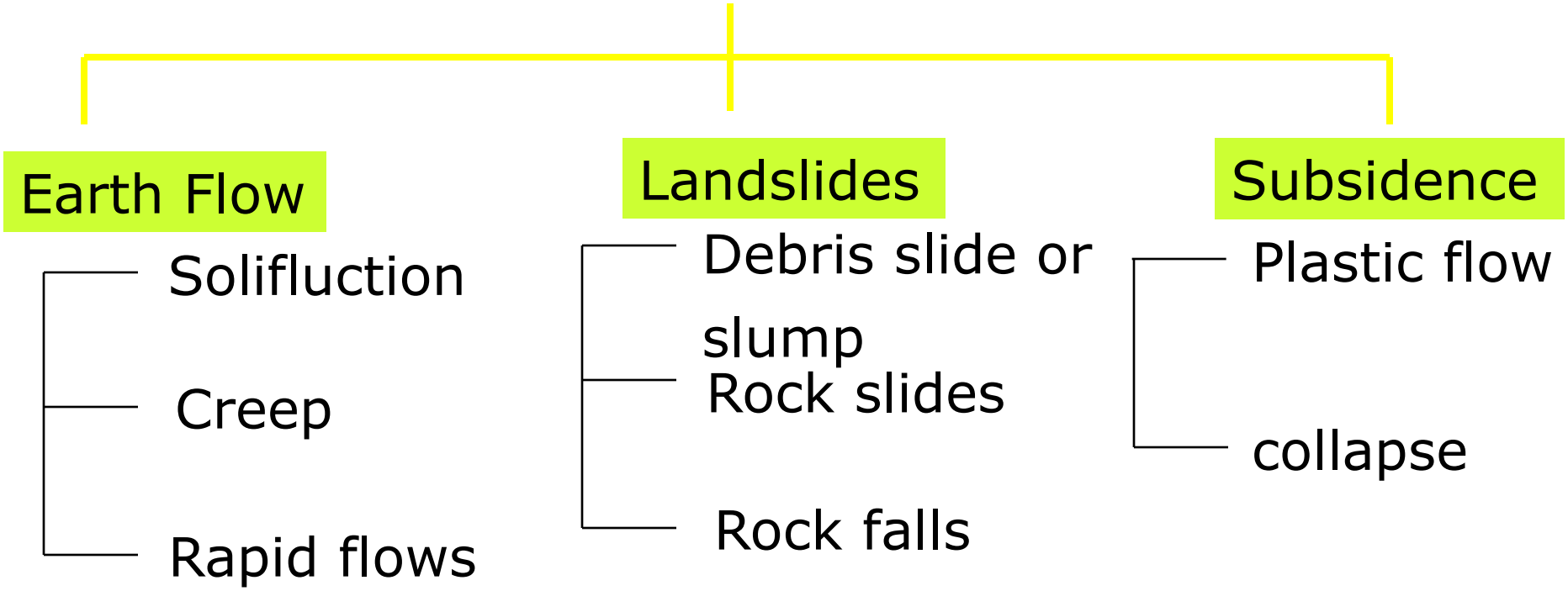


Landslides and fooding by heavy rain fall at Kedarnath in 2013

Classification of Earth Movements

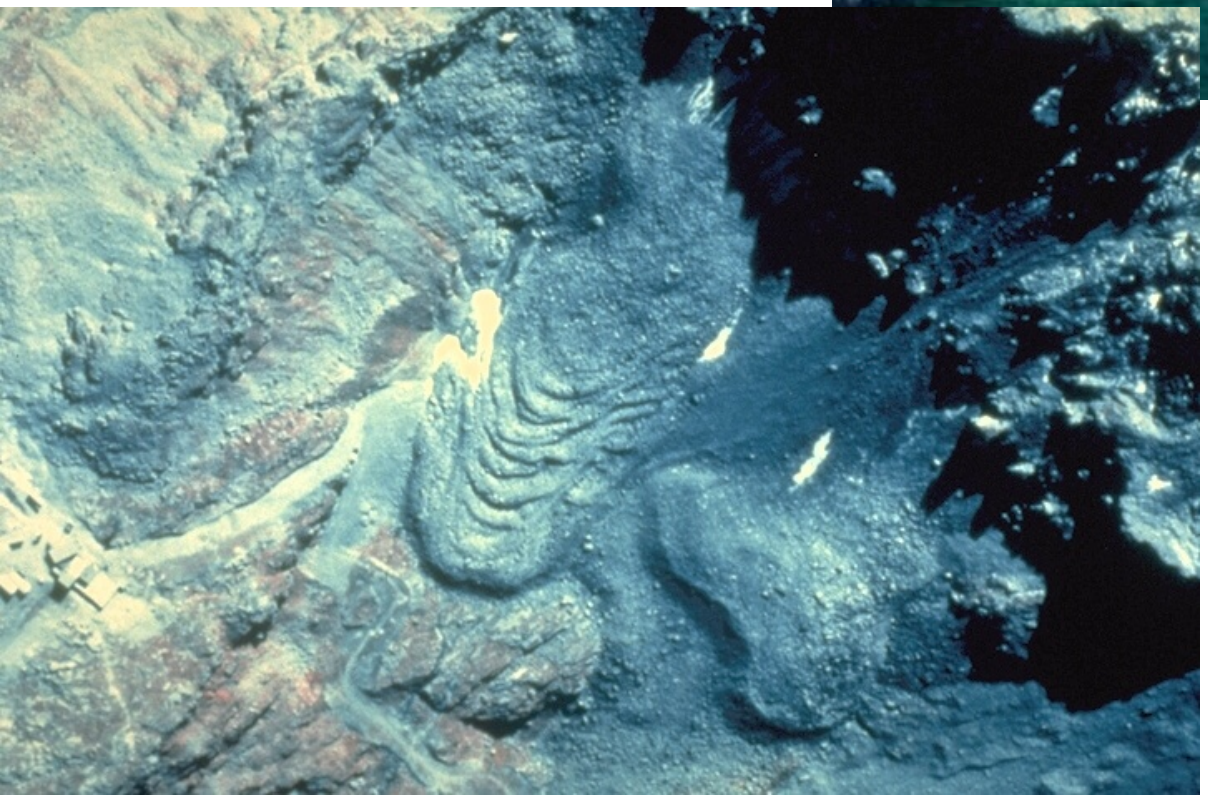
- **All movement of land masses are referred as landslides, but differ in many respects, therefore all types of landslides are categorized as <u>Earth Movements</u>.**

These are classified as



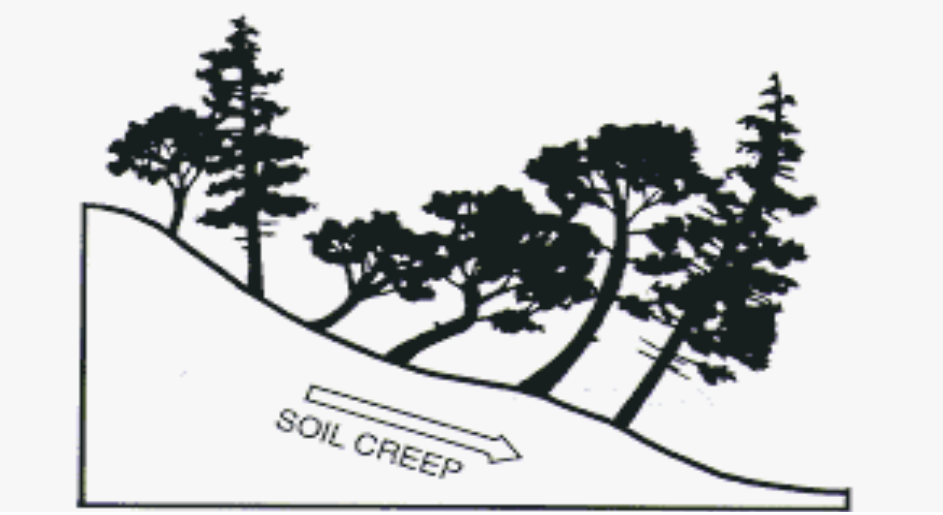
SOLIFLUCTION

- Solifluction is a downward movement of wet soil along the slopes under the influence of gravity.



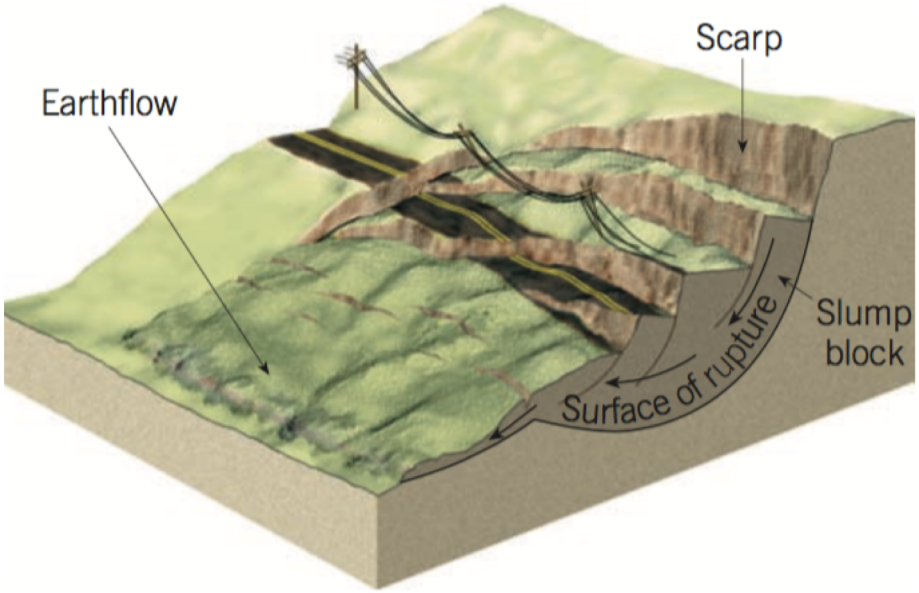
SOIL CREEP

- Creep is extremely slow downward movement of dry surfacial matter.
- Movement of the soil occurs in regions which are subjected to freeze-thaw conditions. The freeze lifts the particles of soil and rocks and when there is a thaw, the particles are set back down, but not in the same place as before.
- It is very important for Civil Engineers to know the rate of movement



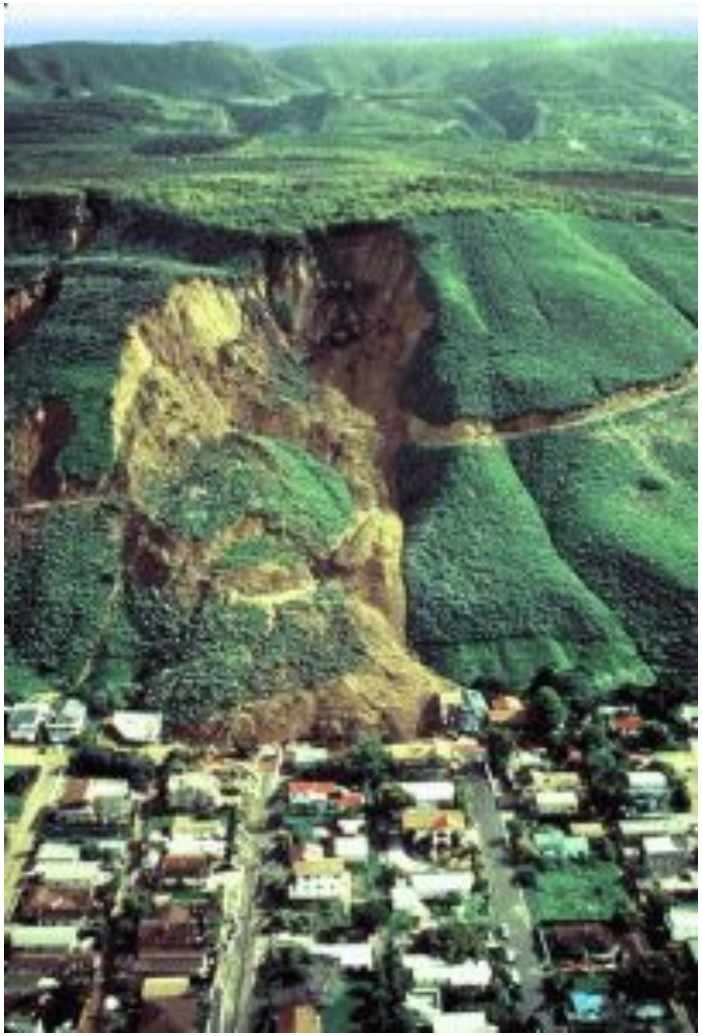
- *RAPID FLOWS: Rapid flow is similar to the creep, but differ in terms of speed and depth. It is faster.*

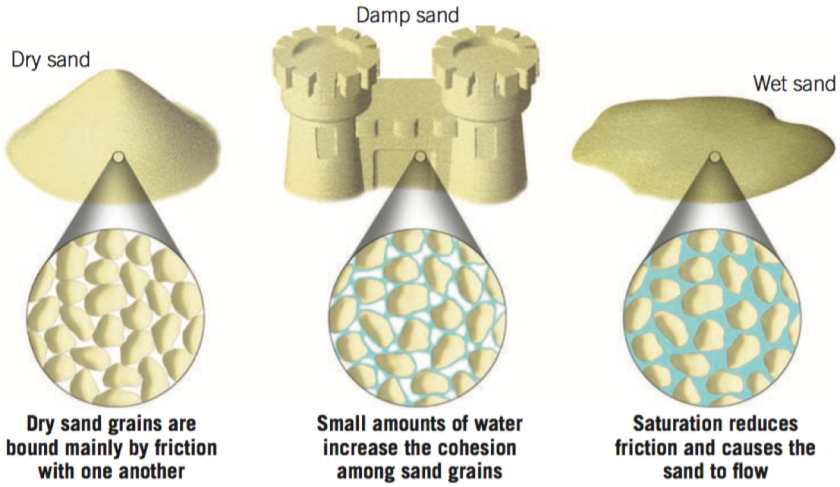
- *Creep is involved upto shallow depth (app. 1-2 m), whereas the rapid flow is involved to greater depth (app. upto 5 m or more)*



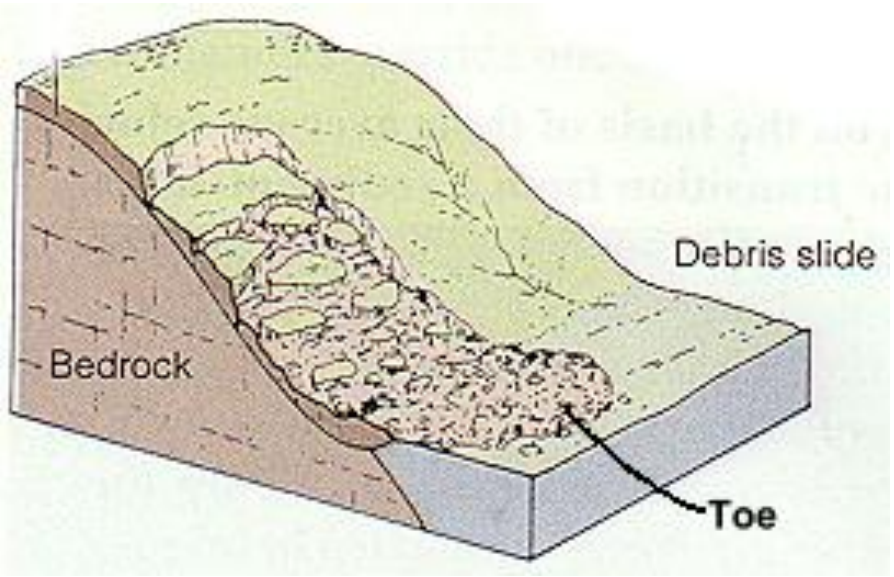
Landslides

- Large block known as a slump block moves during the landslide.
- The scar above a landslide is easily visible.
- They can occur along a slope where the internal resistance of the rocks are reduced or they loose their holding capacity.
- Common after earthquakes or after removal of part of the slope due to construction, particularly for construction of roads.





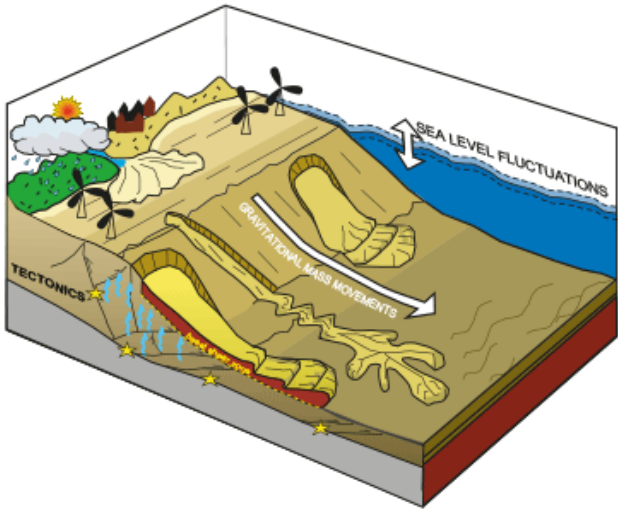
- Landslide can result into:
- Debris slides - are failure of unconsolidated material on a surface;
- Rock slide or Rock Fall – where movement of large rock block rolls



- They are also common along the steep banks of rivers, lakes etc.

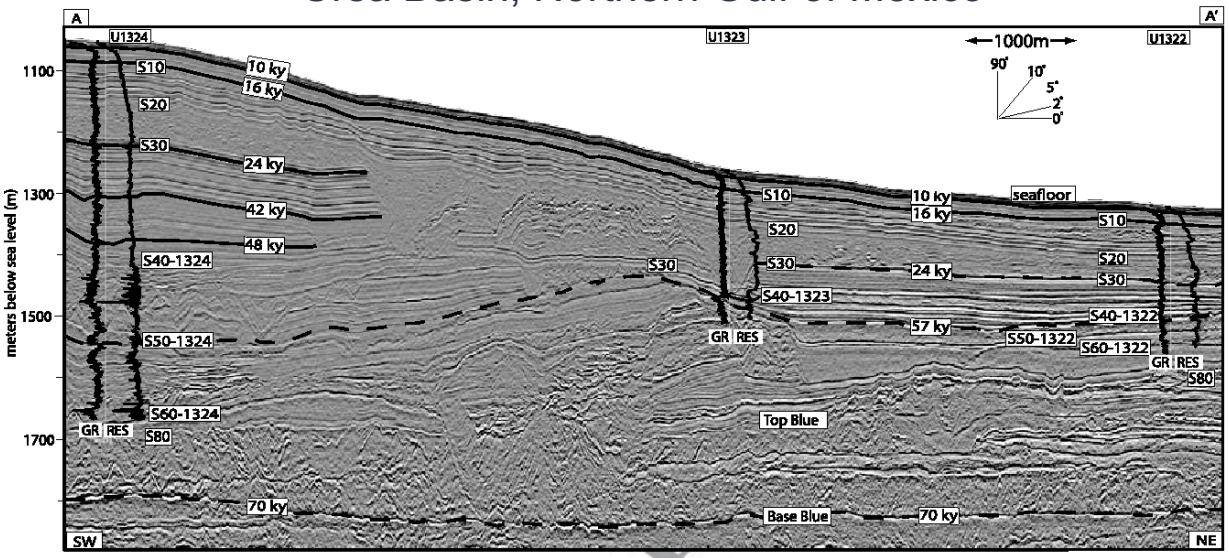
- Pore Water Pressure is the key to monitoring landslides. Shear strength (a resisting force) decreases and the weight (a driving force increases).
- **Talus** – accumulation formed by the coarser rock fragments resulted from the mechanical weathering along a slope under influence of gravity

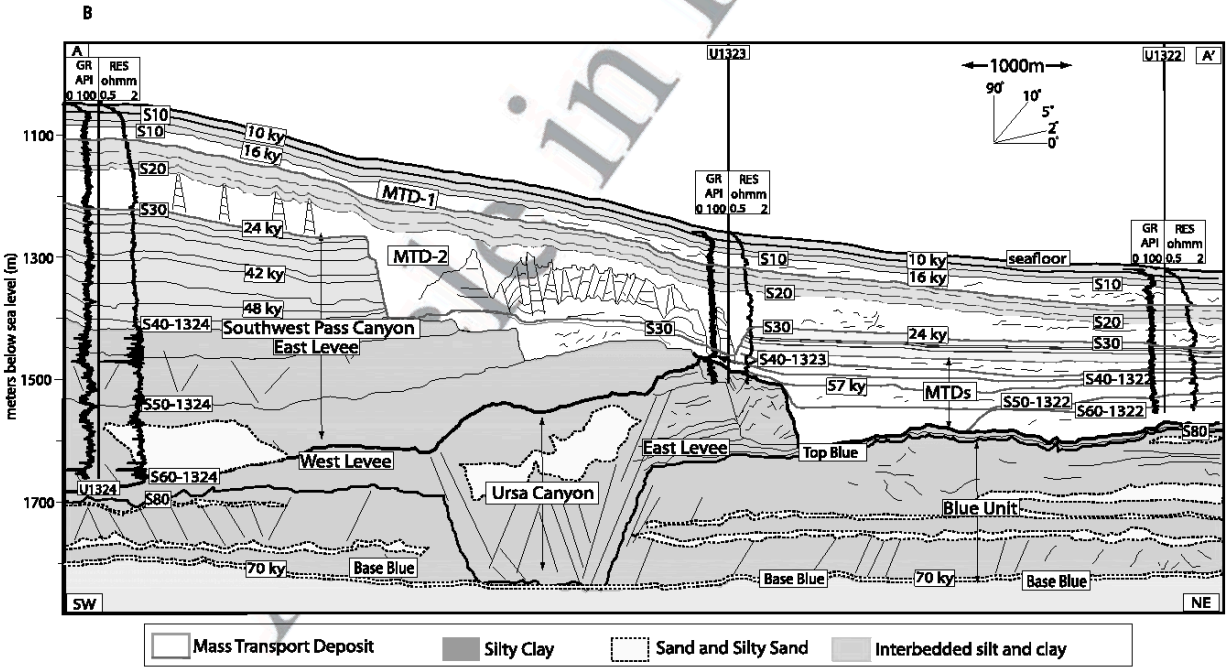
Marine Landslides



Mass Transport Deposits (MTD)

Ursa Basin, Northern Gulf of Mexico

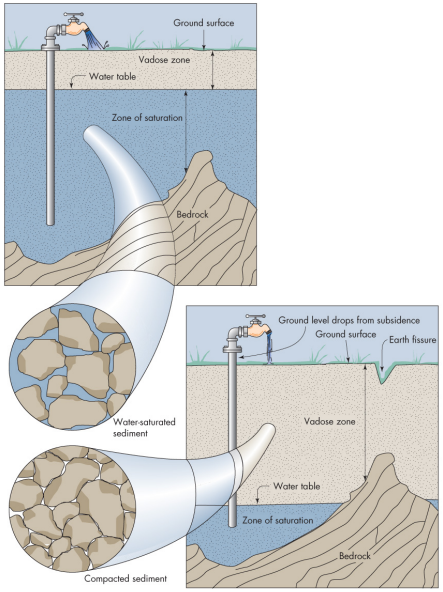




Sawyer et al., 2009

Subsidence

- It represents the downward movement of the surface
- It may occur due to plastic outflow of the underlying strata or due to the compaction of the underlying material
- (1) ***Subsidence due to Plastic outflow:*** It may occur when a plastic layer like *clay bed is squeezed outward due to overlying heavy load*
- (2) ***Subsidence due to collapse:*** It occur due to extensive *pull out of large volume of underground water, oil, gas* or due to subsurface solution activity in limestone terrain.



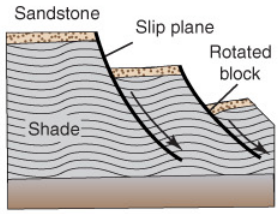
- The Leaning Tower of Pisa, Italy, the tilting of which accelerated as groundwater was withdrawn from aquifers to supply the growing city.

Removal of Solid Materials

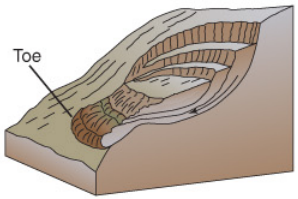
- Sinkholes
  - Dissolution of carbonate rocks, limestone, and dolomite
  - Natural or artificial fluctuations in water table increasing the problem

- Salt and coal **mining**
  - Salt dissolution and pumping
  - Active coal mines and abandoned coal mines
  - Ground failure due to depleted subsurface pressure
  - More than 8000 km^2 of land subsidence due to underground coal mining

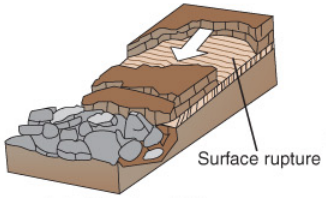
Summary: Types of Landslides



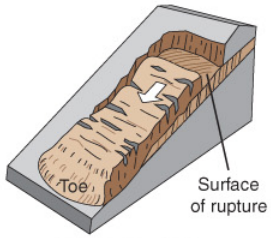
(a) Rock slump



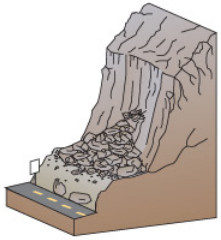
(b) Soil slump

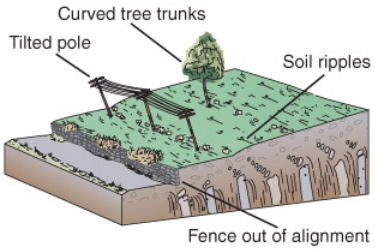


(c) Rock slide



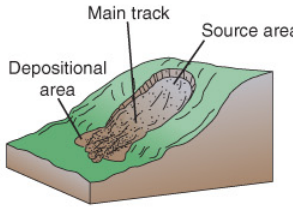
(d) Soil slide


(e) Rockfall

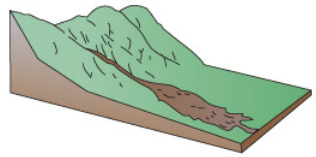


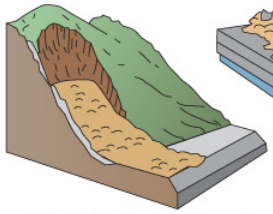
(f) Soil creep

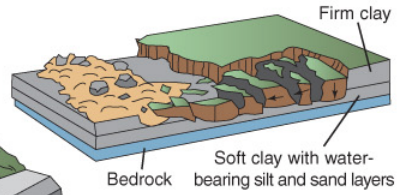
Type of Movement	Materials	
	Rock	Soil
Landslides with variable water content and rate of movement	Rotational	
	Slump(a)	Slump(b)
	Translational	
	Rock slide(c)	Soil slide (slip)(d)
Falls	Rock fall(e)	Soil fall
Flows — Slow	Rock creep	Soil creep(f)
Flows — Rapid	Unconsolidated rock and soil (saturated)	
Flows — Rapid	Earth flow(g)	
Flows — Rapid	Debris flow / mud flow(h)	
Flows — Very rapid	Debris avalanche(i)	
Lateral spread	Rock(j)	Soil
Subsidence	Rock(k)	Soil
Complex	Combination of slides, slumps, and flows(l)	



(g) Earthflow

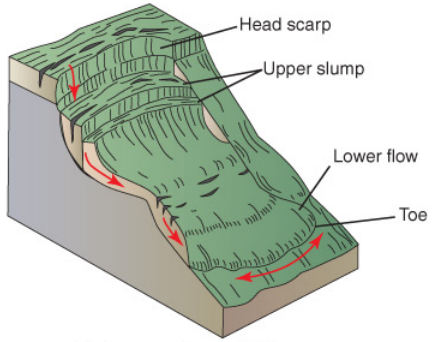

(h) Debris flow


(i) Debris avalanche



(j) Lateral spread


(k) Subsidence



(l) Complex slide

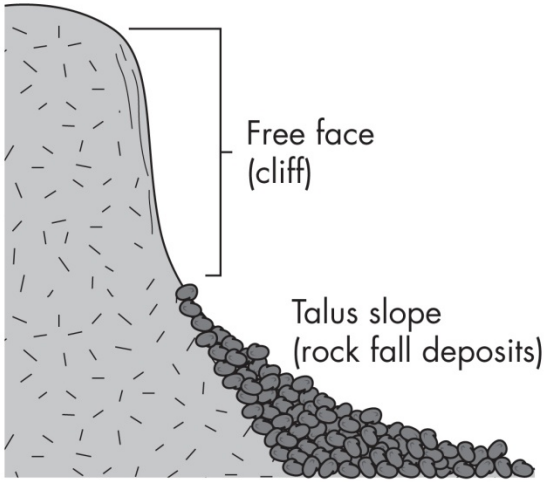
Causes Of landslides

- ***LANDSLIDES OCCUR DUE OF VARIOUS REASONS***
- ***Internal Causes:***

- Influence of slope- Slopes are the most common landforms.
- Although they appear stable and static, slopes are actually dynamic, evolving systems.
- Provides favourable condition for landslides; steeper slope are prone to slippage of land. It is known that most of the materials are stable upto certain angle- "Critical angle" or "angle of repose" – it varies from 30^0 for unconsolidated sediments to 90^0 for massive rocks and 60^0-90^0 for partially jointed rocks.

- Material is constantly moving on slopes at rates varying from imperceptible creep to thundering avalanches and rock falls moving at high velocities.
- Consists of cliff face ("free face") and talus slope ***or*** upper convex slope, a straight slope, and a lower concave slope

Slopes



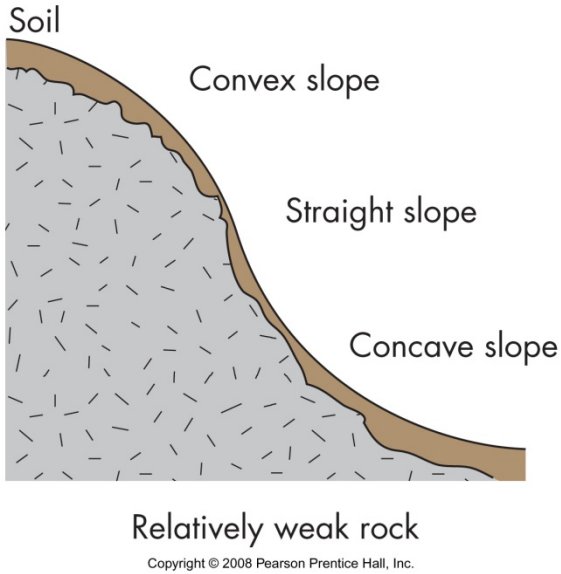


Figure 9.3

Slope Stability

- **Safety Factor**: = Resisting/Driving Forces

  If SF >1, then safe or stable slope

  If SF <1, then unsafe or unstable slope

- Driving and resisting force **variables**:
  - Slip surface – "plane of weakness"
  - Type of Earth materials
  - Slope angle and topography
  - Climate, vegetation, and water
  - Shaking
- Causes vs. triggers

- Ground water or associated water- Main factor responsible for slippage. Suppose the hard or massive rocks are underlained by softer rocks (shale or clay bed). When rain water percolates through some fractures or joints the clayey beds become very plastic and act as slippery base, which enhance the chances of loose overburden to slip downward.
- Water is the most powerful solvent, which not only causes decomposition of minerals but also leaches out the soluble matter of the rock and reduces the strength.
- **Lithology-** rock which are rich in clay (montmorillonite, bentonite), mica, calcite, gypsum etc are prone to landslide because these minerals are prone to weathering.
- **Geological structures-** Occurrence of inclined bedding planes, joints, fault or shear zone are the planes of weakness, which create conditions of instability.
- **Human Influence-** undercutting along the hill slopes for laying roads or rail tracks, Dam construction can result into instability.
- Deforestation in the uplands, result into more erosion during the rainy season.

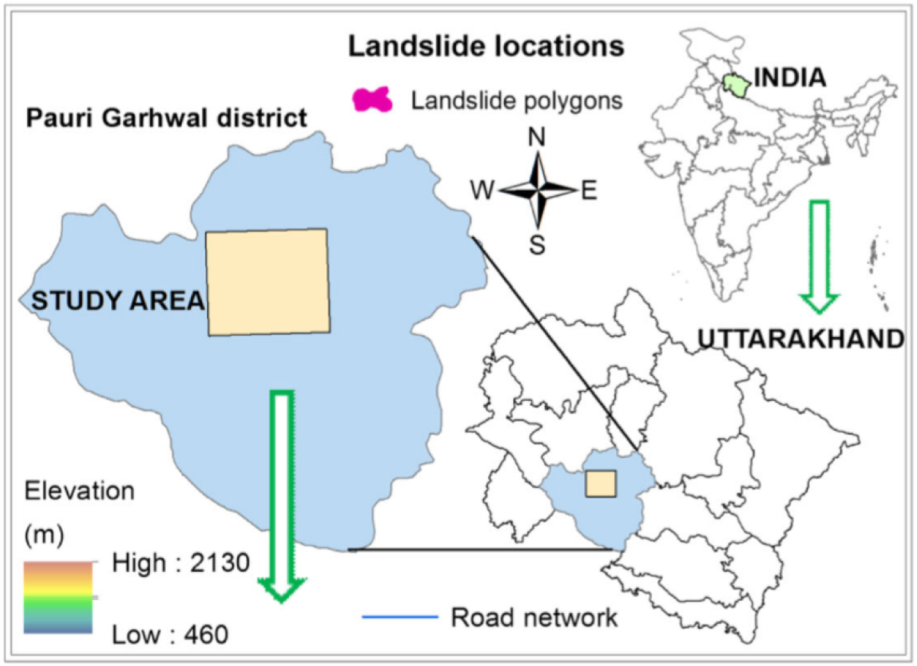
- **External factors**

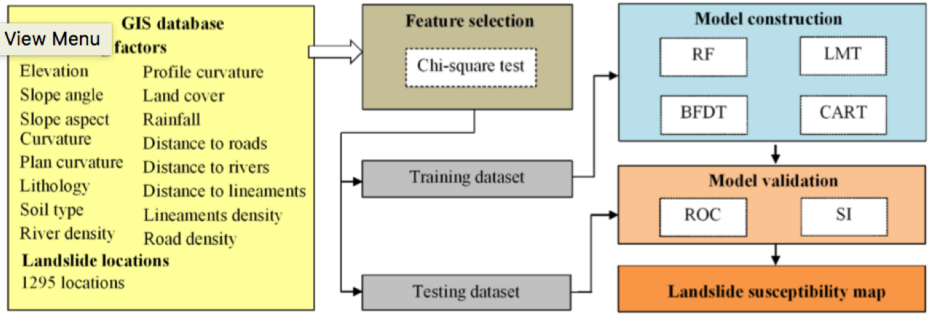
- Most common is the vibration resulted due to earthquakes; blasting to explosives; volcanic eruption etc.
- Earthquakes often initiate mass failures on large scale eg. 1897 Assam quake produced gigantic landslide ever recorded in the region.

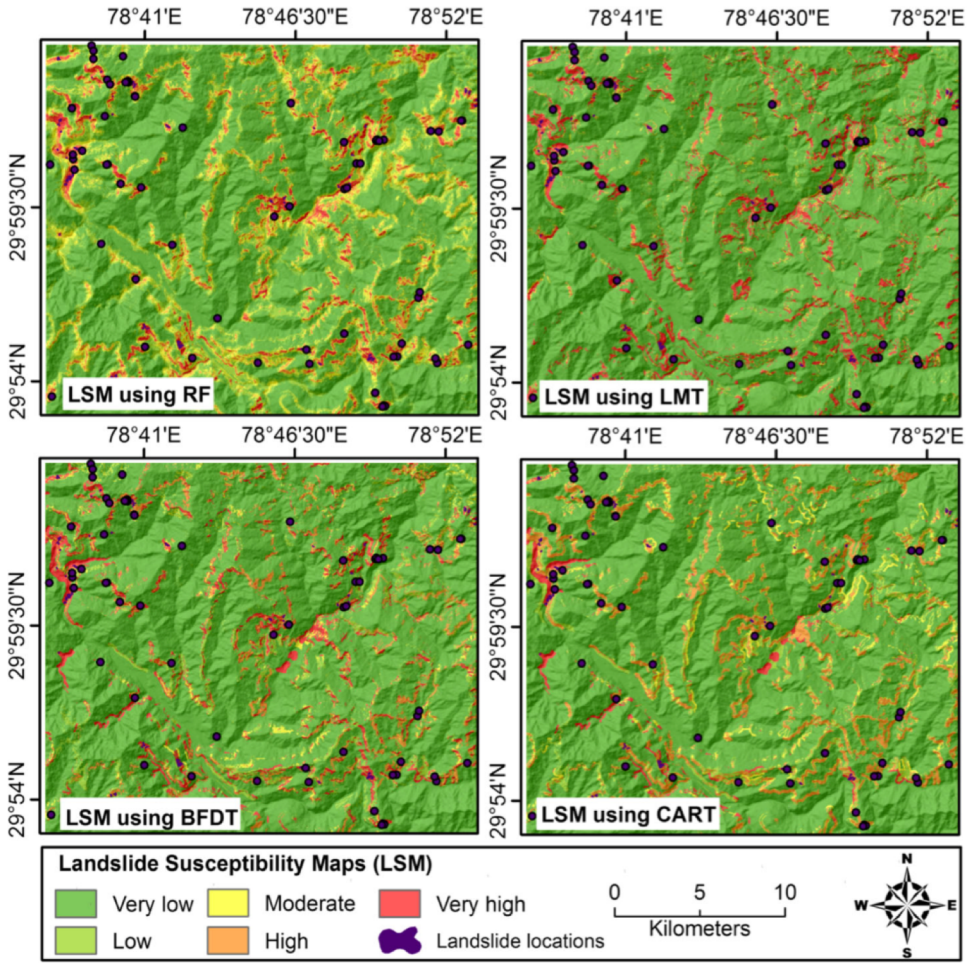
Preventive measures

- The main factors which contribute to landslides are ***Slope, water content, geological structure, unconsolidated or loose sediments, lithology and human interference.***
- ***Slope:*** Retaining wall may be constructed against the slopes, which can prevents rolling down of material. Terracing of the slope is an effective measure. Plant ground cover on slopes and build retaining walls.
- ***Effect of water:*** Make proper drainage network for quick removal of percolating moisture or rain water by constructing ditches and water ways along the slope. In mudflow areas, build channels or deflection walls to direct the flow around buildings.
- ***Geological structures:*** Weak planes or zones may be covered to prevent percolation of water, this increases the compaction of loose material.
- Install flexible pipe fittings to avoid gas or water leaks.
- **Identify** potential landslides
  - Photographic analysis
  - Topographic map and detailed field check
  - Historic data
  - Human surveillance
  - Instrumental survey: Tilt meter and geophones
- Landslide hazard inventory map
  - Grading code from the least stable to the most stable

Landslide Susceptibility map







Pham et al., (2017)

Application of geologic and engineering knowledge before any hillside development

What Can You Do?

- Development of landslide early warning systems
- Professional geologic evaluation for a property on a slope
- Avoid building at the mouth of a canyon, regardless of its size
- Consult local agencies for historical records
- Watch signs of little slides—often precursor for larger ones
- Look for signs of structure cracks or damage prior to purchase
- Be wary of pool leaking, tilt of trees and utility poles
- Look for linear cracks, subsurface water movement
- Put observations into perspective, one aspect may not tell the whole story