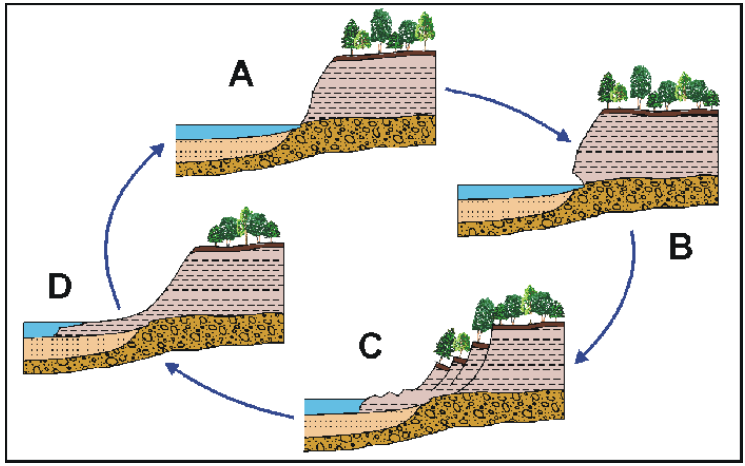
Coastal hazards Fact Sheets #3: Coastal Landslide in Cities

What is Coastal Landslide?

The mass movement of materials like rocks and debris down the slope due to gravity is called landslide.[i] When the strength of the material is weakened due to additional weight or any other external factors, the equilibrium of the land gets disturbed, and landslides occur when it can no longer resist the forces of gravity.[ii]

According to UN-Habitat, The Economic Role of Cities (2011), 80% of the world's wealth is generated in cities, and 60% of the world population will live in urban areas in 2030.[iii] World Health Organization (WHO) reports state that in 1998-2017, an estimated 4.8 million people were affected, and more than 18,000 deaths were reported due to landslides.[iv] It has been found that landslides are more severe in developing countries, where between 1950 and 2011, debris flows killed an average of 23 people per event in developing countries, compared to 6 fatalities per flow in advanced countries.[v]

Figure 1: Figure showing the cycle of a coastal landslide



Source: https://www.maine.gov/dacf/mgs/hazards/landslides/facts/landslide.htm

Causes of Coastal Landslide

- *Geological Factors:* The occurrence of landslides is highly related to the type, composition, and stability of rocks and soils of the area. A weathered area is more prone to landslides than the ones with stable and robust binding capacity areas.
- *Wave Action and Erosion:* The intensity and frequency of waves hitting coastal cliffs can erode and weaken them over time, leading to instability and potential collapse.
- *Heavy Rainfall:* Excessive rainfall can saturate soils and rocks, adding weight to the top land, making it unstable and leading to landslides.
- *Human Activities:* Human activities like construction and development, deforestation, mining, etc., can disturb the natural balance and destabilize the land, making it prone to landslides.
- *Earthquakes*: Natural factors like earthquakes also cause landslides due to the movement of tectonic plates beneath the ground.
- *Sea Level Rise:* As the sea level rises, the waves and ocean currents get stronger due to the increased water level, leading to coastal erosion and landslides.[vi]

How does Coastal Landslide affect city systems?

1. **City Infrastructure**
   - *Roads and Transportation Networks:* Landslides can affect connectivity and cause disruptions in roads, bridges, and other transportation infrastructure; roads near eroding coastlines may become unstable or collapse due to erosion-induced land loss.
   - *Utilities, Water Supplies and Sewage Systems:* It can disrupt essential services like water, gas, sewage and power lines.
   - *Buildings and Residential Areas:* Landslide causes the foundation's instability, resulting in collapse or structural damage to buildings and houses.
   - *Coastal Infrastructures*: Landslides can impact coastal protection infrastructure, such as sea walls, dikes and groins, and contribute to costly repairs or replacements.

- *Tourism and Economy:* Landslides can impact the beach areas that are recreational and tourist attraction spots and the area's economy.
- *Cultural and Historical Sites*: Some cultural and historical infrastructures critical to indigenous communities may also be at a loss due to the potential damage caused by landslides.

In Durban, south province in Africa, 2022, floods and resulting landslides claimed the lives of 459 people, more than 4,000 homes were destroyed, and over 40,000 people became homeless. Infrastructure and business losses are estimated to be around $2 billion.[vii]

In the coastal district of Dakshina Kannada in Karnataka, heavy rains caused a landslide in July 2023, damaging 29 houses and disrupting transportation and electricity poles and lines.[viii]

2. Social Impacts

- *Loss of Life and Injury:* The sudden collapse of land can result in fatalities and injuries among residents, causing them physical injuries or trauma.
- *Displacement and Relocation:* Due to the occurrence of landslides, communities of coastal land may be forced to relocate to safer areas, causing disruption in daily life and adding mental and emotional stress.
- *Livelihood Threats:* The livelihood of coastal communities relying heavily on agriculture and forest areas are impacted the most due to landslides.
- *Community Disruption and Social Inequity*: Displacement can fragment communities and cause social inequity as they are forced to start their lives elsewhere.
- *Health and Safety:* Landslides can cause several accounts of accidents and injuries. Access to healthcare, emergency services, and safe drinking water may also be hampered.
- *Migration and Urbanization:* The displacement caused by landslides can also lead to migration to urban areas, causing overcrowding, competition for resources, and social challenges.

In July 2021, a coastal landslide occurred in Atami, a city southwest of Tokyo. The landslide caused 80 people to be trapped and missing from a torrent of mud, trees and rocks ripped, killing at least four people.[ix] The disaster led to evacuations, displacing residents and disrupting their lives. The incident

highlighted the vulnerability of communities built on steep slopes near the coast.
During May 2023, in Emilia-Romagna (Italy), a flood and landslide claimed at least 14 lives, leaving more than 36,000 homeless, and thousands remain in emergency accommodation, their houses and apartments destroyed.[x]

3. **Ecosystem Disruption**
    - *Habitat Destruction:* Coastal erosion results in alteration and loss of vegetation, soil, and other physical features. Trees and plants are uprooted, soil is displaced, and rock debris can cover the ground, altering the landscape and causing disruption in species habiting the area.
    - *Erosion and Sedimentation:* The movement of soil and debris during a landslide can lead to soil erosion and sedimentation in nearby water bodies.
    - *Water Pollution:* Due to erosion and sedimentation, landslides can introduce pollutants from the eroded soil and debris into rivers, lakes, and coastal waters. This pollution can harm aquatic life and affect marine ecosystems.
    - *Altered Coastal Dynamics:* Changes in coastal geomorphology due to coastal erosion can affect the breeding and nesting grounds of species like turtles and shoreline birds.
    - *Loss of Biodiversity:* Alteration in the habitat of plant and animal species can result in the loss of keystone species
    - *Carbon Release:* Landslides can release carbon stored in vegetation and soils, contributing to greenhouse gas emissions and climate change.

In 2016, Hurricane Matthew triggered a coastal landslide in the city of Baracoa, Cuba. This event resulted in habitat destruction, particularly affecting coastal vegetation and mangroves.[xi]

In 2017, a large coastal landslide occurred in Tokyo Bay, Japan. The landslide destroyed coastal defense structures, infrastructure, and habitats. This event highlighted the vulnerability of coastal ecosystems to rapid changes caused by landslides, potentially leading to shifts in species distribution and overall ecosystem health.[xii]

How does Climate Change impact Coastal Landslide?

- *Increased Precipitation:* Climate change can lead to heavy rainfall in some areas and drought in some. In places where storm surges accompany heavy rainfall, landslides can occur. The sixth assessment report on IPCC confirms that precipitation will increase over much of Asia (high to medium confidence).[xiii] A research conducted by Cambridge University confirmed that Model-based projections of future climate indicate that extreme precipitation events are likely to increase, causing more landslides.[xiv]
- *Increased Erosion:* Erosion makes the land surface weaker and destabilises it, making it more prone to landslides. The coastal erosion on the west coast of Kerala, Karnataka and Goa is more severe. There is a similar condition in the Kanyakumari region of Tamil Nadu, Maharashtra and Gujarat, where the coastal areas are affected by coastal erosion.[xv]
- *Sea Level Rise:* As sea levels rise, the base of coastal slopes is exposed to higher water levels. The constant action of waves, currents, and tides can erode and undercut the bottom of these slopes, triggering landslides. As per the sixth IPCC Report (AR6), the average global sea level exhibited a yearly increase of 3.7 millimetres from 2006 to 2018 which was nearly three times greater than the 1.3 millimetres per year observed from 1901 to 1971.[xvi]
- *Thawing Permafrost*: Thawing permafrost due to higher temperatures can destabilize coastal slopes in Arctic and subarctic regions. Permafrost acts as a natural stabilizer, and when it melts, it can lead to increased landslides along coasts. A study conducted by Patton A. et. Al. in August 2021 confirmed a positive feedback between permafrost thaw and landslide development with maximum elevation loss of 0.8 ± 0.04 and 1.0 ± 0.08 m over the study period in Alaska. [xvii]
- *Extreme Heat Events:* When extreme heat events occur, the land becomes dry, and when excessive rainfall occurs, the land becomes unstable as it cannot hold excess water. The extreme heatwave caused landslides along the Jurrasic coast of the beach in the UK in August 2022. The heat caused the rocks to expand, disturbing the balance and causing a landslide.[xviii]

- *Human Development:* Human activities like urbanization and infrastructure development can pressure natural landscapes and increase landslide potential. A landslide ruptured California's Highway due to a flood and increased tourism and traffic, overwhelming the coastal region's infrastructure and environmental ecosystems and causing severe damage.[xix]

Image 1: Picture showing landslide causing a 150ft section of Highway 1 to wash away into the sea.

Source: https://www.theguardian.com/us-news/2021/feb/06/california-highway-1-landslide-climate-crisis

Adaptation Strategies for Coastal Landslide

Community Level

- Planting and restoring native vegetation in slopes, such as plant roots, can help bind soil together and reduce erosion. Plants and grasses also absorb excess water and stabilize the soil from landslides.[xx]
- Initiate major shift in land use policies demarcating certain areas as 'no development zones and construction restricted zones.[xxi]
- Build strong and gigantic walls along the slopes of the hills to block the debris of the landslide falling onto the roads and houses.[xxii]
- Following landslides, timely stabilization of affected sites can help reduce sedimentation of streams, prevent further landslides and mudflows, and re-establish the livelihoods of local communities.[xxiii]
- Engage community members to map areas with a high landslide risk and encourage vulnerable communities to plan relocation.

- Monitor and research landslide patterns, frequency, and the impacts on lives and property.
- Community engagement by involving local communities in the planning and implementation of conservation efforts and raising awareness about the risks of coastal landslides
- Educate and create awareness among local communities about landslide risks, their causes, and the importance of adaptation through community workshops, training, information campaigns, and programs in schools and communities
- Capacity building of local communities by providing them training and education in the risks and management of coastal landslide
- Collaboration and networking through combined workshops and engagements by bringing in residents, technical experts, environmental experts, businesses and local leaders, local and municipal government bodies together for consultation on landslide
- Establish early warning systems to monitor and create communication systems about landslides to alert residents to potential threats.[xxiv]

Municipal/Government Level

- Application of slope stabilization techniques or solutions like retaining walls, slope terracing, soil reinforcement through methods like geotextiles and retaining grids to stabilize slopes and prevent landslides.[xxv]
- Establish proper drainage systems to divert water away from slopes to prevent accumulation of excess water in the soil[xxvi]
- Implement erosion control measures such as building sea walls, breakwaters, and revetments to protect the coastline from wave action and erosion and reduce the likelihood of landslides triggered by coastal erosion.[xxvii]
- Elevate buildings and infrastructure and implement coastal setbacks for communities that are at risk of being severely affected by both landslides and rising sea levels.[xxviii]
- Strengthening and proper planning of road and transportation, water supply and sewage systems in case of emergencies in landslide prone areas

- Develop and enforce land use plans and zoning regulations that restrict construction in high-risk landslide areas. This can help prevent new development in vulnerable zones and reduce the potential impacts of landslides on communities.[xxix]
- Fund research and innovation initiatives aimed at developing new landslide adaptation technologies, materials, and strategies
- Participate in international agreements and conventions that address coastal landslide, promoting cooperation and shared knowledge

Case Examples

Case Example 1

The area between Tijuana, Mexico and San Diego, California, faced landslide challenges due to its location on steep coastal land. Their proactive collaboration led to successful coastal landslide adaptation measures. The joint effort of both cities included conducting geotechnical assessments to identify landslide-prone areas, establishing early warning systems, improved data sharing and communication, and adequate drainage systems and slope stabilization measures that successfully significantly reduce the risk of coastal landslides, protecting communities.[xxx]

Case Example 2

Mumbai, located along the Arabian Sea coastline, has made some progress in reducing coastal landslide risks. The city faced landslide challenges due to rapid urbanization, hilly terrain, and monsoon rains. With the combination of scientific assessments like landslide vulnerability assessment, infrastructure improvements like applying slope stabilization measures and drainage infrastructures, community engagement, and disaster preparedness, the city successfully reduced the risk and impact of coastal landslides.[xxxi]

End Notes/References:

[i] https://www.bgs.ac.uk/discovering-geology/earth-hazards/landslides/
[ii] https://unhabitat.org/sites/default/files/download-manager-files/State%20of%20the%20World%20Cities%2020102011%20-%20Cities%20for%20All%20Bridging%20the%20Urban%20Divide.pdf
[iii]https://www.who.int/health-topics/landslides#tab=tab_1
[iv]https://link.springer.com/article/10.1007/s11069-013-0907-4
[v]https://www.downtoearth.org.in/news/africa/2022-durban-floods-were-most-catastrophic-natural-disaster-yet-recorded-in-south-african-province-89047
[vi] https://www.maine.gov/dacf/mgs/hazards/landslides/facts/landslide.htm
[vii]https://www.indiatoday.in/india/story/heavy-rains-lash-coastal-karnataka-woman-dies-in-landslide-2403322-2023-07-07
[viii]https://www.npr.org/2021/07/05/1013145932/80-people-missing-4-dead-as-huge-mudslide-wrecks-japanese-resort-town
[ix]https://www.wsws.org/en/articles/2023/05/29/e143-m29.html
[x]https://www.wsws.org/en/articles/2023/05/29/e143-m29.html
[xi]https://pubs.usgs.gov/of/2001/ofr-01-0276/
[xii]https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_Asia.pdf
[xiii]https://www.cambridge.org/core/books/abs/landslides/physical-impacts-of-climate-change-on-landslide-occurrence-and-related-adaptation/FE48C01D4799F6606A74381A49B866A1
[xiv]https://www.toppr.com/ask/content/concept/landslide-coastal-erosion-206082/
[xv]https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_FullVolume.pdf
[xvi]https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2021GL092959#:~:text=Permafrost%20degradation%20increases%20meltwater%20saturation,may%20contribute%20to%20triggering%20landslides.
[xvii]https://www.travelandtourworld.com/news/article/warning-issued-as-heatwave-causes-landslide-along-jurassic-coast-uk/
[xviii]https://www.theguardian.com/us-news/2021/feb/06/california-highway-1-landslide-climate-crisis
[xix]https://link.springer.com/chapter/10.1007/978-3-030-86211-4_10
[xx]https://sdma.kerala.gov.in/wp-content/uploads/2019/12/IEE-Landslides-of-Kerala-2018_compressed.pdf
[xxi]https://nidm.gov.in/PDF/pubs/Landslide_Preparedness_Guide_.pdf
[xxii]https://www.unisdr.org/preventionweb/files/53056_i3245e.pdf
[xxiii]https://www.mdpi.com/2076-3417/10/19/6718
[xxiv]https://www.mdpi.com/2076-3263/10/4/130
[xxv]https://www.mdpi.com/2076-3263/10/4/130
[xxvi]https://journals.sagepub.com/doi/10.1177/1178622120988722
[xxvii]https://nre.tas.gov.au/Documents/Tasmanian_Coastal_Works_Manual_Chapter_15_Shoreline_Modification.pdf
[xxviii]https://timesofindia.indiatimes.com/blogs/voices/pre-engineered-structures-a-game-changer-in-landslide-prevention-and-disaster-management/
[xxix]https://sdma.kerala.gov.in/wp-content/uploads/2019/12/IEE-Landslides-of-Kerala-2018_compressed.pdf
[xxx]https://www.conservation.ca.gov/cgs/landslides

[xxxi] http://startcc.iwlearn.org/doc/Doc_eng_16.pdf