Disaster risk Management on Tropics: Geomorphological Perspective

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1. UNDERSTANDING THE BASIC CONCEPT OF DISASTER RISK MANAGEMENT IN GEOMORPHOLOGICAL PERSPECTIVE

DISASTER

RISK REDUCTION & MANAGEMENT

DEFINITION OF TERMS

HAZARD

- Is a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihood & services, social & economic disruption or environmental damage...
- Could be a potentially damaging phenomenon
- It could be natural or human-induced.

EXPOSURE

- The degree to which the element at risk are likely to experience hazard events of different magnitude.

VULNERABILITY

- Is the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.
- This may arise from various physical, social, economic & environmental factors.

VULNERABILITY

- **Social Integration**
  - Ethnicity
  - Age
  - Gender
  - Location
  - Status
  - Wealth
  - Income
  - Education
  - Family type

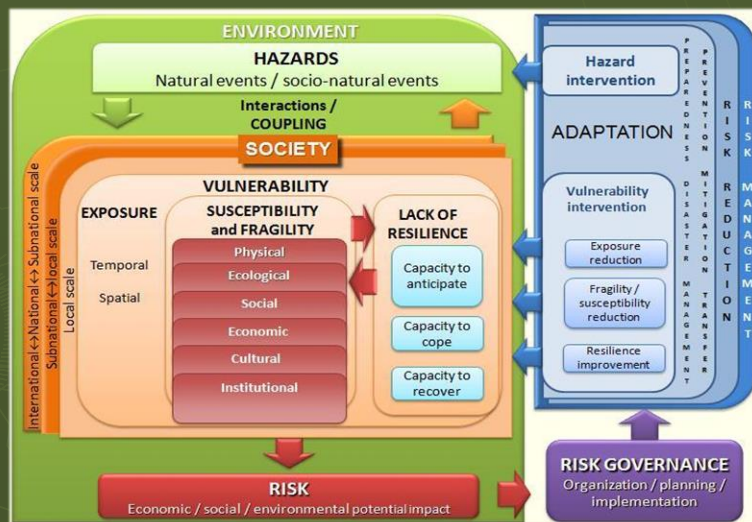
Physical vulnerability
  - River bank
  - Hill slope
  - Meteorological

- **Psychological & Physiological**
  - Locus of control
  - Disability
  - Coping-style
  - Individual's perception
  - Lifestyle
  - Agility
  - Mobility
  - Experience

Britton and Walker 1991

CAPACITY

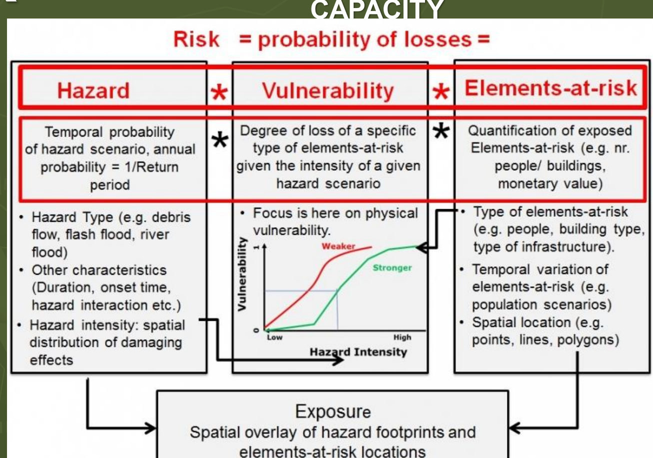
- Is the combination of all strengths and resources available within the community, society or organization that can reduce the level of risk or effects of a disaster.



RISK

- Is the combination of Probability of an event to happen and its negative consequences...

$$R = \frac{\text{HAZARD x VULNERABILITY (exposure)}}{\text{CAPACITY}}$$



Risk = Hazard * Vulnerability * Amount of Element-at-Risk
(UN-ISDR, 2004)

The way in which the amounts of elements-at-risk are characterized (e.g. as number of buildings, number of people, economic value) also defines the way in which the risk is presented. The aforesaid equation can be modified in the following way:

$$R_s = P_{(T:Hs)} * P_{(L:Hs)} * V_{(Es/Hs)} * A_{es}$$

$P_{(T:Hs)}$ is the temporal probability of occurrence of a specific hazard scenario (H_s) with a given return period in an area

$P_{(L:Hs)}$ is the locational or spatial probability of occurrence of a specific hazard scenario (H_s) with a given return period in an area impacting the elements-at-risk

$V_{(Es/Hs)}$ is the physical vulnerability, specified as the degree of damage to a specific element-at-risk E_s given the local intensity cause d due to the occurrence of hazard scenario H_s

A_{es} is the quantification of the specific type of element at risk evaluated (e.g. number of buildings)

DISASTER

- A disaster is a natural or man-made (or technological) hazard resulting in an event of substantial extent causing significant physical damage or destruction, loss of life, or drastic change to the environment. A disaster can be defined as any tragic event stemming from events such as earthquakes, floods, catastrophic accidents, fires, or explosions. It is a phenomenon that can cause damage to life and property and destroy the economic, social and cultural life of people.

- In contemporary academia, disasters are seen as the consequence of inappropriately managed risk. These risks are the product of a combination of both hazard/s and vulnerability. Hazards that strike in areas with low vulnerability will never become disasters, as is the case in uninhabited regions.

Disasters are NOT natural

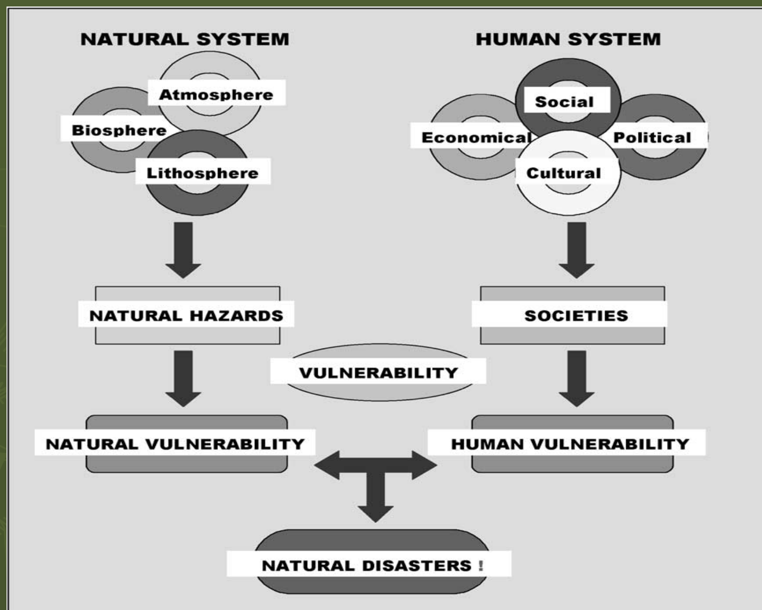
- ✓ Greater exposure to natural and human-induced hazards, climate change and variability
- ✓ Socio-economic drivers: poverty and unsustainable development, unplanned urban growth and migrations, lack of risk awareness and institutional capacities…
- ✓ Physical drivers: insufficient land use planning, housing & critical infrastructure located in hazard prone areas…
- ✓ Environmental degradation: ecosystem and natural resource depletion

WHEN IS AN EVENT TERMED AS A DISASTER?

DISASTER

1. At least **20% of the population** are affected & in need of emergency assistance or those dwelling units have been destroyed.
2. A great number or at least **40% of the means of livelihood** such as bancas, fishing boats, vehicles and the like are destroyed.
3. **Major roads and bridges are destroyed and impassable** for at least a week, thus disrupting the flow of transport and commerce.
4. **Widespread destruction** of fishponds, crops, poultry and livestock, and other agricultural products, and
5. **Epidemics**

NDCC Memo Order No. 4, dated 04 March 1998

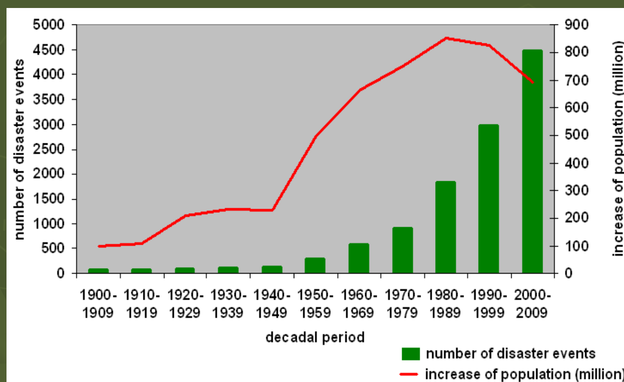


WHY ARE DISASTER IMPACTS INCREASING?

1. Increasing population
2. Climate change
3. Increased vulnerability due to:
   - Demographic changes
   - Increased concentration of assets
   - Environmental degradation
   - Poverty
   - Rapid urbanization and unplanned development

DISASTER

Decadal increase of population and corresponding number of disaster events between 1900 and 2009



decadal period	number of disaster events	increase of population (million)
1900-1909	72	100
1910-1919	71	110
1920-1929	96	210
1930-1939	100	230
1940-1949	142	229
1950-1959	293	494
1960-1969	582	662
1970-1979	910	752
1980-1989	1,832	853
1990-1999	2,975	825
2000-2009	4,478	693

CLASSIFICATIONS

Natural Disaster

- A natural disaster is a consequence when a natural hazard affects humans and/or the built environment. Human vulnerability, and lack of appropriate emergency management, leads to financial, environmental, or human impact. The resulting loss depends on the capacity of the population to support or resist the disaster: their resilience. This understanding is concentrated in the formulation: "disasters occur when hazards meet vulnerability". A natural hazard will hence never result in a natural disaster in areas without vulnerability.

DISASTER

CLASSIFICATIONS

DISASTER

Man-made or Human Induced Disaster

- Man-made disasters are the consequence of technological or human hazards. Examples include stampedes, fires, transport accidents, industrial accidents, oil spills and nuclear explosions/radiation. War and deliberate attacks may also be put in this category. As with natural hazards, man-made hazards are events that have not happened, for instance terrorism. Man-made disasters are examples of specific cases where man-made hazards have become reality in an event

Classification of natural hazards/Disasters

Geological	Earthquakes Tsunamis Volcanic activity and emissions geological fault activity
Geomorphological	Mass movements e.g. landslides, rockslides, rock fall, liquefaction, submarine slides Subsidence, surface collapse, River bank erosion Channel shifting Flood and flash flood Soil Erosion
Climatological	Tropical cyclones, storm surges, thunder/hailstorms, rain and windstorms, blizzards and other severe storms
Hydro-meteorological	• Floods, debris and mudflows • Drought • Desertification • Veld fires • Heat waves • Sand or dust storms • Permafrost • Snow avalanches
Biological	Outbreaks of epidemic diseases • Plant or animal contagion • Extensive infestations

ENVIRONMENTAL GEOMORPHOLOGY

The term **Environmental Geomorphology** was introduced by Coats in 1971. He defines his field as follows:

"Environmental Geomorphology is the practical use of geomorphology for the solution of problems where man wishes to transform or to use and change the surficial processes".

ENVIRONMENTAL GEOMORPHOLOGY

According to the same author (Coats, 1972) this discipline involves the following issues and themes:

- **The study of geomorphic processes and terrain that affect man, including hazard phenomena such as floods and landslides.**
- **The analysis of problems where man plans to disturb or has already degraded the land water ecosystem.**
- **Man's utilization of geomorphic agents or products as resources, such as water or sand and gravel.**
- **How the science of geomorphology can be used in environmental planning and management.**

COMPONENTS OF ENVIRONMENTAL GEOMORPHOLOGY

The Geomorphological components may be schematically subdivided into:

--- ***Geomorphological Resources*** *include* both raw materials (related to geomorphological processes) and landforms-both of which are useful to man or may become useful depending on economic, social and technological circumstances. For instance, a sea beach can acquire value and considered as a geomorphological resource when utilized as a seaside resort.

--- ***Geomorphological hazards*** 'can be defined as the 'probability that a certain phenomenon of geomorphological instability and of a given magnitude may occur in a certain territory in a given period of time'.

Geomorphological Resources

GEOMORPHOLOGICAL RAW MATERIALS → **(if valuable)** → **GEOMORPHOLOGICAL ASSETS** → **(if used)** → **GEOMORPHOLOGICAL RESOURCES**

Earth Material

- **Resources directly connected with relief** (building material, clastic mineral ores, basin mineral deposits like coal..etc)
- **Resources indirectly connected with the relief** (gas, mineral oil etc)

Earth materials more directly related to Geomorphology are sand and gravel. According to their origin, they can be subdivided as follows:

- **Alluvial deposits**
- **Marine-coastal deposits**
- **Slope deposits**
- **Glacial deposits**

Geomorphological Hazards

Geomorphic hazards are those extreme events that occur incidentally or accidentally on the Earth's surface induced by geomorphic processes, affecting the environment at large. **Landslides, avalanches, River Bank Erosion, Soil Erosion, floods, desertification, droughts** are the geomorphic hazards which take place mainly when the nature tries to balance abruptly some irregularities formed on it. The study of Geomorphic Hazard is of great relevance to the present day society since the resultant disaster from every hazard event pose serious toll on lives and properties of human society.

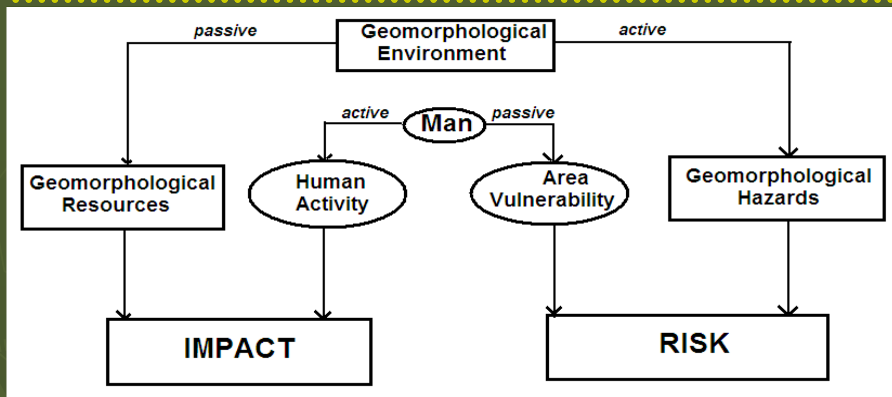
In the context of relationships with the environment, man represents:

--- ***Human activity***

is the specific action of man which many be summarized under the headings of hunting, grazing, farming, deforestation, utilization of natural resources and engineering works.

--- ***Area vulnerability***

is the complex of all things that exist as a result of the intervention of man in a given area and which may be directly or indirectly sensitive to material damage like population, buildings and structures, infrastructures, economic activity and development programmes for an area.



Relationship between Geomorphological Environment and Man(Panizza, 1992)

IMPACT is the consequences of Human Activity on Geomorphological Resource and
RISK is the consequences of Geomorphological Hazards on a situation of Area Vulnerability

Disaster risk reduction

Disaster risk reduction (also referred to as just disaster reduction) is defined as the concept and practice of reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse effects. Disaster reduction strategies include, primarily, vulnerability and risk assessment, as well as a number of institutional capacities and operational abilities. The assessment of the vulnerability of critical facilities, social and economic infrastructure, the use of effective early warning systems, and the application of many different types of scientific, technical, and other skilled abilities are essential features of disaster risk reduction.

Disaster risk management

Disaster risk management is the systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, polices and improved coping capacities in order to lessen the adverse impacts of hazards and their possibility of disaster. Disaster risk management aims to avoid, lessen or transfer the adverse effects of hazards through activities and measures for prevention, mitigation and preparedness (UNISDR, 2009).

The interaction between disaster risk reduction and disaster risk management is clear.

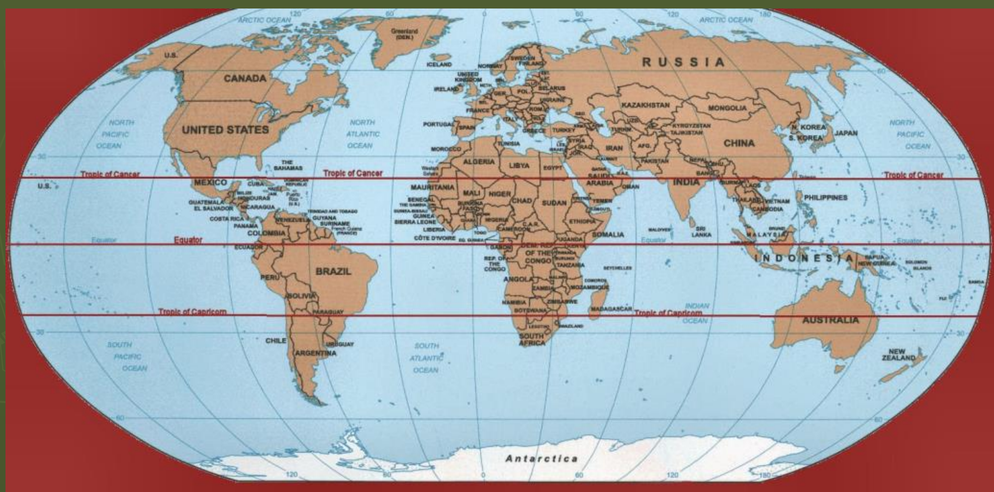
Disaster risk reduction concerns activities more focused on a strategic level of management, whereas disaster risk management is the tactical and operational implementation of disaster risk reduction.

DISASTER RISK IN THE TROPICS

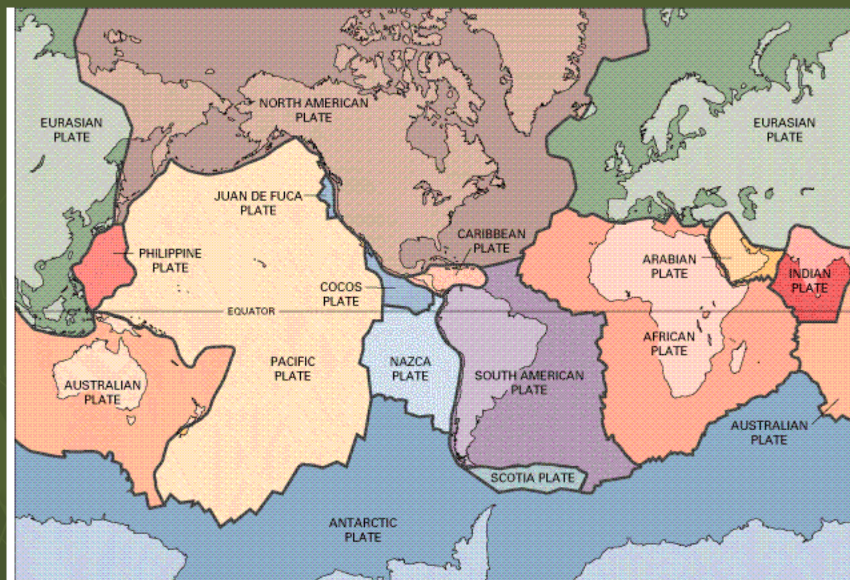
- The tropics are in essence a climatic region, although the only shared meteorological component across the belt of low latitudes is high temperature. Considerable climatic variations exist across the tropical zone: the most impressive of which is the variation in rainfall.
- The annual total, the seasonal pattern and occasional synoptic disturbances all vary across the tropics. The Amazon lowlands, the Rift Valley of Africa, Raub al Khali of the Arabian Peninsula, the Ganga–Brahmaputra Delta, the wetlands of eastern Sumatra and a considerable part of the Red Heart of Australia are all areas of low elevation in the tropics, but they exhibit huge differences in rainfall.

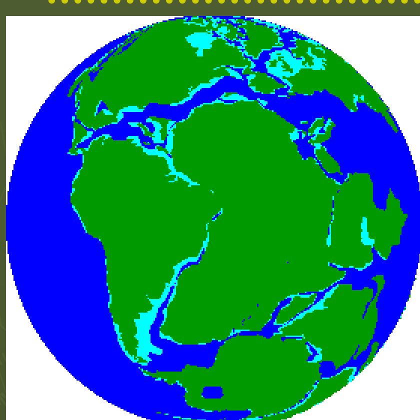
The tropics can be divided into two primary units based on annual rainfall: the humid tropics and the arid topics. The transition between the two can be sharp (for example, where an orographic barrier prevails), or gradational (with a subhumid zone in between). About half of the tropical land surface is humid, with the annual rainfall exceeding annual evapotranspiration. The rest is subhumid or arid. Certain climatic characteristics, such as high temperature, high intensity of rainfall and high potential evapotranspiration are generally associated with the tropics but do not occur with the same intensity everywhere.

TROPICAL BELT OF THE WORLD

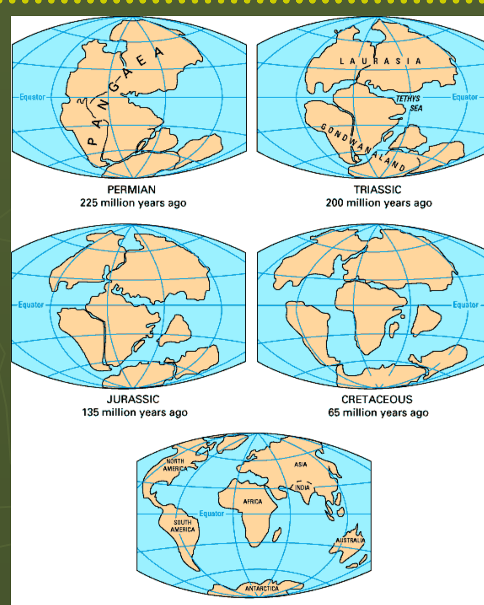


Landmasses that are now in the tropics were once part of a single large continent on Earth, known as **Pangaea**, before its break-up about 200 million years ago. The present tropical landmasses (Australia, part of Southeast Asia, the Indian subcontinent, Africa, South America) and a number of islands of various dimensions together with the cold Antarctica constituted the southern part of Pangaea, known as Gondwana or Gondwanaland.





Continent
200m
Continental Shelf



Tropical geomorphology highlights three areas:

1. geology, landforms and geomorphic processes across the tropics

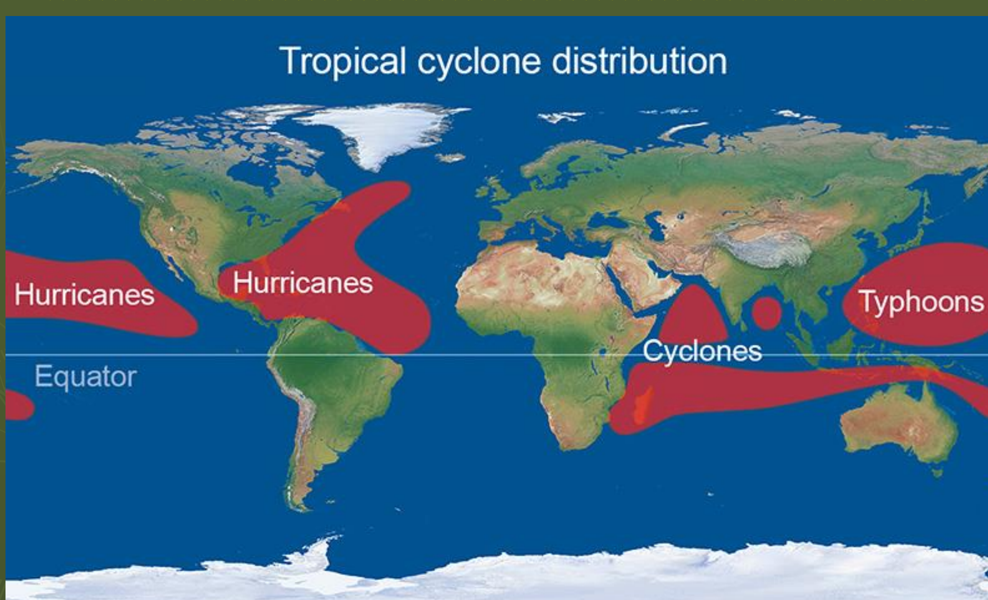
2. the passage of water and sediment from the mountains to the coast, mainly via river systems: a large volume of moisture is in circulation over the humid tropics

3. anthropogenic alteration of the natural rates and processes, associated environmental degradation, and related geomorphic principles for better environmental management.

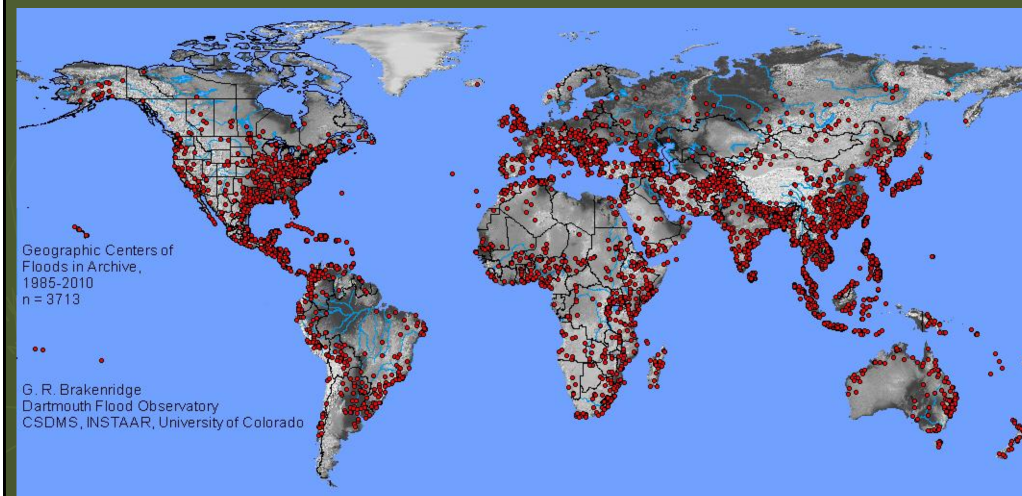
SUMMARY DESCRIPTION OF TROPICAL GEOMORPHOLOGY

Topic	Description
Major controls in geomorphology	• Location of tectonic belts, volcanoes, cratons,alluvial valleys, deltas, etc. as determined by plate tectonics • Wind pattern and rainfall systems (especially tropical storms) • Distribution of vegetation cover • Deforestation, agricultural expansion, urbanisation and channel controls
Major operating processes; same as in other parts of the world, but different in rates and relative importance	• Tropical weathering, and its effect on slope material and river load • Mass movements on tropical slopes • Rivers, a number of which are seasonal and prone to flooding • Glacial, glacio-fluvial and fluvial processes operating on high mountain slopes • Fluvial and aeolian processes in the arid tropics • Coastal processes, presence of mangroves, salt marshes and coral reefs • Tectonic movements and volcanism
Quaternary inheritance	• Pleistocene glaciations of the tropical mountains • Climate change • Sea-level changes affecting coasts and lower river reaches
Present and future changes	• Common anthropogenic changes • Global warming and climate change

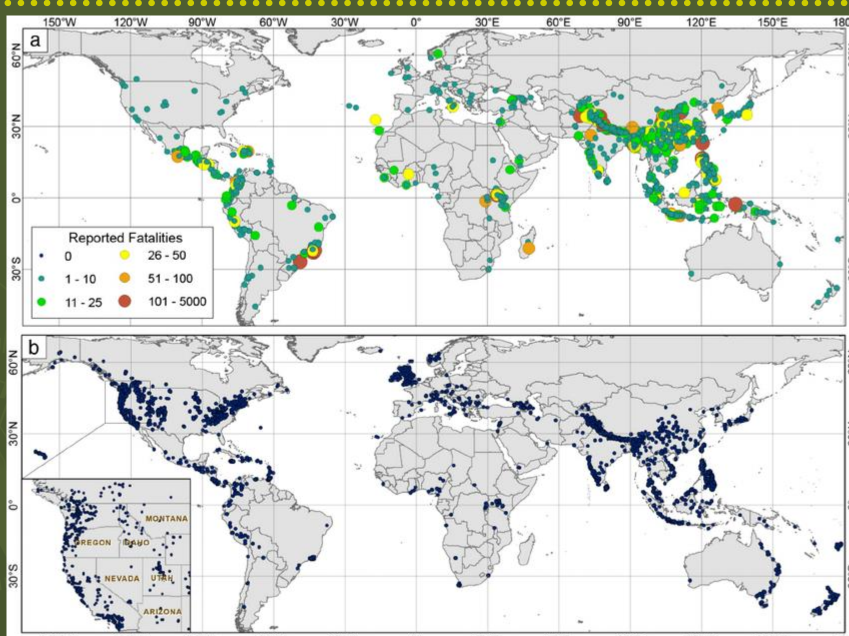
Temperature Extremes shown in **RED** Precipitation Extremes shown in **ORANGE**



FLOODS



Geographic Centers of Floods in Archive, 1985-2010
n = 3713
G. R. Brakenridge
Dartmouth Flood Observatory
CSDMS, INSTAAR, University of Colorado



150°W 120°W 90°W 60°W 30°W 0° 30°E 60°E 90°E 120°E 150°E 180°
60°N 30°N 0° 30°S
a
Reported Fatalities
0
1 - 10
11 - 25
26 - 50
51 - 100
101 - 5000
b
MONTANA
OREGON
IDAHO
NEVADA
UTAH
ARIZONA

FROM KOWLEDGE TO PRAXIS

Develop critical thinking about disaster management of various disaster in Geomorphological perspective

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DISASTER OR EMERGENCY OPCEN

Emergency protection or operation

- Is a central command and control facility responsible for carrying out the principles or functions of emergency / disaster preparedness and management at a strategic level in an emergency situation, and ensuring the continuity of operation of a company, political subdivision or other organization.
- An Emergency / Disaster OPCEN is responsible for the strategic overview, or "**big picture**", of the disaster.
- Used in varying ways at all levels of government and within private industry to provide coordination, direction and control during emergencies.

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- The common functions of all **E/D OPCEN** is to collect, gather and analyze data; make decisions that protect life and property, maintain continuity of the organization, within the scope of applicable laws; and disseminate those decisions to all concerned agencies and individuals.

- In most **E/DOC**'s, there is one individual in charge, and that is the **Emergency/Disaster Manager**.

BRINGS TOGETHER THE VITAL ASPECT OF

- SITUATION MONITORING
- DISSEMINATION of WARNING
- SITUATION ASSESSMENT AND MONITORING
- ACTIVATION of the RRMC - responders & others
- COORDINATION & COMMUNICATION
- INFORMATION COLLECTION & ANALYSIS
- RESOURCE DISPATCH, TRACKING & REQUEST
- TASK ALLOCATION
- With DISASTER MNGT FUNCTION
- ACTION PRIORITIES
- MEDIA & PUBLIC INFORMATION
- Working 24/7

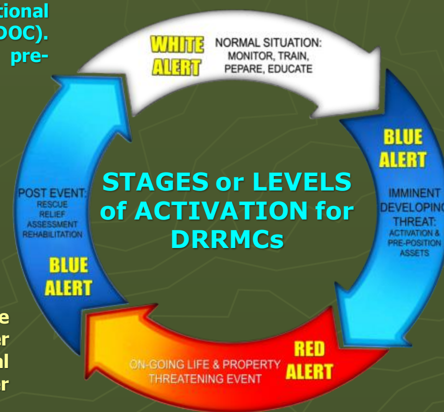
UNDERSTANDING THE COLORED ALERT STATUS & DISASTER WARNING SYMBOLS

NOTIFICATION - When an event/disaster occurs, notification is made to all partner agencies, and CDRRMC Disaster Operations Center support staff who needs to take actions as part of their pre-assigned tasks and responsibilities;

BLUE ALERT (PARTIAL ACTIVATION) - An initial limited or a post Red Alert scaled down operational condition of the Disaster Operations Center (DOC). All field personnel go on stand-by, assets pre-positioned for easy deployment;

RED ALERT (FULL ACTIVATION) - All primary and secondary support agencies of the CDRRMC are on active status/on-call, manning respective stations along with DOC staff, while directing-coordinating personnel/assets on a 24-hour basis during an on-going event;

DEACTIVATION - The DOC Chief as may be directed by the Chief Executive or Action Officer to deactivate the alert status and normal operations of the Disaster Operations Center resumes.



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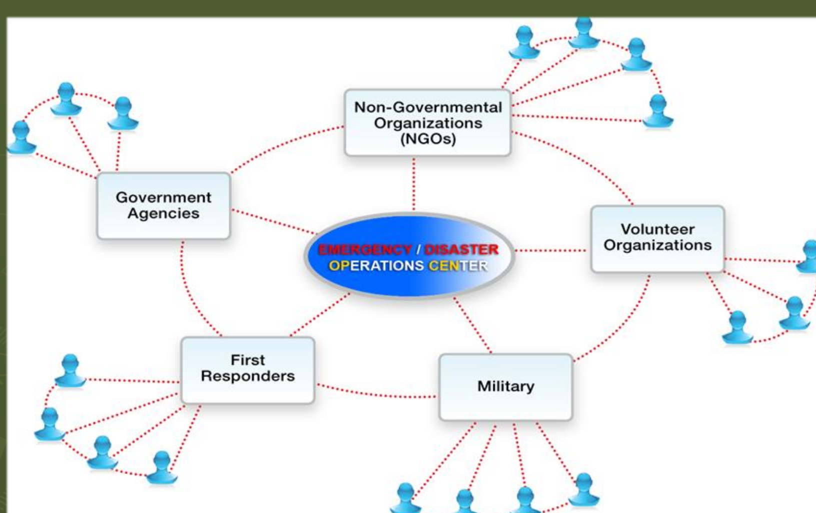
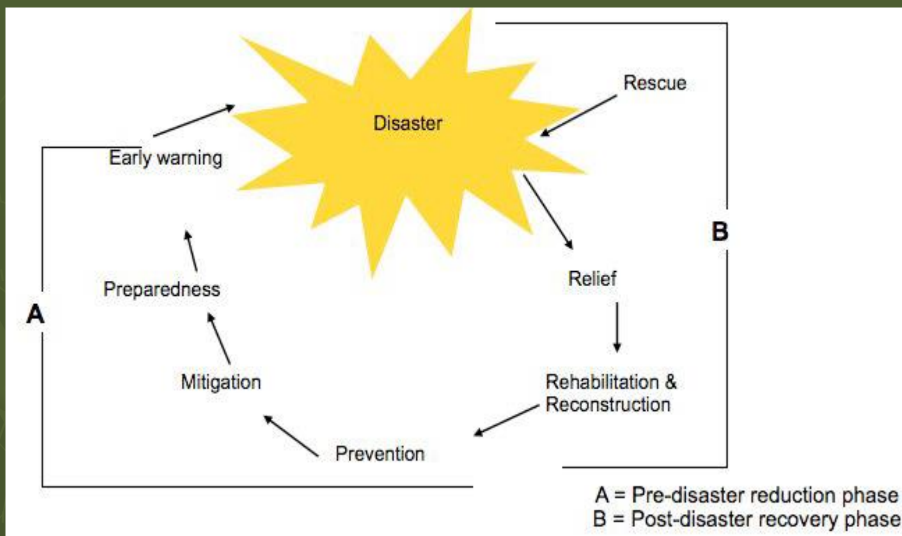
COORDINATION

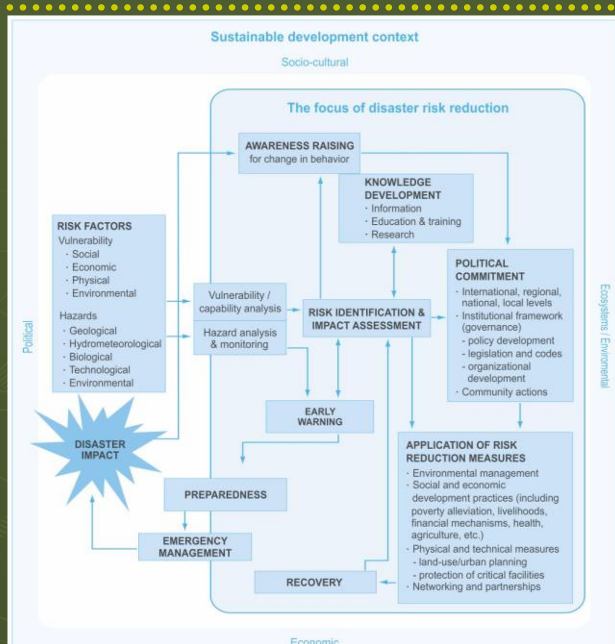
- WHAT?
- WHERE?
- WHEN?
- WHO?
- HOW?
- Others



The traditional disaster Risk Reduction cycle



A FRAMEWORK FOR DISASTER RISK REDUCTION



LANDSLIDE –

A GEOMORPHIC HAZARD

Landslides

A landslide is a massive outward and downward movement of slope-forming materials.

The term landslide is restricted to movements of rocks and soil masses. These masses may range in size up to entire mountainsides. Their movements may vary in velocity.

A landslide is initiated when a section of a hill slope or sloping section of a sea bed is rendered too weak to support its own weight.

This is generally triggered by other natural hazards such as prolonged, heavy rainfall or by other sources of water which increase the water content of the slope materials. Landslide as a geological hazard is caused by earthquake or volcanic eruption. Susceptibility of hill slope to landslide is developed as a result of denudation of mountainsides which removes the trees or ground cover that holds the soil, or alteration of the surface of the ground like grading for roads or building constructions.

Triggering Factors of Landslide

- ✓ Rainfall
- ✓ Earthquake
- ✓ Anthropogenic activities

MECHANISM OF LANDSLIDES

Factors of safety

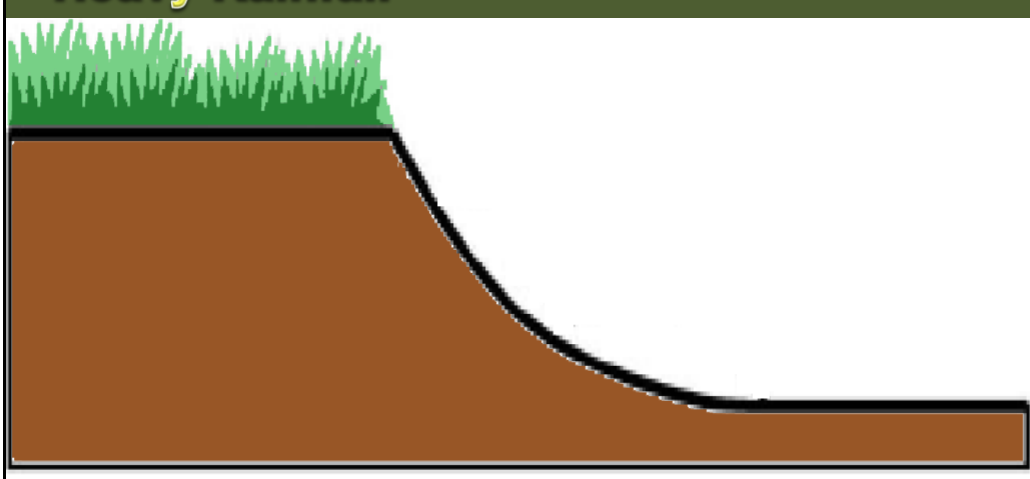
The stability of a slope is usually expressed in terms of a factor of safety, F_s,

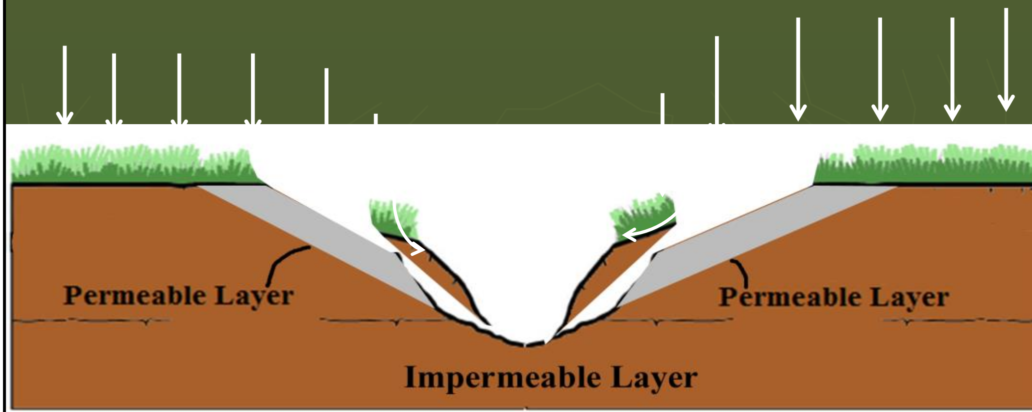
Where, F_s = Sum of the resisting forces / sum of the driving forces

or F_s = Shearing resistance or strength of the materials / magnitude of the shearing forces

where the forces promoting stability are exactly equal to the forces promoting instability, i.e. $F = 1$;
where $F < 1$ the slope is in a condition for failure;
where $F > 1$ the slope is likely to be stable.
Most natural slopes upon which landslides can occur have F values between 1 and 1.3, until earthquakes, undercutting or high pore water pressure reduce this value and trigger a landslide.

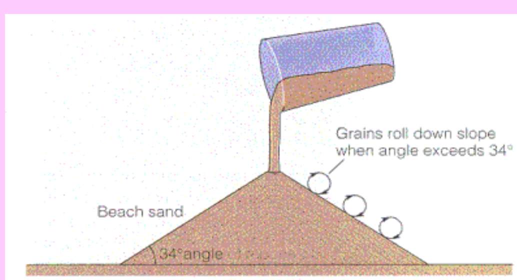
Heavy Rainfall





Angle of Repose

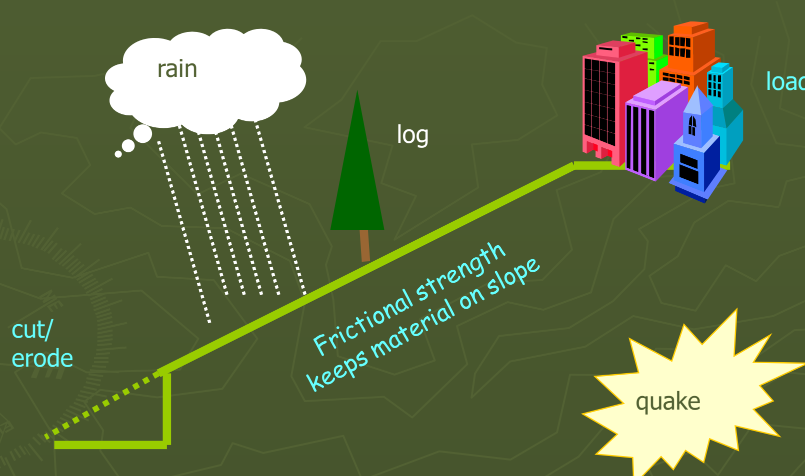
- The maximum slope at which loose, cohesionless material is stable



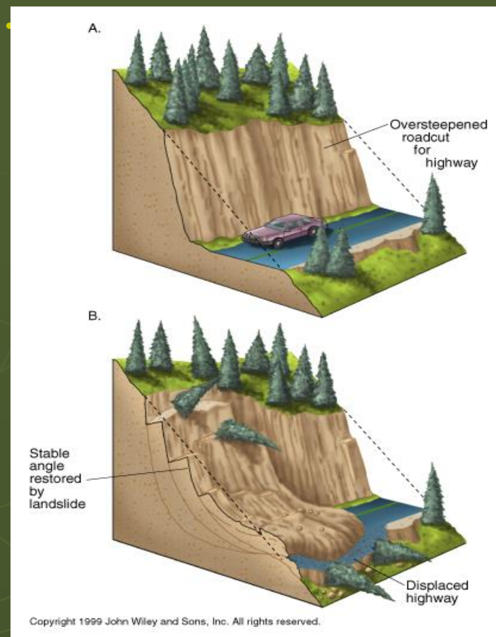
Recognizing Problem Areas

- Curved trees
- Stuck windows
- Stuck doors
- Leaning walls
- Plaster cracks
- Foundation cracks
- Damaged chimneys
- Leaning poles
- Scarps
- Toes
- Seeps
- Pavement damage

Factors of Reducing Slope Strength



- During the movement landslide can result into the 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).



WHAT TO DO TO SAVE LIVES AND PROPERTIES
(SHORT TERM)

Preparedness and Mitigation (What to do before)

- Secure clearance from the competent authority on status of possible landslides.
- Prepare the people for evacuation upon the direction of the proper authorities.
- Maintain a list of contact numbers during emergencies.
- Plant grasses to cover slopes or build riprap to prevent soil erosion.
- Reinforce the foundation and walls of the buildings and other structures when needed.
- Conduct regular drills on evacuation procedures.
- Recommend to proper authorities to enforce land use regulations geared at mitigating landslide or mudflow hazards.
- Promote public awareness and involvement on landslide mitigation.
- Recommend to proper authorities the construction of channels, catchments, basins, dams, levees, and similar structures
- Develop a preparedness and evacuation plan.

Response (What to do during)

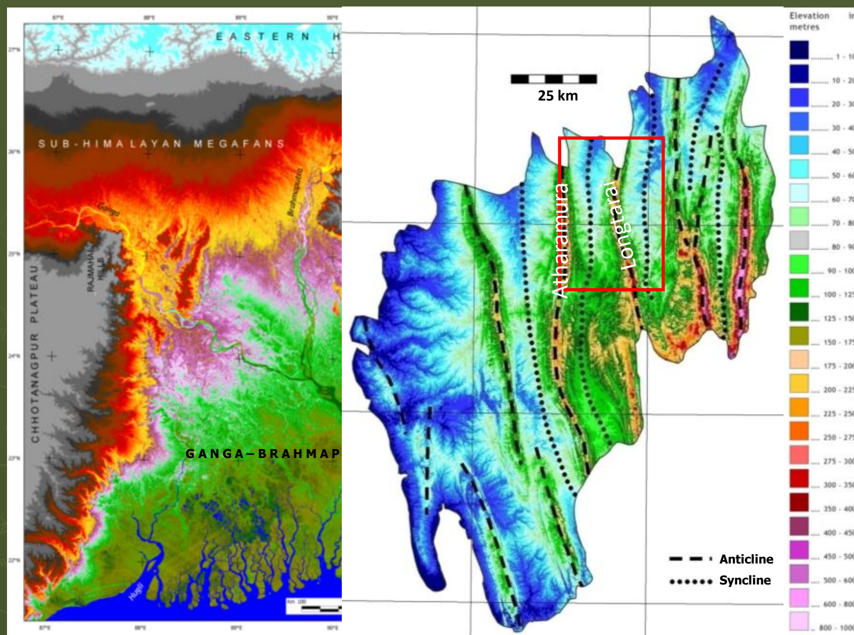
- Evacuate the community immediately if warned of an impending landslide or mudflow.
- Advise people to stay away from the path of landslide debris, or seek refuge behind a sturdy tree or boulder.
- Get out of the buildings as soon as possible when rumbling sounds are heard from upstream or the trembling of the ground is felt, indicating a possible mudflow. Run across a slope, not downwards.

Rehabilitation (What to do after)

- Recommend to proper authorities to examine thoroughly the damaged structures and utilities before re-occupying facilities.
- Stay away from the landslide area. There may be danger of additional landslides.
- Check with caution injured and trapped persons within the landslide area. Direct rescuers to their locations.
- Listen to local radio or television stations for the latest emergency information.
- Seek the advice of a geotechnical expert for evaluating landslide hazards or designing corrective techniques to reduce landslide risk.

LONG RUN MANAGEMENT STUDIES AND PLAN
CASES FROM TRIPURA, INDIA

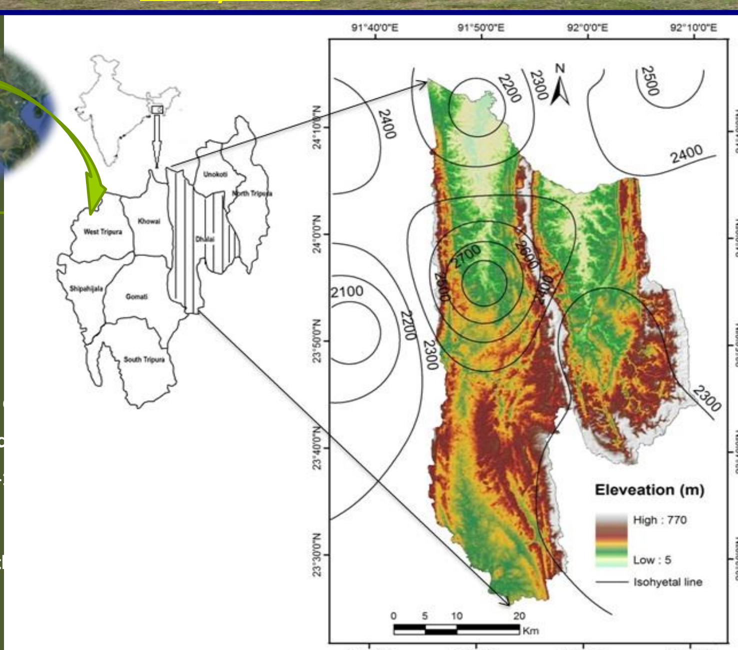
THE CHATTAGRAM-TRIPURA FOLD BELT: PHYSICAL SETTING

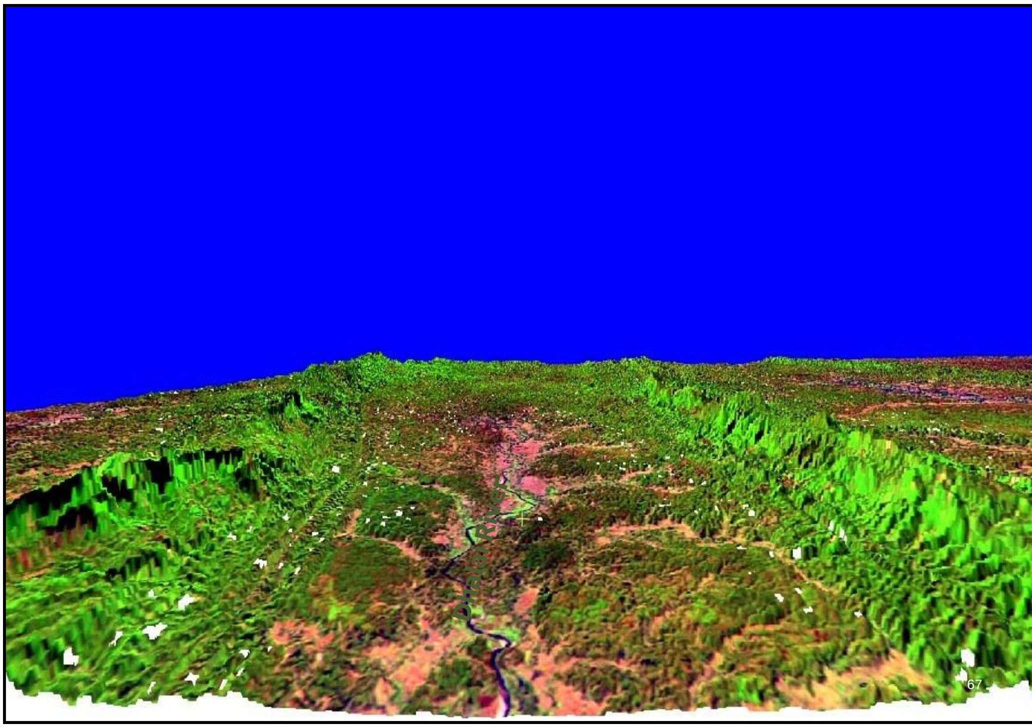


Study Area

Study area

- Total area 2395 km^2
- Maximum Elevation : 770 m
- Average Annual rainfall : 215
- Maximum Temperature : 28^{0}c
- Minimum Temperature : 8^{0}c -
- Forest cover : 63.95%
- . The major hill ranges are At and part of Sakhantlang
- The major river systems Gomati, & Khowai.





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Landslide Risk Assessment

❑Landsli... ent using Fuz...

The most ... ct of the f... izz ... alysis is the assignment of fuzzy membership values, which must lie in the range (0 ... choice of fuzzy membership values. Values are simply chosen to reflect the degree of me... base ... dgment Landslide ris... usin ... ry concept requires two input layer i.e. the landslide susceptibility or hazard map and the land use/ ... ource potential map of the area.

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Landslide Susceptibility Mapping

❑Weight- Rating based method

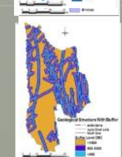
All the thematic layers (lithology, road buffer, slope, relative relief, rainfall, fault buffer, land-use/landcover, and drainage density) were arranged according to their relative importance or probable influence on landslide and weighting number (from 1 to 8) was assigned based on multiple criteria decision-making techniques. Similarly, rating was assigned for each class within a layer which is ranging from 0 to 9. The relative score of each thematic unit in a theme was calculated by multiplying the weight of the theme with the rank of the thematic unit. Finally using multi criteria decision techniques in GIS and cumulative score of weight-rating index known as LSI was calculated.

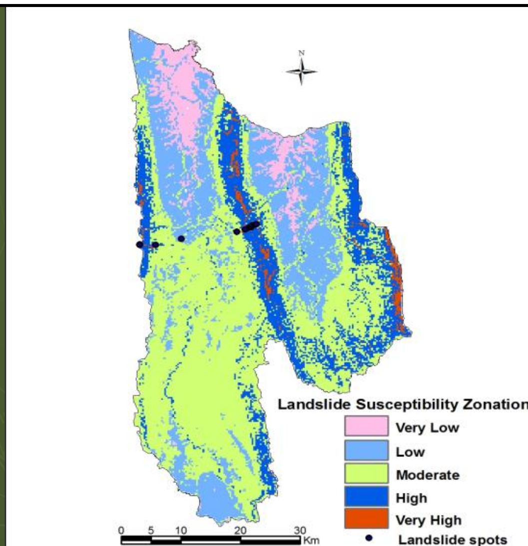
Finally this final susceptibility zonation map was verified in cross checking method by using recent landslides inventory. The following equation was used for the LSZ mapping using a multi-criteria decision-making technique.

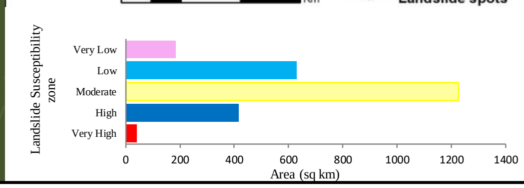
$LSI = \Sigma\ [(Wt_1) * (Rt_1) + (Wt_2) * (Rt_2) + (Wt_3) * (Rt_3) + \ldots\ldots\ldots\ldots\ldots\ [(Wt_8) * (Rt_8)]$

Where, W is the weight of the theme, R is the rating of the theme and t_1, t_2 t_3.....t_8 are the theme numbers

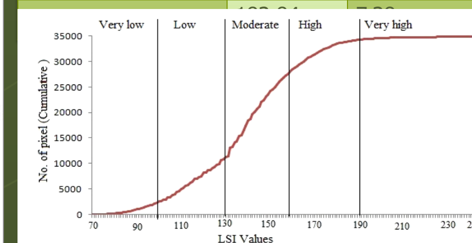
Table . Thematic maps, weight and ranking for landslide susceptibility zonation study.

Factors	Classes	Weightage	rating	
Rainfall (mm)	<2200 2200-2400 2400-2600 >2600	4	5 6 7 8	
Fault Buffer (m)	<500 500-1000 >1000	3	7 5 3	
Landuse	Evergreen forest Agricultural land Water body Waste land Deciduous forest Build up area Shifting cultivation	2	1 2 1 6 4 8 9	
Drainage density (Km/sq.km)	0-2 2-4 4-6 6-8 >8	1	1 2 3 5 7	





Landslide Susceptibility Zone	Area (km²)	Area (%)
Very High	40.89	1.64
High	416.30	16.68
Moderate	1225.19	49.11
Low	628.78	25.20



Landslide susceptibility zone	WEIGHT-RATING METHOD		
	Area (%)	No. of landslides	Incidence per km²
Very low	7.38	0	0
Low	25.20	0	0
Moderate	49.11	6	0.004
High	16.68	6	0.015
Very high	1.64	1	0.024

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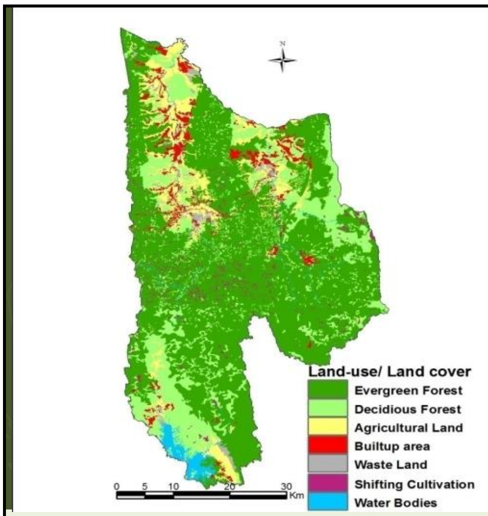

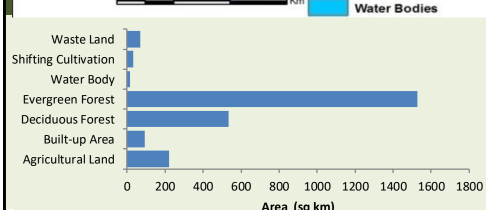

Source: IRS-P6, LISS III (Satellite Image)

Land use/ land cover Factor

Land-use/ land cover type has been considered as resource potential of the Study area. Barren slopes are more prone to landslides than green areas. Vegetation canopies help to reduce the direct action of rainfall over the ground surface and thereby prevent erosion.

. Areas with dense vegetation are less susceptible to landslide because deep rooted vegetation anchors soil separates and make less susceptible to landslide.

Landuse/ Land cover	Area (sq. km)	Area (%)
Agricultural Land	219.5696	8.80
Built-up Area	94.4897	3.78
Deciduous Forest	534.3201	21.46
Evergreen Forest	1527.29	61.23
Water Body	14.5622	0.58
Shifting Cultivation	33.5338	1.34
Waste Land	70.3948	2.82

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Risk Scoring of Resource Potential

Landslide Susceptibility

For risk scoring of landslide potential (LP), AHP method has been applied and eigenvector was calculated by pair-wise comparison matrix. Very high susceptibility zone (VHS) was taken in first column, because maximum landslide spots falling within this zone and the probability of further occurrences is also very high in this zone. The second column compares the high susceptibility zone with the remaining categories. The other categories were compared in the same way like previous two categories. According to their relative importance to landslide occurrence, the calculated eigenvector values have been considered as fuzzy membership value. Fuzzy membership values representing the Risk score of landslide potential (LP).

The study area was classified into seven land use/ land cover categories namely agricultural land, built-up area, deciduous forest, evergreen forest, shifting cultivation, waste land and water bodies. The road networks have been included with the built-up category. These resource categories may be subjected to landslides, which result into resource damage. Generally, built-up area and road network have higher damage potential compared to other categories like barren land, water bodies. The AHP method has been used in order to get fuzzy membership values of different land use/ land cover categories. Based on fuzzy AHP method, fuzzy membership values representing the resource damage potential are assigned to each resource category as risk scores of different land use/ land cover classes .

Table. pair wise comparison matrix of land use/ land cover (resource potential)

Input Layer	categories	[1]	[2]	[3]	[4]	[5]	[6]	[7]	Eigenvector (fuzzy membership value)
Landuse/ land cover (Resource Potential)	[1] Build up area	1	2	3	4	5	5	7	**.35942732**
	[2] Shifting cultivation	1/2	1	2	3	4	5	6	**.25656521**
	[3] Waste land	1/3	1/2	1	2	3	4	5	**.15274067**
	[4] Agricultural land	1/4	1/3	1/2	1	3	4	5	**.09222643**
	[5] Deciduous forest	1/5	1/4	1/3	1/3	1	3	4	**.06470923**
	[6] Evergreen forest	1/5	1/5	1/4	1/4	1/3	1	2	**.04308909**
	[7] Water body	1/7	1/6	1/5	1/4	1/4	1/2	1	**.03124205**

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Landslide Risk Assessment Matrix

Landslide potential and resource damage potential were combined in order to get the landslide risk of the present study area.

Land slide potential values and resource damage values were integrated by using the following formula:

LRI = LPI *RDPI

Where LRI, LPI, RDPI denotes landslide risk Index, Landslide potential Index and Resource damage potential Index respectively.

Table. Landslide risk assessment matrix for different combinations of landslide susceptibility and resource damage potential

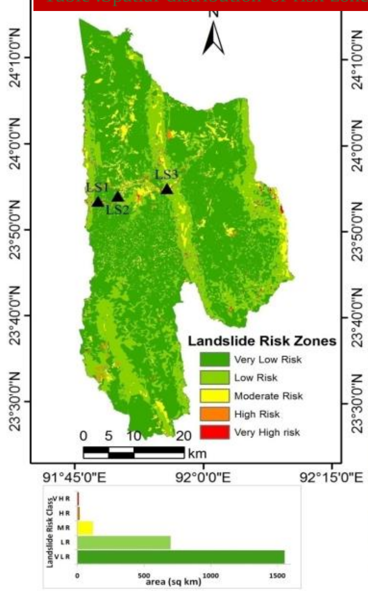
Resource damage Potential (Land use/ Land cover)	Landslide Susceptibility				
	VHS (0.51281)	HS (0.2615)	(MS) (0.12898)	(LS) (0.06338)	(VLS) (0.03334)
Built-up area (0.3594273)	0.184319	0.09399	0.046358	0.022779	0.011982
Road (0.3594273)	0.184319	0.09399	0.046358	0.022779	0.011982
Shifting cultivation (0.25656521)	0.13157	0.067092	0.033091	0.01626	0.008553
Agricultural land (0.09222643)	0.047295	0.024117	0.011895	0.005845	0.003074
Deciduous forest (0.06470923)	0.033184	0.016921	0.008346	0.004101	0.002157
Evergreen forest (0.04308909)	0.022097	0.011268	0.005557	0.002731	0.001436
Water body (0.03124205)	0.016021	0.00817	0.004029	0.00198	0.001041

Landslide Risk Zones

Very High Risk | High Risk | Moderate Risk | Low Risk | Very Low Risk

Final Risk Assessment

Table .Spatial distribution of risk zones and resource categories



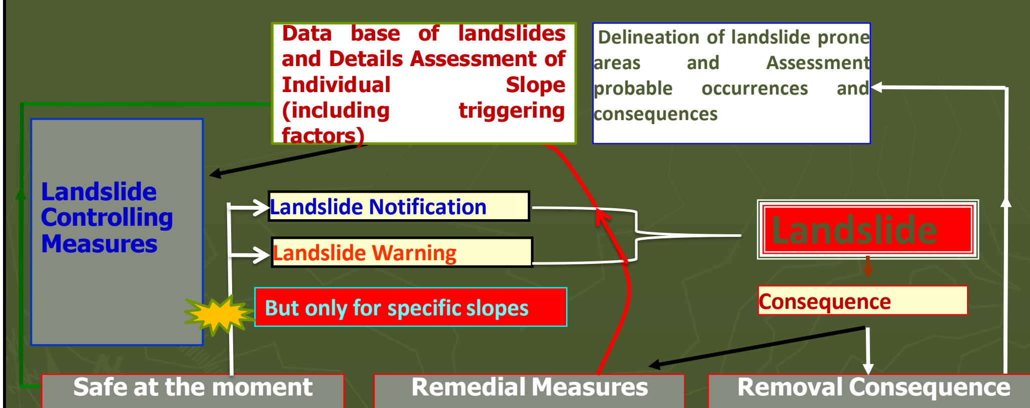
…ories (% of total area)

Shifting Cultivation	Road	Water Bodies
1125 (0.14)	68 (0.01)	15511 (1.95)
837 (0.10)	164 (0.02)	357 (0.05)
5886 (0.74)	718 (0.09)	40 (0.00)
3 (0.00)	546 (0.07)	11 (0.00)
2499 (0.31)	373 (0.05)	(0.00)
10350 (1.3)	1869 (0.23)	15919 (2.00)

…0.09, … for … ve … he **80** … ery … ne … **5.4** … gh … nly … ay, … lly … he … to … ow … rly … **52.8**

…udy area) of ever green forest …green forest is under very low …cultural practice of this district …2 pixels (**0.01%** of the study …e road section contains **1869**

Landslide Management



Proposed Frame work of landslide Management

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Landslides: Removal the Consequence

Alternative route – for vehicles

Agartala- Shillong Road NH-44

Case Study (Details Investigation) for Controlling Measures

- **Landslide 1**
- **Latitude:** 23⁰53'20.50"N
- **Longitude:** 91⁰46'29.78"E
- **Altitude:** 296m.
- **Type of Slide:** debris slide

A large volume landslide have occurred on the slopes of Surma deposits of Atharamura Hill in Dhalai District, Tripura . This slide is about 9 km. east to Ambassa. Results obtained through field studies, it is revealed that the height of the scarp is about 33 m and dip ranges between 40^0 and 45^0 in south, south-west direction. Unconsolidated sandy materials with occasional intersection of moderate to poorly sorted silt or clay layers, continuous seepage through the fractures and unscientific cutting of hill slopes for reconstructing and widening of the road (NH44) have been found responsible for the occurrence of such menace which is further triggered by heavy and concentrated rainfall during monsoon periods.

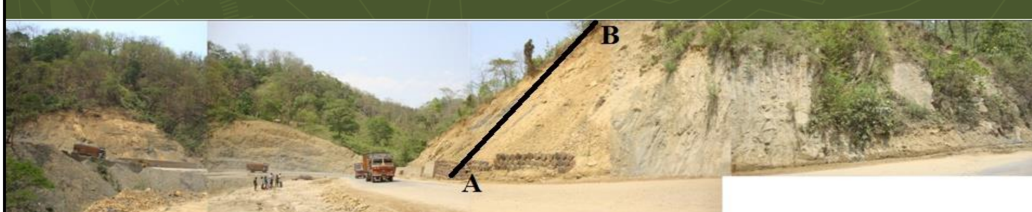
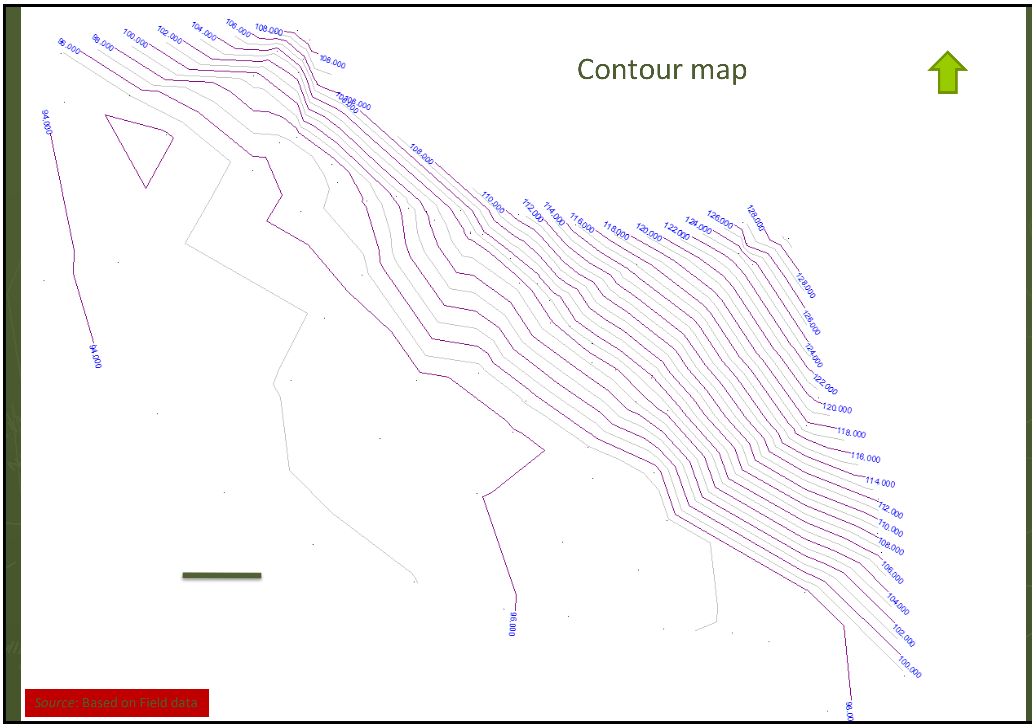


Plate: LandSlide1



Physical set up	Post – Slide Condition	Post – Slide Effect
Rocks: Surma groups (huge thickness of laminated siltstone, sandstone silty shale with narrow bands of shale; occasionally lenticular zone of medium to coarse sandstone with mudstone)	Horizontal Length of the Slope: 54m	The NH44 connects with Assam, Shillong, Gawahati and Tripura has been disrupted which is a life line of all north-eastern states.
Altitude: 545ft -627 ft	Dip ranges between 40^0 and 45^0 in south, south-west direction.	
Slope: Steep, vertical, elongated & Undulating slope.		
Vegetation: Scattered vegetation with little long trees.		
Rainfall: rainfall in the month of July is 855mm in the year between 2004.	Total area : 1500.721m^2	
Land use: mainly consists of scattered type of vegetation.	Total volume : 3044.652 m^3	
Soil : Upper top soil contain sandy loam whose pH is 6.2 i.e. acidic in nature. Middle part contain loamy sand soil and lower part contain sandy soil. The soil layer are thin, loose and unconsolidated. Most of the soils are light brown and yellow in colour.	Processes primarily Responsible: unscientific cutting of hillside slope for widening of roads, Weak geology, spontaneous erosion due to heavy rainfall.	
	Modified slope: steep and irregular with convex and overhang slope	
	Type of slide: Translational Slide from the middle portion due to continuous seepage and flow of water. Block Subsidence from Northern port, Block movement from southern part of the scarp.	

Existing Controlling Measures (landslide 1)

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Proposed Controlling Measures

Table . Recommended slope gradient for cut slope

Slope segment	Ground slope condition			
	lithology	Soil type	Slope length	Slope gradient ((V:H)
S1-S2	Unconsolidated Sandstone with clay alteration (Bhuban Formation)	Medium sand (Moderately Well Sorted)	6m	**1: 0.5- 1:1.2**
S2-S3		Medium sand (Well sorted)	15.4m	**1.2:1.5**
S3-S4		Fine sand (poorly sorted)	8.3	**1:1.2- 1:1.15**
S4-S5		Fine sand (poorly sorted)	5m	**1:1.2- 1:1.15**
S5- S6		Medium sand (Moderately Well Sorted)	3.2m	**1:0.8- 1:1.0**
S6-S7		Medium sand (Moderately Sorted)	8m	**1:1-1:1.2**

Grain size ϕ

Grain size ϕ

Grain size ϕ

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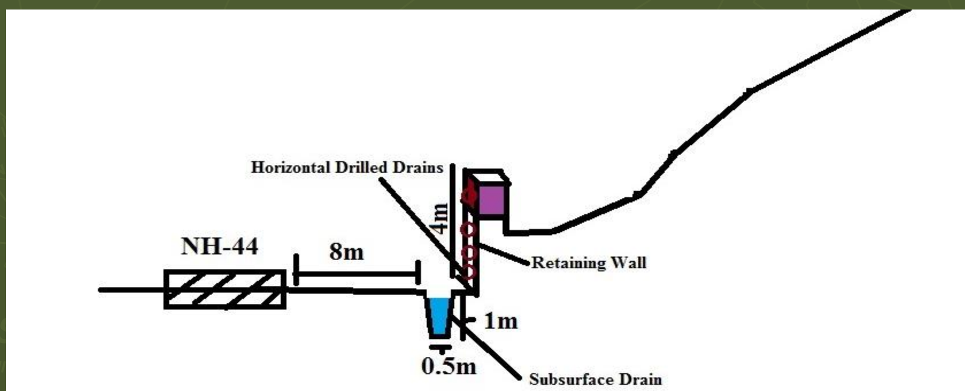
Sub-surface Drain and horizontal drilled Drains

- The present study area received high amount of (about 2100mm) rainfall in every year
- Slope is made of with unconsolidated material
- Surface drains is not recommended
- Sub-Surface drains and horizontal drilled drains for slope management is recommended .
- The length of the horizontal drilled drain should be as equal to the length of the landslide scarp.



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Retaining wall

Retaining wall can be constructed to act as effective barriers to arrest debris or small rock fragments. In case of landslide 1, the retaining wall should be extended across the foot of the landslide scarp. From the field investigation, it is suggested that the height of the retention wall should be extended at least more one metre and the length should be extended unto the two end of the scarp, because the present retaining wall is not adequate to arrest the debris, which is being produced in every year by reactive of the landslide.

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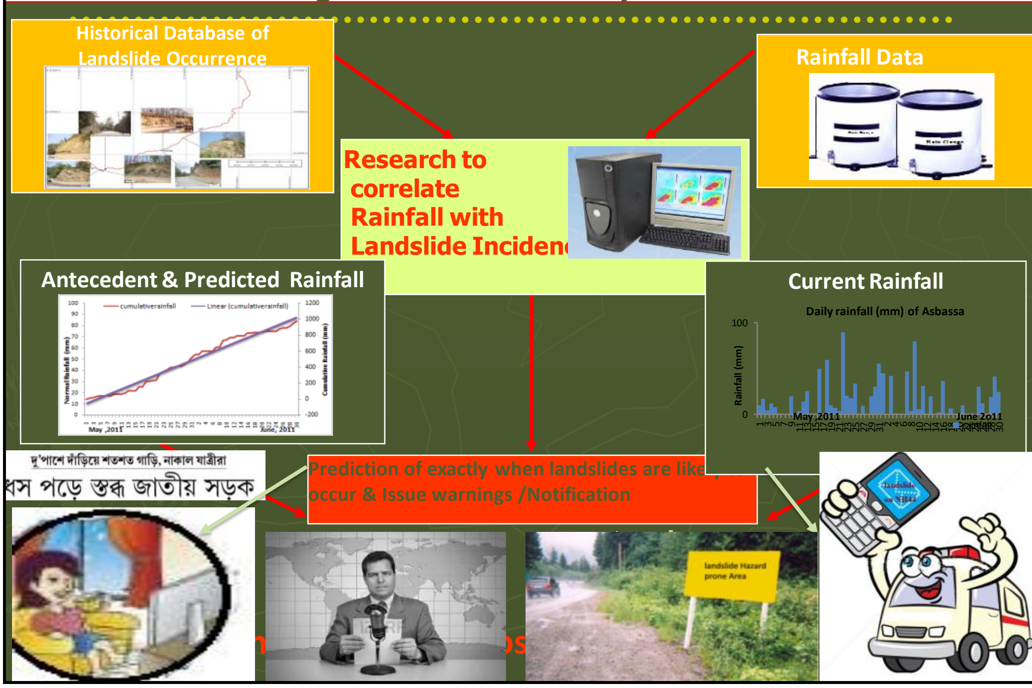
Figure. Proposed extension of Retaining wall for landslide 1

Landslides: Warning and Notification System

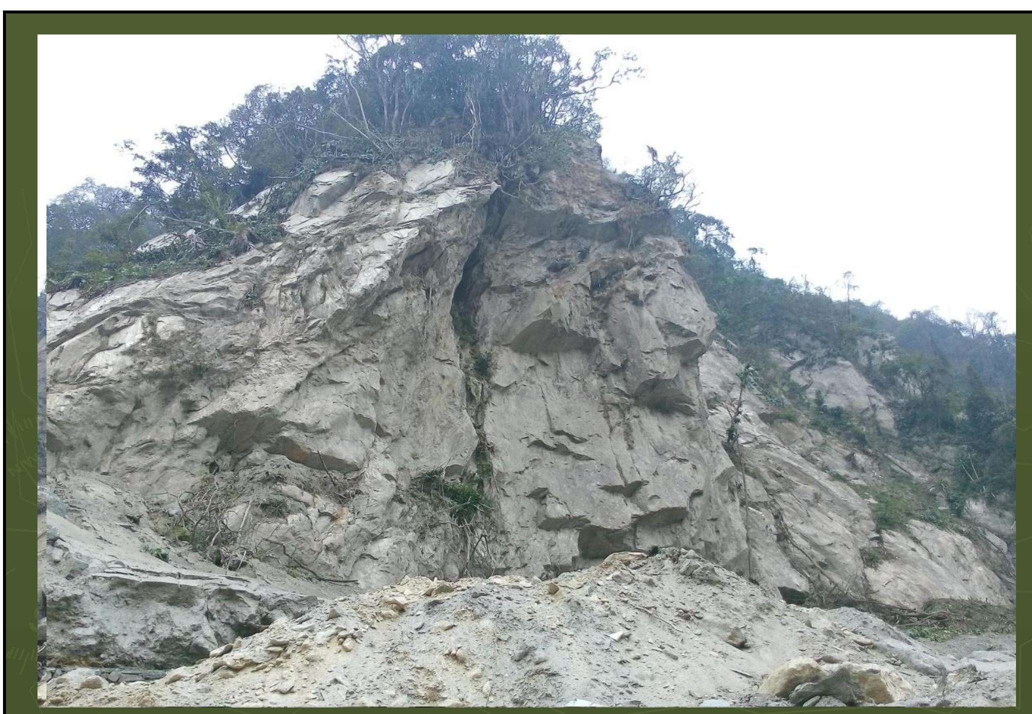


(Trench drainage of toe of active slide)

(Debris Torrent Chute)

Debris flow dam


Zonghu, Sikkim
15th August, 2016



Vegetal treatment of Damaged Slopes

To arrest erosion, it is advisable to provide a protection of vegetation to the landslide-affected/ threatened area. The damaged slope is first fenced, and then seeded with quick-growing local grass. The seeded soil should be covered by a net of coir, jute or synthetic yarn with an opening of about 2.5 – 1.5 cm. The net prevents the breaking of the soil and thus allows unhampered growth of the grass.

Hybrid “hard-soft” landscaping solutions

Checking movement by Engineering Structures

A variety of retaining walls of concrete or masonry provide support to the threatened slope at its foot. Low in height but heavy in weight, the buttress walls accomplish much the same objective. These engineering structures not only prevent movements of the slope material, but also ensure protection against toe erosion along streams. The water that percolates through the affected rocks/soils poses a problem to these walls, as there is a build up of pore-water pressure. It is therefore, necessary to have a cushion of permeable gravel or coarse sand behind the walls, and weep holes in the structures themselves. The weep holes provide an outlet to the water accumulated behind the walls.

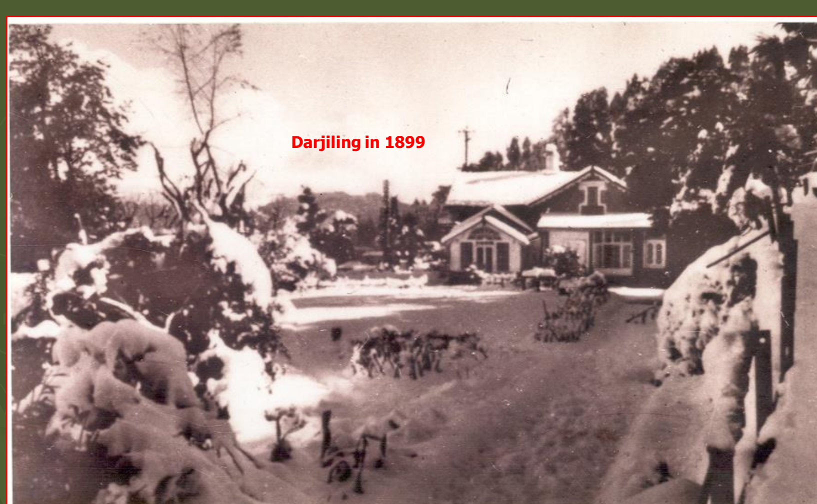
MAKING THE AREA RESILIENT

- ✓ **Large Scale Physical Vulnerability Maps should be prepared**
- ✓ **Settlements should be shifted to the safe areas. Govt. and NGO's should be involved in the process**
- ✓ **Closed / Left out tea gardens should be afforested**
- ✓ **Construction of high-rise buildings should be restricted**
- ✓ **Retaining wall may be constructed against the slopes, which can prevents rolling down of material specially along the roads. Terracing of the slope is an effective measure.**
- ✓ Measures should be taken for open-air toilets, solid waste disposal

Making Areas Resilient: My Area is Getting Ready!

Ten-Point check list – Essentials for Making Areas Resilient

1. *Put in place **organization & coordination** to clarify everyone's roles & responsibilities.*
2. **Assign a budget** & provide incentives for homeowners, low-income families, private sector to invest in risk reduction.
3. Update data on hazards & vulnerabilities, **prepare & share risk assessments**
4. Invest in & maintain **critical infrastructure**, such as storm drainage.
5. Assess the **safety of all residents and health facilities** & upgrade these as necessary
6. Enforce **risk-compliant building regulations & land use planning** principles, identify safe land for low-income citizens.
7. Ensure **education programmes & training** on disaster risk reduction are in place in schools and local communities.
8. **Protect ecosystems & natural buffers** to mitigate hazards, adapt to climate change.
9. Install **early warning systems & emergency management** capacities.
10. After any disaster, ensure that the **needs of the affected population are at the centre of reconstruction**.



Courtesy: Das Studio, Darjiling

Thank you

Flood

Flood is the inundation of land areas which are not normally covered by water. A flood is usually caused by a temporary rise or the overflowing of a river, stream, or other water course, inundating adjacent lands or flood-plains. It could also be due to a temporary rise of lakes, oceans or reservoirs and/ or other enclosed bodies of water, inundating border lands due to heavy and prolonged rainfall associated with tropical cyclones, monsoons, inter-tropical convergence zones or active low pressure areas.

Floods are basically hydrological phenomena and they are also caused by storm, and Tsunami along coastal areas. Ecologists also attribute flooding in some regions to the results of human activities like unregulated cutting of trees and urbanization of large areas. These activities have changed the hydrological regime of some areas so that water flows into streams more rapidly. As a result of this, high water levels in water courses occur sooner and more suddenly. Flooding occurs in known floodplains when prolonged rainfall over several days, intense rainfall over a short period of time, or a debris jam causes a river or stream to overflow and flood the surrounding area.

RIVER BANK EROSION AND FLOOD

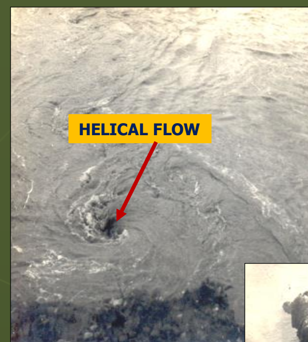
1. The primary reason of bank erosion is the fluctuating nature of water discharges in different seasons.

2. Characteristics of the soil (alternate bands of sand, silt and clay) also have an important bearing on the extent of erosion. Incoming high velocity of water colliding with the sand particles often disrupts the basal support thereby, hastening bank erosion. Virgin banks of stiff clay or other stable materials may generally be absent except at a few places.

Alternate beds of Silt, Sand and Clay found on the river bank, enhance bank erosion by the removal of sand materials by the impinging high velocity water, endangering constructions on river bank at Baidyanathpur.

3.The soils present along the banks have pore spaces, which gets filled up with water of the river during monsoon months. When this water gets inside these pore spaces an equilibrium is maintained among the soil particles (i.e. liquefaction) along the banks but when this water from these pore spaces recedes and returns back to the river during winter months the soil particles loses its equilibrium. The soil particles, thus, become loose and any loss in basal support by flowing water help them to fall, causing bank erosion.

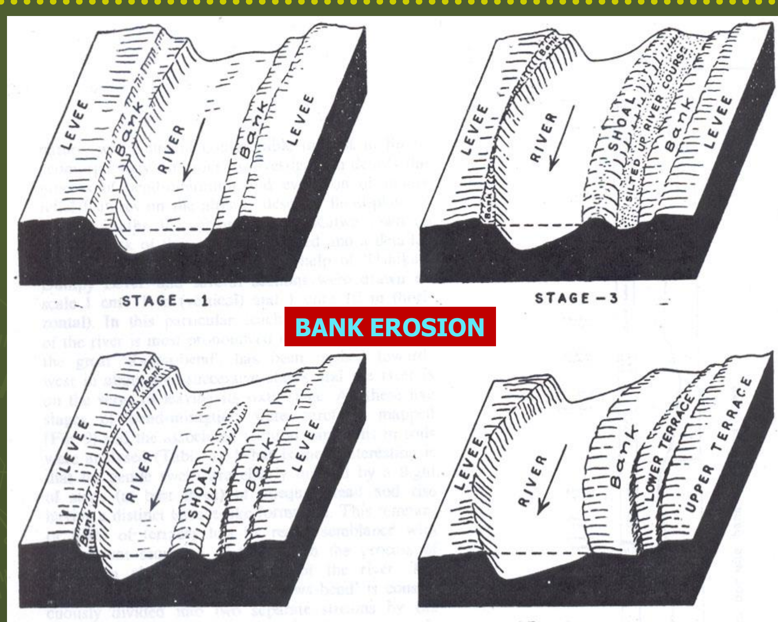
4. Bank erosion also occurs when the river initiates a bend. The most rapid parts of the water are driven by the vertical circular motion towards the concave bank while the convex bank gets the water which comes up from the bottom and has thus a low velocity due to friction with the ground. Hence, the erosion is necessarily stronger on the concave bank with a gradual recession of the same bank.

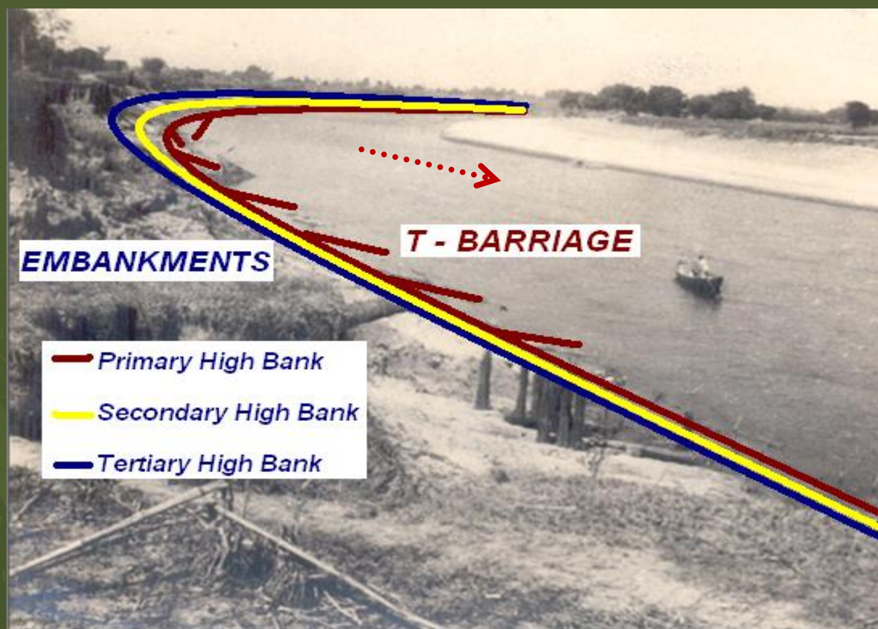


Vertical circular motion (Helical flow) of water attacking the bottom of the bank at Udaypur composed of predominantly clay, causing toe-erosion.

5. Moreover the formation of a shoal (bar) within the channel restrict the large volume of water to move through a reduced channel, causing an asymmetry of erosion on the opposite side of the shoal due to favourable gradient of the channel and this invariably pronounces erosion and the formation of meander in the same direction.

STAGES OF BANK EROSION AND MEANDERING




EMBANKMENTS
T - BARRIAGE
Primary High Bank
Secondary High Bank
Tertiary High Bank

Several factors contribute to flooding. Two key elements are rainfall intensity and duration.

Intensity is the rate of rainfall, and duration is how long the rain lasts.

Topography, soil conditions, and ground cover also play important roles.

Most flash flooding is caused by slow moving thunderstorms repeatedly moving over the same area, or heavy rains from hurricanes and tropical storms. Floods can be slow- or fast-rising, but generally develop over a period of hours or days.

Preparedness and Mitigation (What to do before)

- Find out the frequency of occurrence of fl oods in the locality, especially those that affect the school area.
- Know the flood warning system in the school. If none exists, recommend to the appropriate authority for the creation of one.
- Research from previous occurrences how fast the water floods occur in the school and how high it rises.
- Watch out for rapidly rising water and prepare the students/pupils for evacuation.
- Switch off the electricity and lock the rooms after the children have gone out.

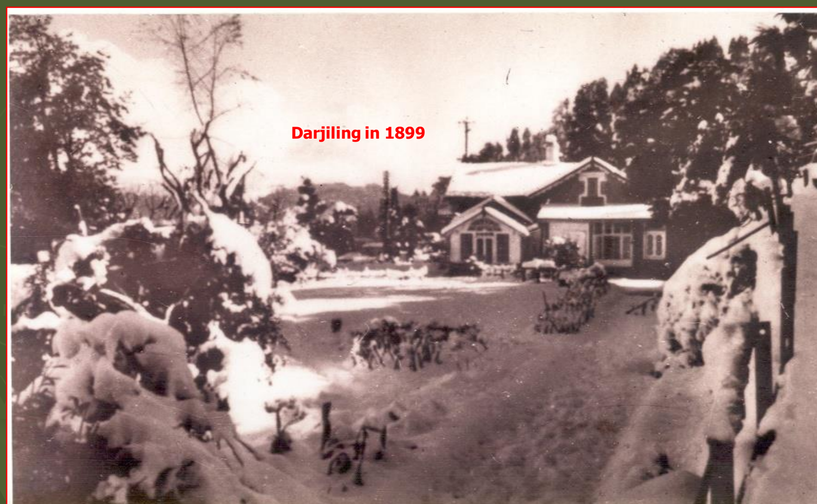
- Have a handy survival kit. It should contain battery-operated transistor radio, flashlight, emergency cooking equipment, candles, matches and first aid kit.
- Offer services and perform the assigned tasks in the event that the area is designated as an evacuation area for families or livestock.
- If it has been raining hard for several hours, or steadily raining for several days, be alert to the possibility of a flood. Floods happen as the ground becomes saturated.
- Use a radio or a portable, battery powered radio (or television) for updated information. Local stations provide the best advice for your particular situation.
- Caution everyone to avoid using lanterns or torches in case there are flammable materials present.
- Protect your school property against flood.

Response (What to do during)

- Keep the people calm and update them with the status of the situation and safety reminders on what to do and where to go in case of evacuation.
- Listen continuously to a radio, or a portable, battery-powered radio (or television) for updated emergency information.
- Remind people not to attempt to cross flowing streams unless they are assured that the water is below knee high level.
- Advise people to avoid areas prone to flash flooding and be cautious of water-covered roads, bridges, creeks and stream banks and recently flooded areas.
- Warn them to not to go swimming or boating in swollen rivers.
- Watch out for snakes in flooded areas.
- Advise them to eat only well cooked food and drink only clean or preferably boiled water and throw away all food that has come into contact with flood water.

Rehabilitation (What to do after)

- Report broken utility lines (electricity, water, gas, etc.) immediately to appropriate agencies/authorities.
- Ensure that electrical appliances are checked by a competent electrician before switching them on.
- Avoid affected areas.
- Continue to listen to a radio or local television stations and return home only when authorities indicate it is safe to do so.
- Stay away from any building that is still flooded.



Courtesy: Das Studio, Darjiling

Thank you