Coastal hazards Fact Sheets #6: Tropical Storm Coastal Cities

What is Tropical Storm?

A tropical storm is a weather system characterized by strong winds and heavy rainfall that develops over warm ocean waters in tropical and subtropical regions ranging from 63 to 118 km (39 to 73 miles) per hour.[i] It is a rapidly rotating storm originating over tropical oceans from where it draws the energy to develop with a low-pressure centre and clouds spiraling towards the eyewall surrounding the "eye".[ii] The intensity of these storms lies in the intermediate stage, i.e. between loosely organized tropical depressions and intense tropical cyclones, also called hurricanes or typhoons, in different parts of the globe.[iii]

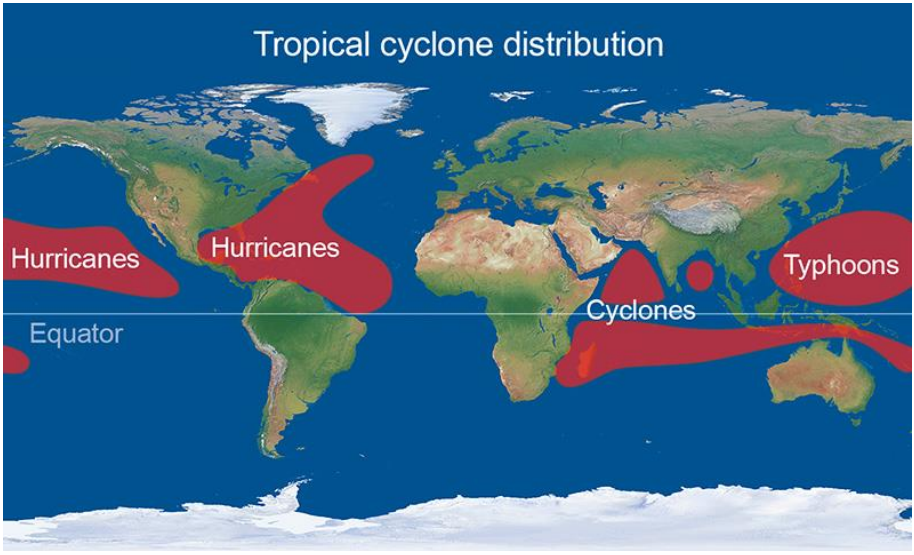

Figure 1: Tropical Storm labelled based on its origin in different parts of the world[iv]

According to the World Meteorological Organization (WMO), in the last half-century, have been 1,942 disasters linked to tropical cyclones, resulting in the loss of 779,324 lives and causing economic losses totaling $1,407.6 billion. On

average, this translates to 43 fatalities and $78 million in damages occurring daily.[v]

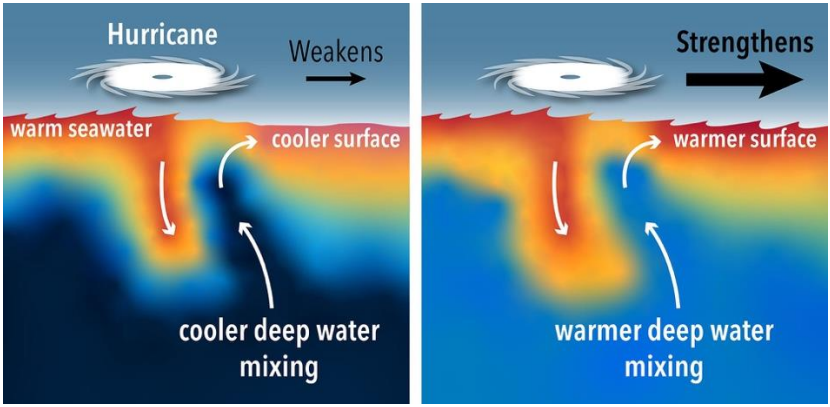

Figure 2: Figure showing hurricanes drawing its energy from warm surface ocean waters[vi]

Causes of Coastal Erosion:

1. Warm Ocean Water: When the sea surface temperature reaches 26 degrees Celsius or more, it provides the necessary heat and moisture to fuel the storm. Warm Ocean water serves as the energy source for the storm.[vii]
2. Atmospheric Instability: Tropical storms thrive in regions where the atmosphere is unstable. This means that warm, moist air at the surface rises and creates a low-pressure system. As this air rises, it cools and condenses, releasing heat and further intensifying the storm. This difference in temperature creates a storm.[viii]
3. Low-Pressure System: A tropical storm begins with the formation of a low-pressure area at the surface. The convergence of warm, moist air into this low-pressure centre sets the stage for further development.[ix]
4. Coriolis Effect: The Coriolis effect, caused by the Earth's rotation, causes a spinning motion rotating counter-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere, which can contribute to the occurrence of tropical storms.[x]
5. Distance from the Equator: Tropical storms typically form over regions more than 5 degrees of latitude of the equator because this is where ocean waters are warm enough to support their development.[xi]

How does Coastal Erosion affect city systems?

City Infrastructure

- Power Grid: Strong winds and falling trees can damage power lines and substations, causing widespread power outages in the city. These outages can last days or weeks, affecting homes, businesses, hospitals, and other essential services.[xii]
- Public Transit: Mass transit systems, including buses and trains, can be severely affected by flooding and power outages caused by the storm. This disrupts the daily commute for many residents and hampers the ability of cities to evacuate people from vulnerable areas.[xiii]
- Transportation Networks: Tropical storms can lead to the closure of roads, highways, and bridges due to flooding, debris, or structural damage.
- Water Supply: Flooding due to the storm can lead to contamination of water treatment plants, which can affect the city's water supply. This can impact access to clean drinking water and create sanitation issues.[xiv]
- Wastewater Treatment: Storm floods can disrupt wastewater treatment facilities, leading to sewage overflows and contamination of water bodies, causing serious health risks.[xv]
- Communication Infrastructure: Tropical storms can disrupt communication networks, including cellular and landline services. This hinders emergency communication and coordination efforts during emergencies.[xvi]
- Housing and Buildings: Residential and commercial buildings can experience structural damage from high winds, flooding, and debris. This can cause high economic costs for repairment of the infrastructures and facilities.
- Essential Facilities: Storms can damage and disrupt essential facilities such as healthcare infrastructure, including hospitals and clinics, schools and education institutes, etc.[xvii]

In 2020, Tropical Storm Isaias in the north eastern United States storm brought strong winds and heavy rainfall, causing extensive damage to the power grid, with thousands of utility poles toppled and numerous power lines downed. Repair teams faced several difficulties while ensuring safety amidst the persistent storm conditions. In certain regions, power restoration went on for several days,

resulting in prolonged electricity outages, impacting businesses, and causing disruptions in their daily lives.[xviii]

In the year 2007, Bangladesh experienced a devastating tropical cyclone called Sidr on November 15th. This potent storm generated waves reaching up to 30 feet, killing over 10,000 lives.[xix] Damages to agricultural engineering infrastructures such as rural roads, embankments, water sanitation, shelters and food security were reported.

Social Impacts

- Loss of Life and Injury: Tropical storms causing floods, high winds, and debris can result in fatalities and injuries among residents, causing physical injuries and trauma.[xx]
- Displacement and Relocation: Tropical storms can force communities to relocate to safer areas, disrupting daily life and adding mental and emotional stress.[xxi]
- Community Disruption and Social Inequity: The displacement can fragment communities and cause social inequity as they are forced to start their lives elsewhere.
- Health and Safety: Tropical storms can cause several accounts of accidents and injuries. Access to healthcare, emergency services, and safe drinking water may also be hampered.[xxii]
- Migration and Urbanization: The displacement caused by tropical storms can also lead to migration to urban areas, causing overcrowding, competition for resources, and social challenges.[xxiii]
- Increased Vulnerability: Vulnerable populations, such as the elderly, disabled, and low-income individuals and children, are often disproportionately affected by tropical storms due to limited resources and mobility challenges.[xxiv]

In 2017, Hurricane Maria struck Puerto Rico with devastating force, leading to a death toll exceeding 2,900 people.[10] 83.9% of children saw damaged homes, 25.5% of youth were forced to evacuate, 32% experienced shortages of food and water, and 16.7% of youth still did not have electricity five to nine months after the storm.[11] Many sought refuge in shelters, and others relocated to the U.S. mainland for better living conditions.

Ecosystem Disruption

- Habitat Destruction: The strong winds of tropical storms can uproot trees, break branches, and damage vegetation, destroying habitats for both terrestrial and aquatic species.[xxv]
- Landslide and Erosion: Tropical storms can lead to coastal erosion and landslides, altering the shape of coastlines.[xxvi]
- Water Pollution: Heavy rainfall and winds can introduce pollutants, sediments, and debris into rivers, lakes, and coastal waters, causing harm to marine species.
- Coral Reefs and Mangroves: The increased wave action associated with tropical storms can cause physical damage to coral reefs and mangrove ecosystems.[xxvii]
- Loss of Biodiversity: Alteration in the habitat of plant and animal species can result in the loss of keystone species.[xxviii]
- Wetlands and Marshes: Storm surges and heavy rainfall can alter wetlands and marshes' water levels and salinity, affecting the flora and fauna that depend on these environments.
- Nesting Sites: Nesting sites for sea turtles and shorebirds may be impacted by tropical storms, causing nest destruction and affecting their breeding.[xxix]

Hurricane Harvey in Houston, Texas, in 2017 caused a devastating impact with high-intensity rainfall. The storm caused widespread flooding in the Houston metro area and carried pollutants in the wastewater treatment plants and industrial facilities of the Gulf of Mexico.[xxx] Over 700,000 gallons of pollutants are released into water or on land, causing adverse effects on aquatic wildlife and fisheries.[xxxi]

How does Climate Change impact Coastal Erosion?

- Changes in Atmospheric Circulation: According to the research conducted by the National Aeronautics and Space Administration (NASA), greenhouse gases alter the natural circulation pattern that influences ozone distribution.[xxxii] Climate change can, hence, alter atmospheric circulation patterns, influencing the movement and behaviour of tropical storms.
- Warmer Ocean Temperatures: According to IPCC Sixth AR, By 2100, the ocean is very likely to warm by 2 to 4 times as much for low emissions (RCP2.6) and 5 to 7 times as much for the high emissions scenario (RCP8.5) compared with the observed changes since 1970.15 Climate change leads to higher sea surface temperatures, providing the energy needed to fuel tropical

storms. Warmer oceans can increase evaporation and moisture in the atmosphere, enhancing storm development and intensification.

- Increased Water Vapor in the Atmosphere: The IPCC Sixth AR Sixth states that the total atmospheric water vapour is increasing by 1 to 2% per decade.[xxxiii] As the GHG emissions increase, temperature increases, increasing water vapour in the atmosphere. This additional moisture can fuel tropical storms, leading to heavier rainfall and potentially more intense storms.
- Warming in the Upper Atmosphere: As per NASA, hurricanes are fuelled by heat in the ocean's top layers and require sea surface temperatures (SSTs) greater than 79 degrees Fahrenheit (26 degrees Celsius) to form and thrive. While the lower atmosphere warms due to climate change, the upper atmosphere cools. The temperature difference can create conditions that are more favourable for storm intensification.

Adaptation Strategies for Coastal Erosion

Community Level

- Identify and create safe shelters within the community that can withstand strong winds and flooding during emergencies caused by tropical storms.[xxxiv]
- Encourage elevated construction techniques to raise homes and critical infrastructure above flood levels.[xxxv]
- Encourage households to maintain emergency food and water supplies that sustain them during and after a storm.[xxxvi]
- Promote community gardens and food-sharing programs[xxxvii]
- Promote livelihood diversification to reduce the community's economic dependence on industries vulnerable to storm damage, such as tourism or fishing[xxxviii]
- Support small-scale businesses and micro-enterprises that can be quickly restarted after a storm[xxxix]
- Develop post-storm recovery plans to facilitate rapid response and aid distribution
- Application of Nature-Based-Solutions like Mangrove restoration, beach nourishment, wetland restoration to manage tropical storms.[xl]
- Implement green infrastructure practices such as rain gardens, permeable pavements, and bioswales to manage stormwater in urban areas.[xli]

- Engage community members to map areas with high risk of tropical storms and encourage vulnerable communities to plan relocation.
- Monitor and research tropical storm patterns, frequency, and the impacts on lives and property.
- Encourage communities to engage in planning and implementing conservation efforts and raising awareness about the risks of tropical storms.
- Educate and create awareness among local communities about tropical storm 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 with training and education in the risks and management of tropical storms.[xlii]
- 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 tropical storms
- Establish early warning systems to monitor and create communication systems about tropical storms to alert residents to potential threats[xliii]

Municipal/Government Level

- Beach and shoreface nourishment in which the sand is spread over the beach where erosion is occurring to compensate shore erosion and restore the recreational value of the beach.[xliv]
- Construction of sea walls and sea dikes, dams, channels, groynes, breakwaters, jetties, and artificial reefs along the coastline to protect land from the impact of waves and storm surges[xlv]
- Update or develop infrastructure and building codes that require erosion-resilient designs and elevated foundations for structures in coastal zones[xlvi]
- Dune construction and strengthening by planting grass, covering the face of the dune with plant debris, construction of fences along the seaward face of the dune to reduce wind speed on the surface and applying combination of hard man-made structures topped with sand, dunes and vegetation.[xlvii]
- Adaptation of storm management plans through grey protection solutions (groynes, break walls) and promotion of green measures, including mangrove restoration and wetland management[xlviii]

- Retreat from high-risk areas by removing infrastructures too close to the beach or rivers without proper authorization by providing compensation and demolition costs[xlix]
- Cliff strengthening and stabilisation, changing the slope angle, and/or reducing cliff heights by removing unstable blocks, eliminating surface runoff and infiltration on the slope, securing unstable rocks to increase cohesion and stability, preventing slippage, etc.
- Building storm surge gates and flood barriers to protect highly vulnerable urban areas and infrastructure where storm surges and sea flooding could have significant impacts[l]
- Strengthening and proper planning of road and transportation, water supply and sewage systems in case of emergencies in landslide-prone areas
- Fund research and innovation initiatives aimed at developing new tropical storm adaptation technologies, materials, and strategies[li]
- Participate in international agreements and conventions that address tropical storms, promoting cooperation and shared knowledge.[lii]

Case Examples

Case Example 1
The city of Bali in Indonesia has been actively promoting green building practices through initiatives such as the Bali Green Building Initiative (BGBI) as a part of Nature Based Solutions to combat natural disasters like tropical storms. BGBI encourages using sustainable materials, energy-efficient designs, and green technologies in construction to reduce the environmental footprint of buildings. Several Indonesian cities have seen an increase in green building certifications, such as Green Building Council Indonesia's (GBCI) certification programs. These certifications encourage sustainable construction and renovation practices.[liii]

Case Example 2
Over the last four decades, there has been a remarkable reduction in cyclone-related fatalities in various cities in Bangladesh, decreasing by more than 100 times. In 1970, cyclones claimed the lives of 500,000 individuals, whereas in 2007, the number dropped significantly to 4,234.17. Khulna, a major city in southwestern Bangladesh, has implemented adequate measures to combat tropical storms and cyclones. The city is located along the coastal region and is vulnerable to storm surges. Success stories in Khulna include the construction of

cyclone shelters, early warning systems, and the planting mangrove forests to act as natural barriers against storm surges. Chittagong, the second-largest city in Bangladesh and a major coastal port city has improved drainage systems, built cyclone shelters, and developed early warning systems to protect its residents from storm-related hazards.[liv]

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