# Mother Earth

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**"Fund Resilience, Not Disasters"**

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# Content

# Indigenous Technical Knowledge (ITK) vis-à-vis Disaster Risk Reduction (DRR) in the Sundarbans

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The Sundarbans, located at the mouth of the Ganga-Brahmaputra-Meghna delta across India and Bangladesh, is the world's largest mangrove ecosystem and home to over five million people. This fragile region faces frequent natural hazards like cyclones, tidal surges, saline water intrusion, riverbank erosion, and floods. Despite these challenges, local communities have evolved unique Indigenous Technical Knowledge (ITK) systems that help them coexist with nature's uncertainties. Integrating these traditional practices with modern disaster management strategies is crucial for sustainable Disaster Risk Reduction (DRR) in the delta.

The inhabitants of the Sundarbans, primarily small farmers, fishers, and honey collectors, have developed a deep understanding of their environment through generations of observation and adaptation. Their ITK reflects a delicate balance between ecological wisdom and livelihood resilience. Local people have long relied on natural indicators to anticipate storms or tidal surges as early warning systems. Sudden silence or abnormal flight patterns of birds, especially herons and egrets, are taken as signs of approaching cyclones. Changes in wind direction, cloud colour, or tidal behaviour warn communities of impending storms. The behaviour of livestock refusal to graze, agitation, or restlessness also acts as a traditional early warning cue.

Houses in the Sundarbans traditionally use locally available materials such as *golpata* (Nypa fruticans), bamboo, and mud, which are flexible and resilient against strong winds. *Chunari* (thatched roofs with gentle slopes) reduce wind resistance. Houses are elevated on earthen plinths or stilts to prevent floodwater entry. Settlements are usually located near embankments but slightly elevated, reducing exposure to tidal floods. Given the saline-prone soils and tidal floods, farmers have evolved adaptive practices like raised field cultivation and paddy-cum-fish farming allow simultaneous rice and fish production, maintaining food security even during inundation. Indigenous paddy varieties like *Matla*, *Talmugur*, and *Hamilton* are salt-tolerant and survive in brackish water conditions.

The social fabric of the Sundarbans is a key element in disaster resilience. Informal groups, women's self-help collectives, and traditional village councils (*gram samitis*) coordinate evacuation, food distribution, and post-disaster rebuilding. Folk songs and local legends embed environmental awareness and warnings, transmitting DRR messages across generations. Rituals like worship of *Bonbibi*, the forest deity, symbolize a moral code of harmony with nature indirectly promoting sustainable resource use and caution in risky zones.

Modern DRR programmes such as cyclone shelters, embankment engineering, and satellite-based forecasting have improved safety, but their impact grows stronger when combined with community knowledge. NGOs and research institutions now document traditional salt-tolerant crops and housing techniques to incorporate them into formal adaptation plans. Participatory mapping of vulnerable areas involves elders who hold spatial memory of historical cyclone paths and erosion-prone sites. Hybrid approaches, blending scientific early warning systems with indigenous communication channels, enhance last-mile connectivity.

Therefore, integrating ITK into formal DRR frameworks such as the Sendai Framework and India's National Disaster Management Plan requires systematic documentation and validation of local practices, capacity building that values both science and tradition. In DRR planning and implementation inclusion of community representatives are essential for better tomorrow.

# Cosmic Hazards:
# Solar Storms and Geomagnetic Threats to Earth

**Dr. Sumanta Das, Assistant Professor, School of Environment and Disaster Management, RKMVERI**

Cosmic hazards arising from solar activity represent one of the most significant natural space weather threats to modern civilization. Among these, solar storms and their associated geomagnetic disturbances have profound implications for Earth's technological infrastructure, global communication networks, and even climate variability.

Solar storms primarily originate from two solar processes: solar flares and coronal mass ejections (CMEs). Solar flares are sudden releases of electromagnetic energy from active regions on the Sun, often linked to sunspot activity. They emit intense bursts of X-rays and ultraviolet radiation that can disrupt Earth's ionosphere, affecting radio wave propagation and satellite communications. Coronal mass ejections, on the other hand, involve the expulsion of massive clouds of plasma and magnetic fields from the solar corona into interplanetary space. When these ejections are Earth-directed, they can trigger geomagnetic storms upon interacting with the planet's magnetosphere.

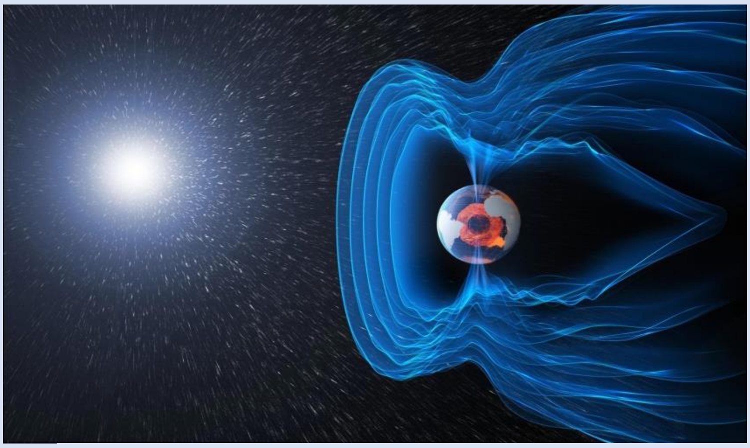


Fig: Earth's magnetic field, shaped by electric currents, exerts powerful forces that strongly influence daily life. It acts like a vast protective shield, deflecting cosmic radiation and solar wind particles from reaching the planet. [Source: ESA/ATG medialab]

The magnetosphere serves as Earth's primary defense against charged solar particles, but strong CMEs can compress it significantly, injecting large amounts of energetic particles into the upper atmosphere. This interaction produces geomagnetic storms characterized by rapid fluctuations in Earth's magnetic field. Such events induce geomagnetically induced currents (GICs) within ground-based conductors, posing severe risks to power transmission networks, oil pipelines, and railway systems. Historical incidents, such as the 1859 Carrington Event and the 1989 Hydro-Québec blackout, demonstrate the catastrophic potential of extreme solar storms. The Carrington Event, for example, disrupted telegraph systems worldwide and produced auroras visible near the equator, while the 1989 storm led to widespread power outages affecting millions. Beyond infrastructure damage, geomagnetic storms pose risks to space-based technologies. Satellites in low-Earth orbit can suffer from surface charging, drag variations due to atmospheric expansion, and potential loss of navigation accuracy in global positioning systems (GPS). Astronauts aboard the International Space Station (ISS) or deep-space missions are also exposed to elevated radiation doses during major solar particle events.

Predicting and mitigating the effects of solar storms remain a major challenge. Space weather forecasting relies on solar observatories, such as NASA's Solar Dynamics Observatory (SDO) and the ESA-NASA Solar and Heliospheric Observatory (SOHO), which monitor solar activity and provide early warnings of CMEs. Ground-based magnetometers and ionospheric sensors further contribute to real-time assessments of geomagnetic disturbances. Nevertheless, accurate prediction of storm intensity and arrival remains limited by gaps in understanding of solar-terrestrial coupling processes. Mitigation strategies involve reinforcing critical infrastructure against geomagnetic interference, developing resilient grid systems with protective devices, and establishing international coordination for space weather alerts. In the longer term, advancing heliophysics research and deep-space monitoring platforms will be vital to strengthening global resilience.

While Earth's magnetic field provides partial protection, the reliance on interconnected electronic systems amplifies exposure to space weather risks. Therefore, proactive investment in scientific monitoring, engineering safeguards, and global preparedness is important to manage the enduring challenge posed by solar activity and geomagnetic effects.

# Next-Gen Satellite Grids for Rapid Disaster Response

**Dr. Malini Roy Choudhury, Assistant Professor, School of Environment & Disaster Management**

In recent time, a number of natural disasters at varied magnitude and frequency are increasing on different scales mainly due to impact of climate change. This has imposed unparalleled burden on global emergency response systems. The world realized there is an urgent need for an accurate and fast response system which acts as a determinant in improving infrastructural resilience, minimizing life loss, and aids in recovery. Although, conventional satellite based systems like Geostationary Operational Environmental Satellites (GOES), Indian National Satellite System (INSAT) is reliable for disaster management. But their latency, areal coverage, and fractional communication have often resulted in delayed decision making during critical hours.

This gap has been bridged by a major shift towards the use of Next-Generation Satellite Grids with their detailed global coverage, real-time information, and connectivity that have enhanced effectiveness and speed of disaster response in emergencies. These grids are now able to provide continuous information on earth from updated digital map through low Earth Orbit (LEO) satellites, supported by laser interlinks and AI-data analytics system. This ensures fast response and timely actions involving government, other organizations to act smartly and quickly at the time of impending disasters like cyclone, earthquake etc. The advantages lie in its revolutionary autonomous, laser interlinked, self-healing designed satellite system that helps through self-coordination, and prevents any data loss even during disruptive disaster emergency. This ensures live, uninterrupted communication systems which conventional satellites have failed to provide.


In addition, orbit edge computing feature with the on-board satellites enables AI based anomaly detection, categorization of severely damaged regions for generating emergency alerts. The dramatic and remarkable effects have been witnessed in flood prone areas where the algorithm in satellite grid accurately predicts riverine floods and ensures prior evacuation systems. On the other hand, real-time fire spreads are monitored by heat-detection system to provide accurate information to the firefighting tanks for the precision. In post-earthquake situation the grid can detect structural damages to guide drone operations for search and rescue missions.

The next-generation satellite with its secure, tiered information access have now become open source and shared through platforms. This has immensely improved coordination between the response of the stakeholders and community resilience. As the launch prices going down, more efficient and smaller satellites are placed on orbit at much less cost, and the once distant dream of global high tech satellites networks now became fully operational. These next-gen satellite grids with high-end space technology, artificial intelligence, and man-made innovation have shielded the life on earth.  Post disaster, during crucial hours, this new satellite constellation network ensures live monitoring, instant response coordination, and maintains continuous communication by enabling smart, effective disaster response than before.

# Disaster-Resilient Built Environment of the Coastal Sundarbans

**Dr. Mahadev Bera, School of Environment and Disaster Management, Ramakrishna Mission Vivekananda Educational and Research Institute, Narendrapur, Kolkata 700103**

The Sundarbans, the world's largest mangrove delta, stands at the frontline of climate change impacts. The coastal regions of the Sundarbans, located at the Ganga–Brahmaputra–Meghna delta, regularly face climate-induced disasters that damage infrastructure. Frequent tropical cyclones, saline water intrusion, flooding, and erosion have rendered traditional construction methods unsustainable. Most rural buildings, made from mud, thatch, bamboo, or unreinforced bricks, are vulnerable to extreme weather. This ongoing destruction leads to economic losses and weakens community resilience. Thus, prioritising disaster-resilient infrastructure is essential for safety, sustainability, and adaptive capacity in an increasingly challenging climate.

**(a)**

**(b)**

**Figure:** Low-cost dwellings in the Indian Sundarban region illustrating typical rural housing structures. (a) The first image shows a house with corrugated asbestos roofing and bamboo mud walling, commonly used for affordability and ease of construction. (b) The second image depicts a tiled roof partially covered with thatch, which is secured by a rope net to prevent the thatch layer from being damaged or displaced during storms- an adaptive local measure to enhance structural resilience in the cyclone-prone coastal environment

Climate-smart building design in the Sundarbans should utilise locally available materials and incorporate modern engineering principles. Stilted foundations are vital for protection against tidal flooding and storm surges. Using reinforced cement concrete (RCC) with corrosion-resistant bars, fly ash bricks, and salt-tolerant cement enhances structural strength against salinity. Aerated concrete blocks or stabilized mud blocks improve thermal comfort and reduce carbon footprint. Aerodynamic roof designs and anchoring systems mitigate wind uplift during cyclones, while locally sourced bamboo and treated timber add flexibility and shock absorption.

Community-centric, resilient infrastructure, such as cyclone-resistant schools and health centres, is crucial for emergency evacuation and recovery. Recent developments include elevated multipurpose cyclone shelters that serve as community halls, equipped with a renewable energy system, rainwater harvesting, and sanitation facilities. Elevated storage for food grains and medical supplies, as well as modular housing clusters connected by elevated walkways, further bolsters disaster preparedness and enhances living conditions in vulnerable regions.

Building material innovation is key to resilience in the Sundarbans. Composite materials like bamboo fiber and jute combined with polymer resins provide an affordable, lightweight, and durable alternative to traditional masonry in saline conditions. Research shows that geopolymer concrete made from by-products like fly ash performs better against saltwater than Portland cement. Green roofing and porous paving enhance drainage and reduce waterlogging and erosion around settlements. Passive ventilation, bioclimatic design, and shading improve indoor comfort while reducing reliance on energy-intensive cooling systems.

Urban and rural planning should adopt an eco-engineering approach aligned with natural topography and hydrological flow. Construction in flood-prone areas must adhere to zoning regulation and elevate critical infrastructure. Integrating mangroves and salt-tolerant vegetation can act as windbreaks, while resilient transport networks like elevated roads and flexible bridges improve accessibility during extreme events.

In conclusion, building infrastructure resilience in the Sundarbans requires combining indigenous knowledge, scientific innovation, and adaptive governance. The future of housing and community buildings in this delta lies in integrating structural strength, ecological compatibility, and social inclusivity. By promoting modular, low-cost, cyclone-resilient construction rooted in local culture and supported by engineering, the Sundarbans can become a climate-resilient habitat capable of withstanding natural hazards while fostering a sustainable relationship with its unique ecosystem.

# Nature's First Responders: Role of Blue Carbon Ecosystems in Coastal Disaster Risk Reduction (DRR)

**Diksha Kar**

Globally, coastal communities are at the forefront of climate change. Climate-related sea-level rise, more frequent and intense storms, and recurrent flooding have turned disaster risks into an everyday reality for millions of inhabitants. In the midst of increasing threats, blue carbon ecosystems like mangroves, tidal marshes, and seagrasses are surfacing as nature's partners in disaster risk reduction (DRR). With their widely recognized capacity for carbon sequestration and storage, these ecosystems also provide the most important protection to coastlines and livelihood.

One of the most essential roles of blue carbon ecosystems is serving as natural buffers against coastal threats. Mangroves, with their complex root networks, stabilize coastlines by sediment trapping and minimizing erosion. When storm surges or cyclones hit, mangrove belts dissipate much of the energy of the waves, lessening the impact that ultimately reaches coastal settlements. Research has found that even a 100-meter-wide mangrove belt can substantially reduce wave height, hence reduce flood hazard and minimize damage to infrastructure. Seagrass beds and tidal marshes also play their part by filtering wave action and trapping sediments, further enhancing coastal resilience.

These ecosystems offer much more than just physical protection in terms of ecological services. They help coastal communities remain resilient economically and socially by preserving healthy fisheries and supplying wood, honey, and other resources. In times of crisis, livelihoods rooted in these ecosystems frequently serve as safety nets. For instance, fishing or collecting crabs from mangrove areas offers an alternative source of income when flooding damages agricultural fields.

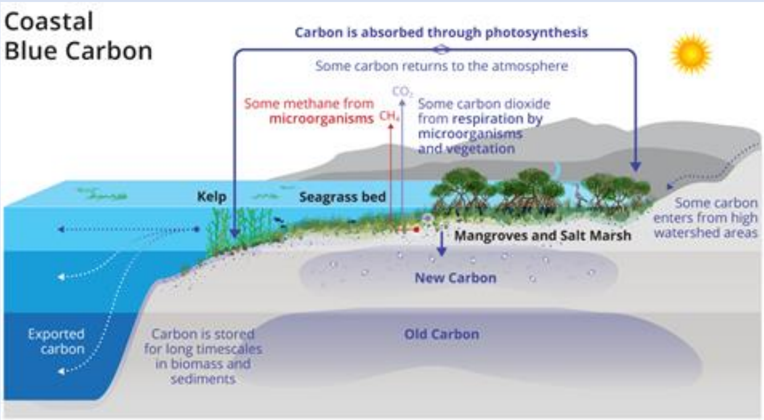



Figure: Coastal blue carbon (Understanding Blue Carbon, 2022)

Blue carbon ecosystems are so important in a comprehensive DRR framework because of this interconnection between ecological and social systems. Yet, their contribution towards disaster resilience is rarely valued in policy and planning. Coastal development, aquaculture expansion, and pollution continue to damage these ecosystems at alarming levels. Blue carbon ecosystems must be seen as living infrastructure rather than as disposable land in order to be incorporated into DRR plans. Investments in disaster preparedness should include restoring damaged mangroves, protecting seagrass meadows, and managing tidal marshes sustainably. It is encouraging that a number of coastal countries have begun implementing ecosystem-based approaches to DRR, which integrate contemporary conservation techniques with traditional knowledge.

At the same time, in India's Sundarbans, nature and innovation coexist. An experiment in "living shoreline" has placed thousands of terracotta silt-traps along embankments to trap sediments, allowing mangroves to naturally regenerate. Between May 2023-August 2024, or sixteen months, these traps have accumulated sediment with a depth of 4-42 cm; during late/post-monsoon periods, new Avicennia marina mangrove sprouts appeared in most locations.

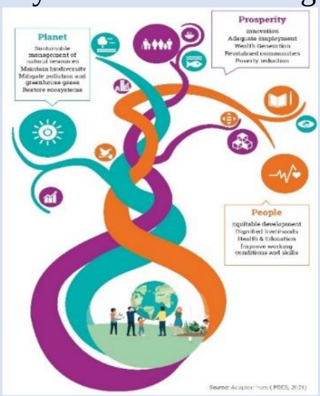
Blue carbon ecosystems are not backgrounds to human activity—they are line-of-defence defenders. From shielding against storm surges, saving lives, rescuing economies, to restoring coasts, these ecosystems hold promise in a warming world. The test now is to ensure their protection, restoration, and judicious integration into our shared defence against climate-driven calamities.

# Food Security and Supply Chain Resilience in Disaster Risk Reduction

**Br. Soumitra**

In an era of increasing global and national climatic conditions, geopolitical tensions, pandemics, and economic shocks, ensuring food security has become a critical global challenge. Addressing this issue is strengthening supply chain resilience within the wider framework of Disaster Risk Reduction (DRR). Disaster Risk Reduction (DRR) is a crucial framework to identifying, assessing, and reducing the risks of disasters. It involves efforts to minimize vulnerabilities and avoiding or mitigating the negative impacts of hazards and to strengthen the capacity to cope with the negative impacts of hazards. While often focused on immediate infrastructure and human safety, a more holistic approach integrates food security and supply chain resilience. Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. As well as Supply Chain Resilience refers to a supply chain's capacity to withstand, adapt, and recover from shocks. A resilient food supply chain is one that can maintain its function and performance, ensuring that food remains available, accessible, and safe even when facing severe and unpredictable disruptions. When disasters strike, whether they are natural calamities like floods and earthquakes or man-made crises, the disruption to food systems can be immediate and severe. By embedding resilience into food systems, nations can better prevent, prepare for, respond to, and recover from disasters—whether natural or man-made. This disruption often leads to a humanitarian crisis long after the initial event. This is not merely an option but a necessity, as a growing body of research and recent global events have demonstrated the profound link between disasters and food system fragility. In the agriculture sector is disproportionately impacted by disasters, absorbing approximately 22% of the economic impact of medium- and large-scale natural disasters in developing countries. This vulnerability is multifaceted. Disasters like floods and earthquakes can cause physical destruction of farms, transportation routes, and storage facilities. Furthermore, systemic shocks, such as the COVID-19 pandemic, highlighted the fragility of highly optimized, just-in-time food supply chains. Border closures and labour shortages revealed that a focus on efficiency over resilience can lead to a humanitarian crisis long after the initial event. These disruptions often lead to price volatility, reduced food availability, and increased malnutrition, particularly in vulnerable communities.

To enhance food security in the context of DRR, we must focus on several key areas for Enhancing Resilience. *Risk Assessment and Mapping:* Understanding hazard-prone areas and vulnerable populations helps in planning food storage, transportation routes, and distribution networks that are less exposed to risks. *Climate-Smart Agriculture*: Promoting practices such as drought-resistant crops, sustainable land use, and water-efficient irrigation that help farmers adapt to changing weather patterns, reduce the risk of crop failure and enhances long-term productivity and reduce greenhouse gas emissions, is a critical long-term strategy. This approach not only secures future food production but also contributes to mitigating the very climate risks that fuel more frequent and intense disasters. *Early Warning Systems and Data Monitoring:* Predictive analytics and satellite imagery can help anticipate real-time data on weather, crop health, and market conditions enable proactive responses (like pre-positioning food stocks) to disruptions. *Public-Private Partnerships*: Collaboration between governments, businesses, and NGOs ensures that resources, technologies, and expertise are pooled for faster and more effective crisis management. *Community Empowerment*: Training farmers and local stakeholders in risk management and sustainable practices ensures grassroots-level preparedness and adaptability.




Strengthening food security through resilient supply chains is not just a response to disaster but a proactive investment in sustainable development. By embedding resilience into every stage of the food system—from production to consumption—communities can better withstand shocks and ensure stable food access for all. Disaster Risk Reduction (DRR) strategies that prioritize food security are crucial for building a future that is equitable, sustainable, and disaster-resilient.

# The Role of COP30 (Belém 2025) in Strengthening Climate-Disaster Synergies

**Abhijit Pal**

The upcoming COP30 (Belém 2025) will be an important moment for climate action, as it will be held for the first time in the Amazon. This place is very symbolic because the Amazon is not only one of the most important ecosystems on Earth, but also a region that faces many climate-related disasters. In recent years, floods, cyclones, droughts, and extreme heat have become more frequent, showing the urgent need to link climate action with disaster risk reduction (IPCC, 2021). COP30 is expected to go beyond talks on emission reduction and also focus on adaptation and resilience. Following the Sendai Framework for Disaster Risk Reduction (UNDRR, 2015) and the goals of the Paris Agreement, the summit will try to turn promises into real action. By giving importance to finance, inclusion, and indigenous knowledge, COP30 can create strategies that protect both nature and people (UNFCCC, 2023).


### Issues / Challenges:

- Intensification of climate-related disasters such as cyclones, floods, and droughts (IPCC, 2021).
- Weak alignment between Nationally Determined Contributions (NDCs) and disaster preparedness.
- Shortfalls in adaptation and resilience finance (UNFCCC, 2023).
- Barriers to participation, excluding vulnerable groups.
- Conflicts between fossil fuel exploration and forest conservation.

### Goals:

- Align climate action with disaster risk reduction principles (UNDRR, 2015).
- Strengthen and revise NDCs to reflect both emissions and resilience objectives.
- Scale up finance for early warning, resilient infrastructure, and health systems (WHO, 2024).
- Empower Indigenous peoples and local communities as central actors in resilience strategies.
- Enhance equity and livelihood security in vulnerable regions.

### Opportunities:

- Position the Amazon as a global symbol of forests as climate regulators and disaster buffers.
- Operationalize the Tropical Forests Forever Facility (TFFF) and expand long-term climate finance.
- Adopt the Global Mutirao concept to promote inclusive, multi-level participation.
- Combine traditional knowledge with scientific DRR approaches for context-specific solutions.
- Reframe resilience as a security and development priority at the global level.

### Expected Outcomes:

The COP30 can help bring climate policies and disaster management closer together. The new NDCs could then focus not only on cutting emissions but also on building adaptation. The summit may also create systems for forest protection, Indigenous-led actions, and community disaster planning, while at the same time increasing funds to support resilience in countries that are most at risk. Most importantly, COP30 can change the global climate agenda from only making promises to actually taking action, with resilience, inclusion, and fairness placed at the center of climate decisions (IPCC, 2021; UNFCCC, 2023).

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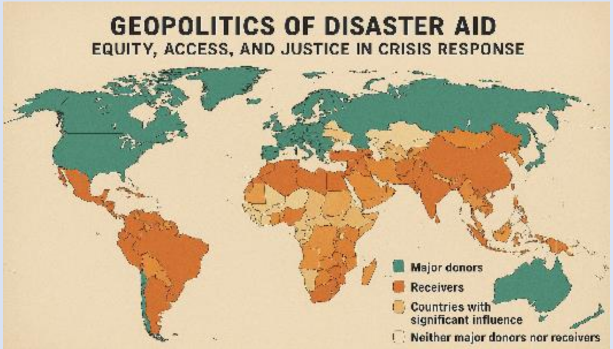
# Geopolitics of Disaster Aid: Equity, Access, and Justice in Crisis Response

**Suchismita Roy**

## Aid as the New Battleground of Soft Power

Disasters are not local tragedies any more. In a connected world, the aftershocks of a cyclone in the Bay of Bengal or a pandemic in Wuhan or a war in Eastern Europe reverberate across continents. Supply chains seize up, migration surges, and global markets quake. Disaster assistance, then, is not just about helping the needy; it is also about shaping global stability and international order. And yet the politics of aid, who gets it, who controls it and whose suffering counts, continues to be one of the clearest indicators of global power relations.




## The Global Cartography of Compassion

Equity in disaster aid lays bare the raw global hierarchies of compassion. Some crises rally billions overnight the 2004 Indian Ocean tsunami, the Haiti earthquake in 2010 or Ukraine in 2022. Others, such as the repeated waves of famine in the Sahel or South Asian floods, attract only a fraction of that attention. This discriminating generosity is not arbitrary. Geopolitically strategic or media-visible regions may fail to avoid being dragged into disasters, no matter how prepared, whereas marginalised corners of the world remain invisible emergencies. The result is an atlas of empathy in which suffering is not mapped according to its intensity but rather according to its strategic value. One helpful way to frame it is that human suffering is a traded commodity. Some lives yield high "market value" in the global conscience; others, while equally precarious, stay discounted.

## The Gatekeepers of Sovereignty

Access to disaster aid usually has less to do with need and more to do with politics. The Myanmar junta in 2008 favoured letting people die after Cyclone Nargis rather than allowing foreign workers to come and help. Then, in countries under sanction, such as Syria or North Korea, there may be legal limitations that make the delivery of food or medical kits difficult. This brings to the fore a difficult global question: is sovereignty more valuable than survival? Humanitarian principles dictate neutral access, but geopolitics frequently weaponises aid, making border crossings bargaining chips. In a connected world, the denial of assistance is not simply a tragic national problem; it destabilises whole regions with refugee flows, disease and spill-over conflicts.

## Climate, History, and the Unequal Burden

The most immediate and overlooked dimension is justice. Disasters are no longer just "acts of God"; they are exacerbated by climate change, advanced disproportionately from industrialised economies. But the regions most ruined by climate change small islands inundated by rising seas, African nations parched for water and delta cities in Asia that are sunk or underwater already are responsible for almost none of it. Justice thus requires more than charity; it requires climate reparations. The incomplete annual commitment of $100 billion for climate finance and the snail's pace on progress toward the Loss and Damage Fund demonstrate how rich countries are more than unwilling to grapple with historical responsibility; they'd rather obfuscate. Without the infusion of justice into aid, the world risks widening divisions between North and South.

## Disaster Aid as a Global Moral Compass

In a century in which pandemics, cyclones, wildfires and conflict will only proliferate, the response to disaster aid has emerged as one of the most visible indicators of whether humanity can act like a community or continue to fracture along lines of power. It is clear what the challenge is: turning aid from a geopolitical bargaining chip into a global public good. Less than that will not only fail the vulnerable — it will fail the idea of humanity.

# Epidemic–Disaster Nexus: Pandemic Preparedness in a Multi-Hazard World

**Dr Saurabh Kole**

The epidemic–disaster nexus is the strong connection between disease outbreaks and disasters. In many situations, disasters and disease outbreaks happen together, compounding the problems each causes on its own. After any disaster, such as a flood or earthquake, some people need to leave the area; sanitation breaks down; and clean, potable water is not available. These create optimal conditions for diseases to be transmitted between individuals. Conversely, when a sizable epidemic is already occurring, that epidemic may inhibit communities from coping effectively with the natural disaster.

There are many historical examples of the epidemic–disaster nexus. The 1918 influenza pandemic occurred during a time when the world was recovering from World War I, and the pandemic spread rapidly through soldiers and displaced persons in Europe. In Haiti in 2010, after the earthquake, many cholera cases were discovered, because a cholera clean water system had been destroyed. The Ebola outbreak (2014–16) in West Africa was in and of itself a disaster, but the situation was exacerbated due to the status of the health system pre-crisis. The most recent example is the COVID-19 pandemic, which clearly became a global disaster. The results of the pandemic were not limited to illness, but job loss, economic situations, and overburdening of hospital and medical services were also challenges related to the pandemic.

Today, we live in a multi-hazard world. Climate change is increasing the frequency of natural hazards such as flooding, heatwaves, and storms. Increasingly crowded cities and rapid urbanization are enabling the spread of infectious diseases. With international travel, there is the potential for infections to cross borders in a matter of hours. In many countries, health systems are fragile and ill-equipped to respond to any shock. At the same time, poverty and inequality place particular groups at an increased level of vulnerability, and when combined with these risks, pandemic preparedness has never been harder.

We need health systems that are strong and resilient, and hospitals and clinics are not just for daily health needs but also for the needs of a crisis; preparedness plans must provide interoperability between disaster management and community epidemic control, and not treat them as separate entities.

Being able to identify early warning signs of unexplained illness in the community, monitoring for outbreak detection and reporting, and rapid response to prevent spread need to be a priority. If illness outbreaks can be contained or prevented before widespread transmission, the health risks will be reduced. New technologies, including smartphones in combination with data systems, are providing new opportunities in public health, but integrating technology into communities can often be a barrier. Therefore, access to advanced community preparedness must be a priority, together with surveillance. Individuals who are aware of how to protect themselves from illness in a pandemic, and who trust health recommendations, are less likely to panic and less likely to believe misinformation.

Training healthcare professionals, as well as strengthening laboratories and maintaining emergency stocks, are critical components. It is also essential for resources to be shared equitably, and for cooperation to take place across countries; diseases do not recognize borders. The COVID-19 pandemic demonstrated that equitable and transparent distribution of vaccines and information is essential.

The key lesson we learned is that we cannot prepare for one hazard at a time. A pandemic or epidemic could accompany a flood, a cyclone, or a political crisis. Only by taking a multi-hazard approach—planning for two or more threats happening at the same time—can we truly protect our communities.

In summary, the epidemic–disaster nexus reminds us that health emergencies and disasters are intertwined. By enhancing health systems, integrating disaster response with pandemic preparedness planning, and launching cross-country collaborative efforts, we will be better prepared for the next time. Preparedness is not just about the next outbreak, but about ensuring that we can withstand whatever comes next.

## Smart Cities and Risk-Informed Urban Planning

**Sujan Mandal**

The pace of urbanization in our world is breathtaking. An estimated 70% of the global population will reside in cities by the year 2050. Such growth presents a great opportunity and a corresponding concentration of risk. As superstorms and flash floods driven by climate change, pandemics, and infrastructure failures pummel them, modern cities are rife with particular and overlapping threats. The answer is not bigger buildings, but smarter buildings. And herein lies the intersection of Smart Cities and risk-informed urban planning – a valuable new paradigm for urban resilience.

A smart city is not all about glitzy devices and a city-wide Wi-Fi system. Put simply, it is a city that uses data and technology to enhance the lives of its citizens. This consists of a complex web of sensors, connected devices (so-called Internet of Things or IOT), and advanced data analytics platforms. They optimize everything between traffic, energy usage, waste management, and public services. But the true power of a smart city resides not in efficiency but in safety and resilience, which comes from using this technological nervous system. This is the foundation of risk-informed urban planning: proactive measures that leverage data to understand, anticipate, and minimize shocks and stresses.

Urban planning has historically been based on existing data and static models. Dynamic and forward-looking, risk-informed planning is fueled by a smart city infrastructure. Here's how it works:

**Observe and Predict:** The IoT sensors installed all over the city function as its eyes and ears. Real-time data is captured from river level monitors, seismic sensors, air quality stations, and smart weather systems. 10 This torrent of information can then be sent to AI and machine learning algorithms to analyze and predict disasters about to happen. An AI, for instance, can take meteorological data, topography maps, and smart drain sensor readings to accurately simulate a possible flash flood and predict what streets will be flooded and at what time.

**Pre-alerting and Alerting:** After the recognition of a possible threat, the integrated communication network of a smart city becomes vital. It can send targeted notifications on mobile devices in precise areas of risk rather than a single, broad siren, alter digital road signs to redirect traffic away from peril, and even activate emergency broadcast alerts. This means quicker, neater evacuations and response.

**Receiving and Adjusting:** While smart technology offers the best situation in a crisis. Or think how drones are going to the unreachable place, real-time traffic data enabling emergency services to bypass a gridlock and reach the victims much faster than they could before. This same data provides an ideal opportunity to assess the impact of an event and inform how to build and bolster an increasingly more resilient infrastructure in the likely not-too-distant aftermath.

**Cities around the globe have been drawing on these principles**:

- An elaborate array of sensors supplies one of the most sophisticated earthquake early-warning systems on the planet **in Tokyo** that grants citizens seconds to duck for cover.
- Sophisticated modeling underlies **Singapore's** water-resource management, allowing the country to anticipate rainfall and maximize reservoir and drainage systems for both droughts and floods.
- Anonymized mobility data has allowed cities to map how the crisis spreads and efficiently allocate testing and vaccination sites to respond.

Naturally, there are pitfalls on this path. But data privacy, cybersecurity, and the digital divide (making sure everyone has access to these kinds of life-saving technologies) are also concerns of the highest order. If the most marginalized demographics in a city are excluded, that city is not resilient. An over-reliance on technology with insufficient backup plans can also be a weakness in its own right.

In the end, we need to build cities that are not only smart but essentially wise as well. Merging the potentials of smart technology and risk-informed planning, we can create communities that function efficiently and easily, but which are also safe, equitable, and genuinely resilient for the future.

# Retrofitting Critical Infrastructure against Earthquakes and Floods

**Mir Wasif Ahammed**

During the last few years, the world has started to focus on vital infrastructure because natural disasters including earthquakes and floods have become more severe during the last few years. The method of upgrading current buildings to handle natural disasters through retrofitting has become essential for disaster risk reduction and resilience planning. The majority of urban infrastructure worldwide exists in areas that experience seismic activity while climate change has made flooding more dangerous because extreme rainfall events have grown by 30% since 1950. India contains about 60 percent of its territory exposed to earthquake danger and more than 40 million hectares of land face flooding risks. The economic cost reached extreme levels because the 2015 Nepal earthquake resulted in $10 billion of destruction and the 2022 Pakistan floods forced 33 million people to flee their homes while causing $30 billion in damages.

## Retrofitting for Earthquake Resilience

Retrofitting for earthquakes is not about making a structure invincible; it's about giving it the ability to "bend, not break." Several advanced techniques have proven highly effective in upgrading existing infrastructure for seismic resistance.

- **Base Isolation** systems are working by separating buildings from ground vibrations which results in major decreases in building movement and damage to structural parts that produces the greatest reduction in building sway and foundation forces which makes it the best solution for protecting critical facilities.
- **Fiber-Reinforced Polymers (FRPs)** serve as revolutionary contemporary materials which bring transformative changes to modern technology. The lightweight high-strength fabrics or sheets wrap around columns and beams to boost their structural strength and flexibility while keeping the added weight very low.
- Well-documented case studies, the 1993 Latur earthquake in India, underscore the life-saving impacts of such strategies and highlight the economic efficiency of preventive versus post-disaster repairs.

## Retrofitting for Flood Resilience

Infrastructure such as substations, hospitals, and water treatment plants are particularly susceptible to inundation, resulting in prolonged outages and high restoration costs.

- The installation of rain gardens and bio-swales and permeable pavements and detention ponds within urban areas provides an effective solution for reducing neighbourhood flooding.
- The implementation of barriers together with water-resistant construction materials leads to decreased property damage and fewer expensive repairs which produces cost-benefit ratios that go beyond 5:1 for each dollar allocated.
- The use of natural systems stands as an effective method for retrofitting according to Nature-Based Solutions. Wetlands and mangroves and floodplains serve as natural flood barriers which absorb water flow to protect levees and seawalls from damage.

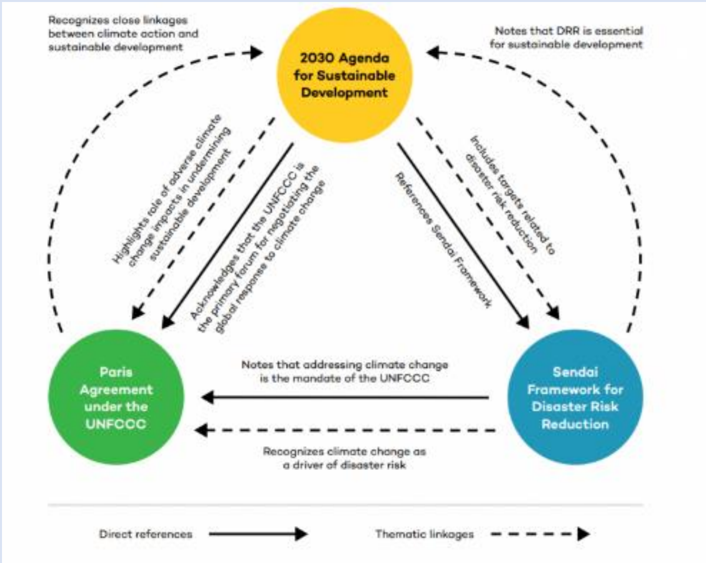
Emerging frameworks advocate for prioritizing retrofitting investments based on location-specific hazard models and asset criticality. The combination of earthquake and flood resilience strategies generates multiple advantages because these strategies prevent harm from one hazard mitigation approach from creating new risks for other hazards. Investing in resilient infrastructure becomes essential because climate change and seismic risks create a dangerous combination which threatens vital services and human safety and sustainable development. The upcoming era requires more than reconstruction since we must advance toward superior development frameworks.

# Mainstreaming DRR in Nationally Determined Contributions (NDCS)

**Priti Biswas**

The Paris Agreement's Nationally Determined Contributions (NDCs) are crucial for countries to develop climate action plans aimed at reducing greenhouse gas emissions and adapting to climate change impacts. These pledges aim to limit the global temperature rise to below 2°C and 1.5°C above pre-industrial levels. Each country must prepare, communicate, and maintain successive NDCs at five-year intervals, allowing countries to increase their commitments and integrate a wider set of climate-related policies, including Disaster Risk Reduction (DRR). The Paris Agreement aims to enhance adaptive capacity and reduce vulnerability, but the traditional separation of these fields has become unsustainable due to climate change acting as a risk multiplier. Mainstreaming DRR into Nationally Determined Contributions is a strategic policy evolution, promoting a more holistic approach for building a climate-resilient future.

**Evolution:** The Paris Agreement, the Sendai Framework for Disaster Risk Reduction, and the 2030 Agenda for Sustainable Development are three global frameworks that have unified efforts to address climate change and disaster risk. These frameworks emphasize the need to enhance resilience against climate-related threats and recognize climate change as a primary factor in disaster risk. The rapid progression of climate change has led to a stronger alignment of goals, as it serves as a "risk multiplier" and highlights the shortcomings of addressing disaster risk reduction and climate change adaptation separately. The Global Assessment Report on Disaster Risk Reduction (GAR 2025) emphasizes the importance of proactive measures in DRR for future prosperity. The UN Office for Disaster Risk Reduction and the UN Framework Convention on Climate Change advocate for an integrated approach, focusing on efficient resource use and synergies between climate action and disaster resilience.




**Significance:**

Integrating DRR into NDCs allows for a holistic approach to risk management. By considering both historical disaster data and future climate projections, countries can develop a more comprehensive understanding of their vulnerabilities across various sectors, like energy, industry, and ecosystems. This integration enables the creation of Nature-based Solutions (NbS), which can simultaneously reduce emissions and enhance resilience to climate impacts while providing co-benefits for biodiversity and livelihoods.

An integrated approach to disaster risk reduction and climate action is crucial for mobilizing climate finance. Proactive investments in resilience minimize future disaster costs, attracting new financial instruments and private investment to accelerate the transition to a climate-resilient economy.

Moreover, Nationally Determined Contributions (NDCs) are integrated with other national strategies like National Adaptation Plans (NAPs) and Disaster Risk Reduction (DRR) frameworks to ensure efficient resource use and a "whole-of-government" approach, thereby meeting global agendas like the Sendai Framework for Disaster Risk Reduction.

**Conclusion:** This integrated approach moves beyond the limitations of siloed policies to forge a unified framework for climate and development action. The present climate change issues demonstrates that this is not a choice between reducing emissions and preparing for disasters, but rather a synergistic pathway that enables countries to achieve both goals more effectively and efficiently.

The benefits are extensive and multi-dimensional, ranging from significant economic returns on investment to the protection of the most vulnerable communities and the preservation of vital ecosystems. The process of mainstreaming also serves as a catalyst for transformative governance reforms, improving policy coherence, strengthening institutional capacity, and mobilizing the diverse stakeholders necessary for large-scale change.

# Water–Sanitation–Health (WASH) Security under Disaster Stress

**Sanchita Saha**

In a period of rising climate uncertainty and multisectoral humanitarian crises, WASH system security has become a crucial pillar of successful disaster response and long-term community resilience. "Disaster stress" is defined as the immense and often compounded stress placed on essential infrastructure and services following a catastrophic event. This stress is not just the initial physical destruction but a cascading sequence of disruptions—from water source contamination and sewer system destruction to the logistical nightmares of delivering relief to a hysterical and displaced population. When these underlying systems collapse, the effects are immediate and catastrophic, risking the transformation of a natural hazard into a public health disaster.

Disaster stress has as wide an impact on the WASH infrastructure as does the disaster itself. Flooding of water treatment plants implants within them contamination comprising raw sewage, industrial chemicals, and agricultural runoff. These pose a double threat: firstly, it is a lack of clean water for consumption; secondly, it is a toxic environment for the survivors. On another note, earthquakes may leave above-ground buildings intact but may locate within their underground network of pipes and sewers. Widespread pipeline failure, creeped out by the liquefaction of soils common in seismic events, can render huge urban areas without supplying water services and create a conducive atmosphere for waterborne diseases. Droughts, being a slow-moving but also quite devastatingly stressful event, initiate water scarcity such that pollutants accumulate in the shrinking water sources and that basic hygienic practices have become impossible.

The immediate health consequences confirm the grim value of WASH security. Absence of potable water for drinking and cooking places populations at high risk of the outbreak of water-borne diseases such as cholera, typhoid, and dysentery. A compromised system of sanitation leads to open defecation of human excreta, further spreading infectious diseases and making the environment toxic for survivors. The health fallout goes beyond the primary infections such as malnutrition caused by contaminated food and water sources causing nutrient malabsorption and the increased risk of vector-borne diseases. Furthermore, the psychological trauma caused by lacking basic services is the final nail in the coffin for mental health in already traumatized disaster victims. Going by their listing by UN entities, poverty and climate change rank first and second as eminent issues confronting the world. Millions live in abject poverty-days trying to get basic food items, clean water, and simple shelter. The climate crisis aggravates in intensity with increases in the frequency and ferocity of disasters, food insecurity, and displacement. Global warfare, violations of human rights, and widespread disinformation are the other issues that add to instability and suffering experienced by people worldwide.

The above paragraph contrasts the reactions to the 2010 Haiti earthquake and the 2005 Hurricane Katrina, putting stresses on the importance of WASH security. In Haiti, the earthquake struck down a fragile WASH system and started a cholera pandemic as a consequence of the absence of safe water and sanitary conditions in the refugee camps. This shed light on the need for pre-disaster investments aimed at building strong WASH systems. Once more, despite the faulty response to Hurricane Katrina during the early days, a strong national system emerged finally to assist in the positive reconstruction of infrastructures. The absence of basic clean-water and sanitation facilities was, of course, there during the early days. Still, the presence of local resources and a national disaster relief system prevented the outbreak of rampant disease, unlike in Haiti.

Finally, WASH security is not merely an emergency response but a cornerstone of long-term community resilience. Developing this resilience requires shifting from reactive measures to proactive risk reduction. This involves strengthening infrastructure to resist natural hazards, establishing decentralized and redundant WASH systems, and including climate change adaptation strategies in urban and regional planning. International campaigns, such as the UN's Sustainable Development Goal 6 (Clean Water and Sanitation), strengthen this message, calling for universal access to safe water and sanitation as a prerequisite for human health and sustainable development. Investing in resilient WASH systems is the one most important action a country can do to safeguard its people and make sure that, when the worst happens, there is a base for survival and for rebounding.

# Resilient housing for climate refugees and displaced populations

**Sneha Bhattacharyya**

As the effects of climate change worsen, millions of people throughout the world are being forced from their homes owing to extreme weather events, sea-level rise, desertification, and other environmental challenges. These folks, known as "climate refugees", are facing a growing humanitarian crisis. Providing resilient housing options for climate refugees and displaced people is crucial not just for their dignity and security, but also for promoting sustainable development in the face of climate change.

In sensitive places like coastal zones, low-lying island nations, and dry regions that are susceptible to drought, climate-induced relocation is becoming more common. The particular difficulties that these relocated communities have are frequently not adequately addressed by traditional housing options. Structures made to endure environmental pressures while maintaining long-term sustainability, comfort, and safety are referred to as resilient housing. These housing options need to be reasonably priced, flexible, and eco-friendly.

Using sustainable, locally accessible materials is one of the main tenets of resilient housing. Traditional building techniques that make use of regional resources like bamboo, rammed earth, or compressed stabilized earth blocks (CSEB) frequently offer an affordable and climate-appropriate option. These materials reduce the carbon footprint of building, provide natural insulation, and lessen reliance on imported materials. Additionally, they are frequently easier for nearby communities to fix, improving sustainability over the long run.

Flexibility in design is yet another essential component. Different climate threats must be accommodated by resilient housing. Elevated buildings, for example, can provide protection from flooding and sea level rise, while aerodynamic designs can lessen the impact of wind during storms or cyclones. As families grow or more resources become available, modular designs enable gradual growth. In an emergency, prefabricated and lightweight shelters can be quickly set up to provide displaced people with temporary shelter.

Water management and energy efficiency are other important factors. Rainwater collection methods guarantee a consistent water supply in drought-prone areas, and solar panels can offer electricity in isolated locations without grid connections. Green roofs, natural ventilation, and shade all contribute to a decrease in the need for energy-intensive cooling systems, which are frequently unsustainable and expensive.

Resilient housing initiatives need to incorporate social and economic factors in addition to physical infrastructure. Creating safe public areas, communal kitchens, and community centres promotes social cohesiveness among displaced persons, which is crucial for integration and psychological health. Long-term resilience is enhanced by empowering refugees and internally displaced people to take charge of their shelters through training programs on sustainable practices and building maintenance.

Resilient housing for climate refugees is mostly supported by international collaboration and governmental policy. It is essential to implement policies that prioritize the migration of the most vulnerable populations, simplify land tenure rights, and offer subsidies for environmentally friendly building. The corporate sector, non-governmental organizations (NGOs), and international organizations must work together to create creative technical solutions and funding sources.

# Assessing Sea-Level Rise and Resilience of Small Island Nations

**Souvik Dey**

Imagine living on an island only a few meters above the sea and watching the tides creep ever closer. This is the reality of some islands in the world, like Tuvalu, Kiribati, the Maldives, and many others. About 65 million people are living on more than 1000 islands, and together they are called small island developing states (SIDS). This nation is least responsible for climate change; they are only creating 1% of total emissions, but they are suffering some of its worst impacts. Current projection suggests a daunting future. By 2100, with very high emissions, the sea could rise 0.6-1.1 m, and in this situation, some islands would be submerged in the sea. The National Oceanic and Atmospheric Administration (NOAA) estimated that sea level has already risen 0.2 m in the last 2 decades. Each extra centimeter of rise dramatically expands the reach of high tides and storm surges in this land. This island has diverse biodiversity and is an ideal place for the conservation of various species. Sea level rise is a threat of coastal flooding that destroys crops and power grids and causes economic loss. Underground freshwater turns into brackish water that is very dangerous for people's survival. The World Bank warns that climate shocks could push one-third of the populations of Kiribati and Tuvalu into extreme poverty. A Pacific Islander explains that for their climate, catastrophe is always a national event; there is no remote to control it.

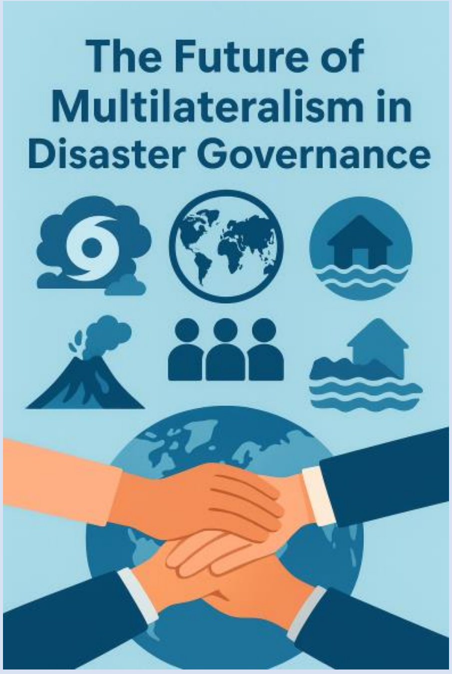
**Adaptation scenario**: Across SIDS, governments are building seawalls, breakwaters, and raised roads. In Samoa and Tonga, the World Bank has helped retrofit hundreds of kilometres of roads and ports to withstand flooding. Tuvalu is reclaiming land by pumping sand to build a 40-ha extension of its runway. The Maldivian Island Hulhumale was built up nearly 2 m high to shelter one-third of the population, and people are adapting by putting houses on stilts and installing water tanks. People are also adapting nature-based solutions in many islands' mangrove plantations; wetland coral reefs provide soft protection against waves and storm surge, and healthy reefs break waves before they hit the land. Barbados is planting coastal mangrove and restoring coral as parts of its 'Reefs to Roofs' program. Such strategies are low cost and sustainable for this small island.

**Resilience strategy:** The resilience of SIDS is not a passive characteristic; it requires dynamic, multi-pronged efforts. We need to take action across several fronts, combining traditional knowledge with modern technology and international partnerships. Farmers are adapting climate-smart agriculture practices in saltwater intrusion areas, cultivating salt-tolerant crops and using raised garden beds; these are helping to protect food security. For the drinking water, they need to adopt rainwater harvesting and desalination plants. International support is required to relocate people in vulnerable condition.

The story of small islands is a warning and a lesson for the world. We need better planning and international support to reduce the climate impact and better resilience for this island.

# The Future of Multi-lateralism in Disaster Governance

**Susmita sarkar**




In recent decades, disasters have become increasingly complex, transboundary, and interconnected, making multilateralism a central pillar of disaster governance. Multi-lateralism refers to the collaboration of multiple nations and international organizations to address shared problems, guided by common principles, standards, and mechanisms. In disaster governance, it underpins frameworks like the Sendai Framework for Disaster Risk Reduction (2015–2030), the Paris Agreement on climate change, and regional mechanisms such as the ASEAN Agreement on Disaster Management and Emergency Response (AADMER). These agreements recognize that no single country can manage the growing scale and frequency of natural and human-induced disasters alone. As climate change intensifies floods, cyclones, wildfires, and pandemics, the future of multilateralism in disaster governance will be defined by deeper cooperation, innovative financing, and a stronger integration of science and local knowledge into global decision-making.

One of the key drivers of future multilateralism will be the need for shared early warning systems and data platforms. The World Meteorological Organization's Global Multi-Hazard Alert System and the UN's Early Warnings for All initiative are examples of how real-time information can transcend national borders. In the future, such systems will likely evolve into interoperable digital platforms that combine satellite imagery, artificial intelligence, and crowd-sourced data to predict risks and guide swift responses. This will require countries to pool resources, harmonize data standards, and agree on protocols for information sharing—something only multilateral arrangements can achieve.

Another major trend is the emergence of climate-related financing for disaster risk reduction. Currently, disaster response is often underfunded and reactive, with funds mobilized after crises occur. The future of multilateralism will likely focus on pre-disaster investment and risk-pooling mechanisms. Instruments such as the World Bank's Catastrophe Bonds, the Caribbean Catastrophe Risk Insurance Facility, and the Global Shield against Climate Risks (launched at COP27) represent steps toward a global disaster insurance system. By spreading risk across multiple countries, these mechanisms can provide timely payouts and reduce the economic shock of disasters, especially for vulnerable developing nations.

Equity and inclusiveness will also shape the next phase of multilateralism. Past approaches often overlooked the needs of marginalized groups and local communities, treating disaster governance as a top-down process. However, global forums are increasingly recognizing the value of local and Indigenous knowledge in risk assessment, adaptation, and recovery. Future multilateral frameworks will need to institutionalize these perspectives, ensuring that local actors are not just recipients of aid but co-designers of strategies. This shift can build trust and strengthen compliance with global norms.

Finally, geopolitical tensions and rising nationalism pose challenges to multilateralism. Competition among major powers, trade disputes, and divergent national interests can impede collective action. The future success of multilateral disaster governance will depend on building flexible coalitions, using regional platforms, and fostering public–private partnerships to complement intergovernmental mechanisms. In an era where disasters know no borders, multilateralism offers the most viable path to reduce risks, enhance resilience, and protect human lives. By embracing innovation, inclusivity, and shared responsibility, the world can reimagine disaster governance as a truly collaborative enterprise capable of meeting the challenges of the 21st century.

# Desertification and Drought Resilience in Arid and Semi-Arid Regions

**Triparna pal**

Humans depend largely on the land system for their existence, drawing dangerously from the land resources, thereby depleting its productivity and degrading it. The overexploitation of land leading to degradation, desertification, and drought which is being exacerbated by climate change. Globally, 24% of the land is degrading and about 1.5 billion people directly depend on these degrading areas for sustenance. Nearly 20% of the degrading land is cropland, and 20-25% rangeland. In Africa two-third of its land is either desert or dry lands; in Asia (including Russia) more than one-third of its land is arid, while almost a third of U.S is affected by desertification; and one quarter of Europe, Latin America, and the Caribbean.

Desertification, Land Degradation and Drought (DLDD) is a climate-related hazard that is globally in nature; with both short and long-term impacts on various aspects of human health, biodiversity and ecosystem services and invariably food security. DLDD poses a great threat to resilience of the socio-ecological systems and to achieving the Sustainable Development Goals (SDGs). Challenges associated with land degradation arise due to pressures on land to meet the demand of ever-increasing global population and from climate change. Increase in global land surface temperature, affects precipitation patterns and invariably the soil moisture content, and soil productivity across the globe, particularly in the drylands with the likelihood of drought. Reduction of societal vulnerabilities to DLDD can be achieve through strengthening the resilience of the communities, individuals and governance institutions through capacity building, so as to reduce the impacts of land degradation. Governance is key for vulnerability and exposure reduction, through structured institutions. The role of governance can be played out through the implementation of the rule of law, awareness raising to build informed norms, which make adaptive, governance to enhance the move from risk to resilience. Various sustainable approaches have been introduced, including sustainable land management practices such as reforestation and agroforestry to negotiate agricultural challenges. These methods sought to stabilize soil and rejuvenate vegetation. Implementation of various techniques namely, crop rotation and reduction in the use of chemical fertilizers boost soil agility. Effective methods for minimizing water loss and boosting productivity include water conservation techniques, such as rainwater harvesting and drip irrigation, while alternative planting options in harmony with rainfall patterns are provided by drought-resistant crops. Furthermore, enabling local communities with expertise of sustainable practices and engaging them in the decision-making procedure can enrich persistence. Additionally, the communities can be moreover, aided in anticipating droughts by satellite-based early warning systems. A remarkable drive is Africa's "Great Green Wall" that aims to fight desertification through which the ecosystem at the southern edge of the Sahara was restored by extensive reforestation efforts.

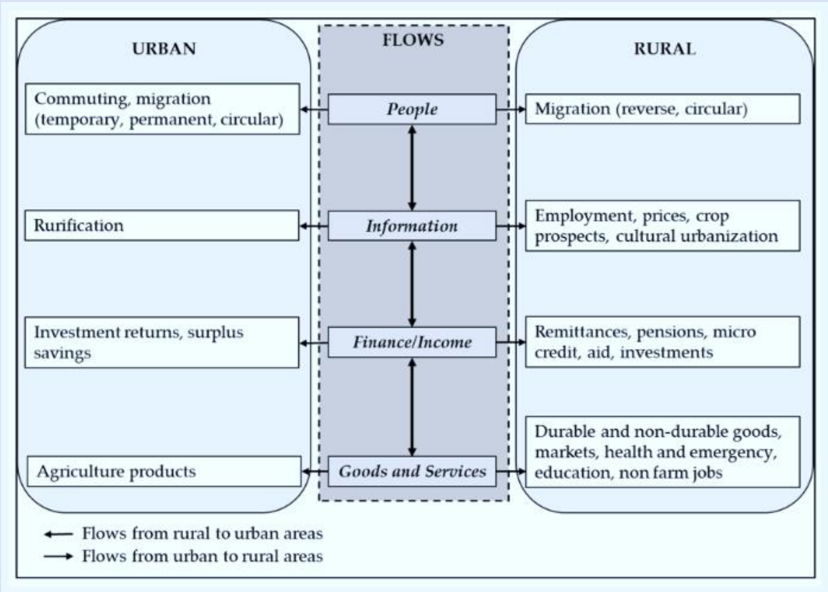
*"The world must come together to confront climate change. There is little scientific dispute that if we do nothing, we will face more drought, famine and mass displacement that will fuel more conflict for decades." -Barack Obama*

# Rural–Urban Linkages in Disaster Preparedness

**Trisha Mondal**

Disaster preparedness is not only about what happens in one place but also about how different areas are connected to each other. Rural and urban areas depend on one another in many ways and this connection becomes very important when a disaster occurs. Rural–urban linkages mean the social, economic, environmental, and infrastructure connections that villages and cities together. When we look at disasters such as floods, cyclones, droughts, earthquakes, or pandemics occurs, it becomes clear that no area can respond alone. When rural and urban areas are viewed as a single system, preparedness increases. Strengthening rural-urban ties is essential to preventing community adversity, promoting sustainable development, building a resilient network that capitalizes on both rural and urban advantages, and disaster preparedness.

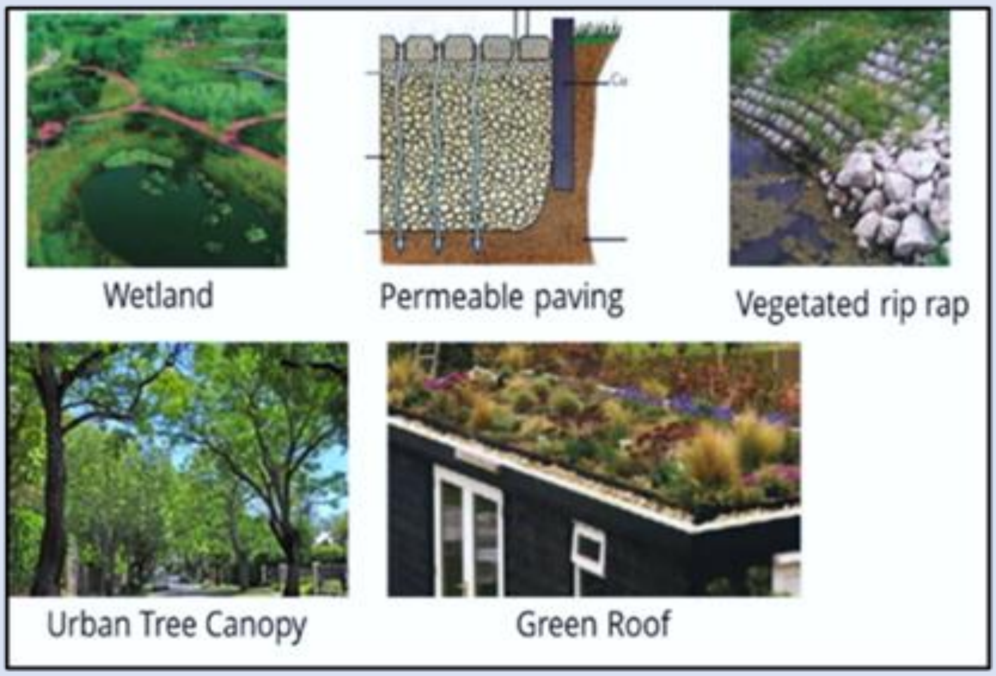
Rural and urban areas are interdependent in many ways. Villages supply raw materials, food, water, and sometimes labour to towns and cities. Cities respond by providing emergency services, markets, schools, hospitals, and technology. In an emergency, these connections become lifelines. For example, during floods, cities may experience transportation disruptions, but food and supplies from nearby villages can be beneficial. However, rural families often rely on urban hospitals, relief camps, and contemporary rescue equipment. Disaster preparedness works best when both domains are seen as a single, interconnected system rather than as separate entities. During crises like COVID-19, urban workers went back to their rural homes. This two-way movement must be taken into consideration when rural and urban areas collaborate on disaster preparedness. Food, shelter, communication, and early warning are all aspects of preparation. It is typically simpler to obtain satellite data, early warning systems, and weather forecasts in urban areas. Many lives could be saved if rural residents were promptly made aware of these warnings. On the other hand, rural residents frequently use traditional knowledge derived from elements such as water levels, wind direction, and animal behaviour to forecast disasters. Preparation is increased by fusing local knowledge with contemporary science. Additionally, infrastructure is crucial. Rural and urban areas are connected by roads, bridges, and power sources. During emergencies, supplies and relief can be transported with ease if they are robust. The growth of this infrastructure benefits both sides equally. Skills and awareness also have an impact on people's level of preparedness. Universities, non-governmental organizations, and urban groups can provide training to rural communities in safe construction, evacuation, and first aid. Rural communities can, however, adopt common coping mechanisms, like storing food grains for droughts or constructing raised homes in flood-prone areas. A strong preparedness culture is produced by fusing official training with regional customs. Instead of working alone, communities benefit from sharing knowledge. The 2020 Cyclone Amphan and the 2015 Nepal earthquakes show what disaster preparedness can do when rural and urban societies come together and deliver the dividend of warning, evacuation, and medical care in a timely fashion. Disaster preparedness is not merely about strong walls and warning—it is also about strong social bonds. Rural and urban societies are two sides of the same coin. Villages ensure access, buffers, and local knowledge, while cities ensure services, technology, and high-standard amenities. Both must work together for disaster resilience. Rural–urban linkages define enhancing support systems that have the potential to minimize hazards, save lives, and accelerate recovery. Ultimately, disaster resilience is optimal when villages and cities prepare as one community together.



# Nature-Based Solutions for Urban Flood and Heat Risk Reduction

**Falguni Murmu**

Nature-based solutions (NbS) are gaining traction globally to combat two urgent climate-related urban issues: urban flooding and the urban heat island (UHI) effect. NbS enhance and work with natural systems to provide environmental, social, and economic advantages while at the same time enhancing resilience. Urban flooding is typically caused by restricted permeable area and saturated drainage systems, and NbS restore the natural water cycle by infiltration, retention, and delayed runoff. Such examples are green roofs that are vegetated layers on the rooftops that soak up rainwater and minimize runoff, such as in Portland where there are incentives for installing it and in Singapore where it is required in new developments. Rain gardens and bioretention cells are shallow, planted basins that catch and clean stormwater, promoting infiltration, with Seattle's SEA Streets project showing reductions in runoff of up to 99%. Rainwater-permeable pavements permit rainwater to percolate into the soil, minimizing surface runoff and groundwater recharge, a method embraced in Chicago's Green Alley Program. Likewise, urban wetlands and retention ponds are natural or constructed reservoirs that hold stormwater, such as Stuttgart's rehabilitated floodplains that harmonize flood protection with biodiversity gain. In addition to flooding, NbS are critical in the alleviation of UHI, a condition caused by heat-absorbing surfaces like asphalt coupled with lesser vegetation. Urban forests and extended tree canopies offer shading and evapotranspiration cooling, with Melbourne's Urban Forest Strategy looking to double canopy cover by 2040 and reduce local temperatures by up to 4°C. Cool roofs and green roofs reflect or insulate buildings, lowering heat absorption, as exemplified by New York City's Cool Roofs Program, having treated over 10 million square feet of rooftops with reflective coatings.




Urban parks of large size and green corridors establish cooling islands, reducing ambient heat and serving as recreational spaces, as in Singapore's Park Connector Network that connects green spaces throughout the city. Blue-green infrastructure combines water elements with vegetation to achieve both cooling and stormwater management, as in Rotterdam's Water Squares that hold rainwater during storms but serve as public spaces in dry conditions. In order to succeed, NbS require good implementation strategies. Integration of policy ensures NbS are incorporated in urban planning, such as in the Cloudburst Management Plan of Copenhagen. Community participation promotes ownership and maintenance over time, which is evident from Philadelphia's Green City, Clean Waters initiative. Intersector collaboration between planners, ecologists, engineers, and health professionals achieves maximum results, such as Berlin's Biotope Area Factor regulation. Adaptive management and monitoring are also essential, with Singapore employing real-time sensors to measure performance and make adjustments. Overall, NbS are sound, sustainable, and multi-functional solutions to mitigating urban flooding and heat islands, providing not just climate adaptation but also ecosystem services, enhanced aesthetics, and public health advantages. Cities that give importance to NbS become more adaptive, resilient, and liveable to future climate threats, transforming themselves as greener and healthier cities for future generations.

# 5G, IoT, and Satellite-Based Early Warning Systems for Disaster Risk Reduction

**Joyeta Basu**

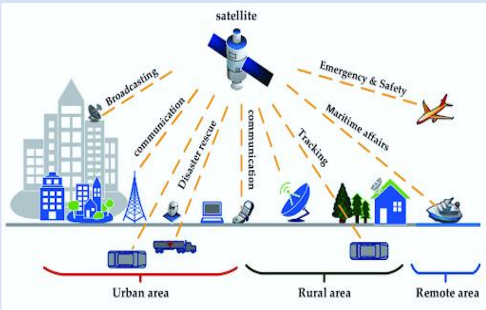
Disasters, either natural or man-made, pose tremendous threats to human life, the environment, and infrastructure. Timely information, rapid communication, and well-coordinated response planning are the keys to successful Disaster Risk Reduction (DRR). Recent years have seen advanced technologies including 5G networks, the Internet of Things (IoT), and satellite-based systems come to the forefront as key enablers of upgrading early warning systems (EWS). As these technologies are blended together, they provide real-time data gathering, processing, and sharing, thereby reducing disaster risks and strengthening community resilience.

## Role of 5G in Early Warning Systems

The 5G network provides ultra-low latency and high data bandwidth, which are crucial for timely early warning messages in disaster management. It enables real-time video observation for accurate risk assessment, supports mission-critical applications like search and rescue drones and telemedicine, and ensures reliable communication for first responders. Moreover, network slicing allows dedicated channels for emergency services, maintaining connectivity even when conventional networks are congested.

## Internet of Things (IoT) for Risk Monitoring and Response

TThe IoT infrastructure includes connected devices and sensors that monitor environmental conditions like rainfall, river levels, soil moisture, seismic activity, and air quality. By deploying IoT sensors in vulnerable areas, authorities can monitor hazards in real-time. For example, flood sensors in river basins provide updates on water levels, while seismic sensors detect ground vibrations for earthquake monitoring. IoT also enables smart evacuation systems using traffic sensors and GPS trackers to guide communities safely. Additionally, wearables can track the health of vulnerable groups, such as the elderly or injured survivors, during and after disasters. With 5G connectivity, IoT devices can transmit large amounts of data quickly, aiding in decision-making.




## Satellite-Based Systems for Wide-Area Coverage

Satellites are crucial for global early warning systems, providing essential data for weather forecasting, cyclone monitoring, wildfire tracking, and disaster damage assessment. Geostationary satellites can detect tropical storm development days in advance, while remote sensing satellites identify areas at risk of drought or landslides. Additionally, satellite communication maintains connectivity in disaster-affected regions, ensuring uninterrupted communication and data transfer even in critical situations.

## Integration Towards Efficient Disaster Risk Reduction

The real potential of these technologies is the integration of all three. Satellite images can provide a macro scale hazard view, while IoT sensors can provide a micro scale ground view, and 5G networks can allow for seamless connectivity and real time processing of the data. For example, during a cyclone, satellite based observations can track current cyclone movements, IoT sensors can measure local wind speed and rainfall, and 5G networks can enable local authorities to push warning notifications through immediate and recurrent messages via mobile phones, sirens or automated messaging. This tiered early warning system provides not only quicker identification of hazards, but more accurate, place based warnings.

The integration of 5G, IoT, and satellite-based technology represents a revolutionary frontier for disaster risk reduction. Together, they enhance situational awareness, promote rapid messaging, and strengthen decision-making capacity at the local and global levels. Although, challenges related to high installation costs, cyber risk, and unequal access all remain, these well-directed investments in technology can help to dramatically lessen the impacts of disasters and save lives. As climate changes contribute to an increase in frequency and intensity of disasters, the application of cutting edge digital and space-based technologies provides a significant opportunity to build resilient societies and promote achieving Sustainable Development Goals.

# Disaster Diplomacy: Leveraging International Cooperation for Risk Reduction

**Lopamudra Mukherjee**

An unexpected disaster can disrupt everyday life, damage economies, and spread across political boundaries. In today's connected world, no country can handle disasters alone. Disaster diplomacy shows that such crises can bring nations together and even reduce conflicts. It's not only about emergency help, but also about learning from shared problems to build strength, protect communities, and prevent future risks.

Disasters don't care about borders and can affect many countries at the same time, whether it's earthquakes, floods, cyclones, or pandemics, which makes international cooperation essential. History shows that disasters can bring even rival countries together. During the 1999 earthquake in Turkey, Greece was among the first to send help, putting aside past disagreements. Similarly, India and Pakistan have supported each other during earthquakes and floods, showing that compassion can briefly ease political differences. These acts show that even in tragedy, disasters can create opportunities for cooperation.

Disaster diplomacy goes beyond just providing relief. It also helps in long-term disaster risk reduction (DRR). The Sendai Framework for Disaster Risk Reduction (2015–2030) emphasizes the need for countries to work together across borders. Regional platforms show disaster diplomacy in action. The SAARC Disaster Management Centre helps South Asian countries work together, while ASEAN has set up joint response systems in Southeast Asia. These efforts promote shared investments in early warning systems, training, and preparedness—actions that save lives and build trust between nations.

The need for disaster diplomacy is growing because of climate change. Rising seas, changing rainfall patterns, and extreme weather are now affecting whole regions, not just individual countries. Small Island Developing States (SIDS) have worked together in global climate talks, using their common challenges to call for more effective measures. This shows that disaster diplomacy is not just about giving aid, but also about guiding international policies to build resilience and protect the environment.

Disaster diplomacy has its challenges. The help shown during a crisis can fade once the emergency is over. Old conflicts may come back, and sometimes aid is used to gain power or influence. True impact comes when countries build trust, work honestly, and cooperate long-term to strengthen communities.

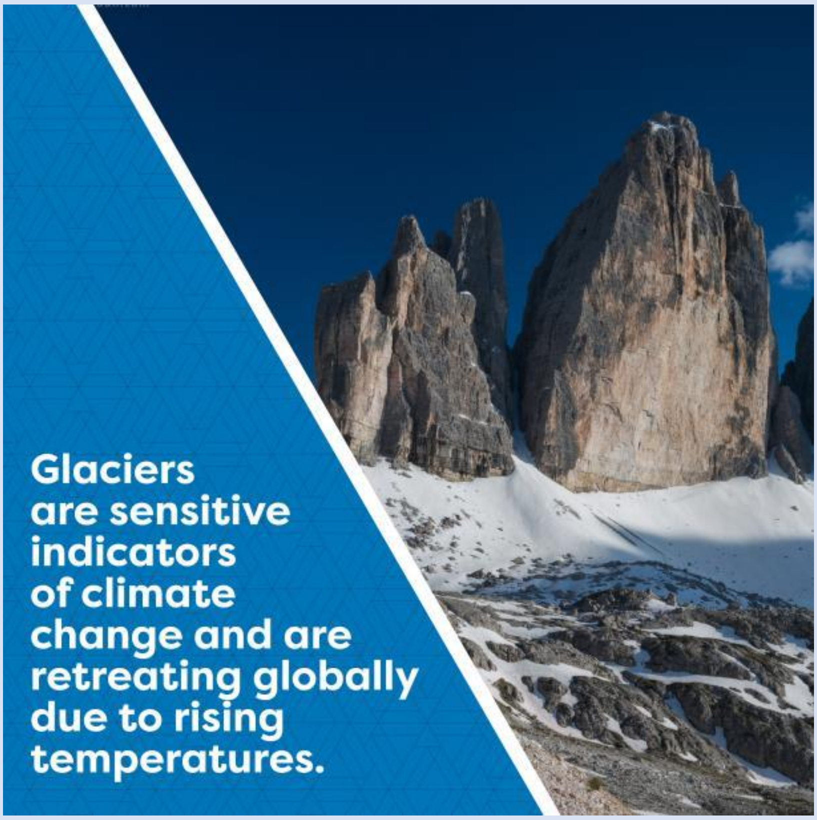
Technology and global institutions are opening new ways for disaster diplomacy. Tools like satellite monitoring, artificial intelligence, and climate modelling provide neutral platforms to share important data. Organizations such as the UNDRR, WHO, and IFRC help countries work together by focusing on humanitarian needs rather than politics. Through these efforts, nations can build trust, improve preparedness, and respond more effectively to crises. Ultimately, disaster diplomacy reminds us of our shared humanity. Disasters may destroy, but they also show how connected we are. By sharing knowledge, resources, and innovations, countries can not only tackle emergencies better but also strengthen peace and resilience. Embracing disaster diplomacy turns challenges into opportunities for cooperation, ensuring that even in times of crisis, unity comes first.

# Glacier Melt and Cryospheric Disasters in High-Altitude Regions

**Maitreyee Biswas**

Science is unequivocal: Increased permafrost thawing, decreased snow cover, increased glacier melt, more intense rainfall events, and natural hazards are all being brought on by warming temperatures. Earth's frozen water systems, or cryosphere, are a vital component of the planet's life support system. Its high albedo and white snow-covered surfaces reflect sunlight into space. Global effects include increasing sea levels, water scarcity, and the release of carbon buried in permafrost increase as this albedo effect fades. Furthermore, because of climatic and hydrological teleconnections, especially between the Arctic and the Third Pole, warming in the cryosphere poses complicated hazards. Both local ecosystems and the stability of the global climate are at risk due to these interrelated changes.

The Asia-Pacific region, known as the Water Tower of Asia, is home to the world's tallest mountains and largest glacier systems. The Third Pole, including the Tibetan Plateau, Pamir-Hindu Kush Himalaya, Hengduan, Tien Shan, and Qilian Mountain ranges, covers 5 million km² and contains 100,000 km² of glacial areas. These regions support nearly 2 billion people and provide essential resources for drinking water, agriculture, energy, sanitation, and industrial purposes. However, rapid melting of glaciers poses long-term threats to water availability and ecological stability.




Asia's mountain ranges and glaciers are warming faster than the rest, making the Third Pole more vulnerable to intense temperatures. Glacier volume in the HKH area may decrease by 30-50% by 2100, causing significant changes and increased runoff, particularly in monsoon-dominated river basins. Stable glacier-fed flows provide electricity, agriculture, and drinking water for millions of people. Therefore, a destabilized cryosphere is a humanitarian as well as an environmental problem.

The phrase "cryospheric disasters" describes dangers associated with the icy regions of the planet. These encompass floods from glacial lake outbursts (GLOFs), avalanches, icefall failures, and thawing permafrost. Among these, GLOFs are especially devastating. When glaciers recede, they can create large, unstable lakes held back by loose moraine, where even a small trigger—like intense rainfall, seismic events, or avalanches—might lead to the dam failing. The abrupt discharge of millions of cubic meters of water can destroy downstream communities and infrastructure in a matter of hours. The Chamoli disaster in Uttarakhand, India, highlights glacier melting's widespread threat, causing landslides, ecological disturbances, and the albedo effect, accelerating regional warming and affecting biodiversity.

A two-pronged approach is needed to address glacier melt and cryospheric disasters in mountainous regions: reducing greenhouse gas emissions to combat climate change and preparing for inevitable changes through improved monitoring, sophisticated early warning systems, risk management, and bolstering community resilience. Promoting energy efficiency, developing regional partnerships suited to particular settings, strengthening local adaptive ability, improving the quality of scientific data, and fostering cooperation among stakeholders are all crucial tactics to manage present and future dangers.

# Digital Twins for Disaster Simulation and Resilient Planning

**Aveek Roy**

The search to create resilience in the face of growing climate-related and geological hazards requires a paradigm shift towards proactive, intelligent preparation from conventional reactive response. On the leading edge of this change is the new and emerging technology of the digital twin. A digital twin is much more than a 3D model; it is a living, breathing virtual representation of a physical object or system- a building, a bridge, or a whole city. The constant flow of real-time data into this virtual model created by a network of sources such as IoT sensors, satellites, and geographic information systems (GIS) enables it to mirror the real world with unparalleled precision, and that too in real-time.

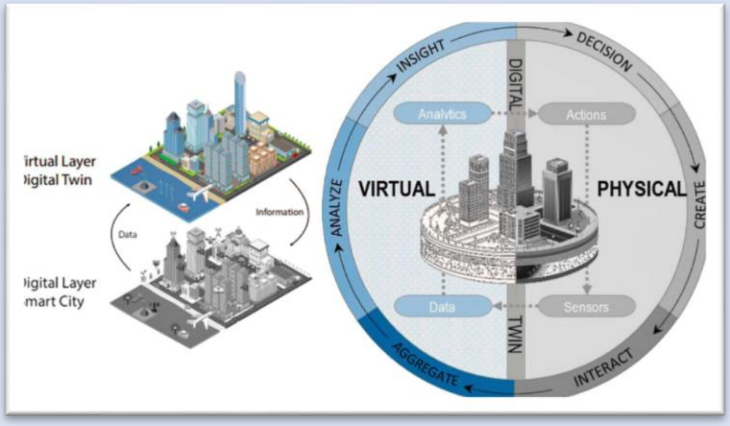



*Figure 1: A representation of digital twin concept. Source: https://www.linkedin.com/pulse/digital-twin-based-disaster-resilience-simulation-smart-reddy-ie1if/*

The real transformational power of digital twins can be truly realised in disaster simulation and planning. Planners and engineers no longer have to stick to theoretical models or 2D static maps to estimate or simulate disaster situations. They are now able to recreate the exact effects of a disaster, such as a Category 5 hurricane on the power grid in a city, recreate the flood patterns of a heavy downpour, or find the structural loads on critical infrastructure in the wake of a major earthquake.

This ability allows a data-driven approach to resilience. By running these "What-If" scenarios in the virtual space, the experts/planners can perform:

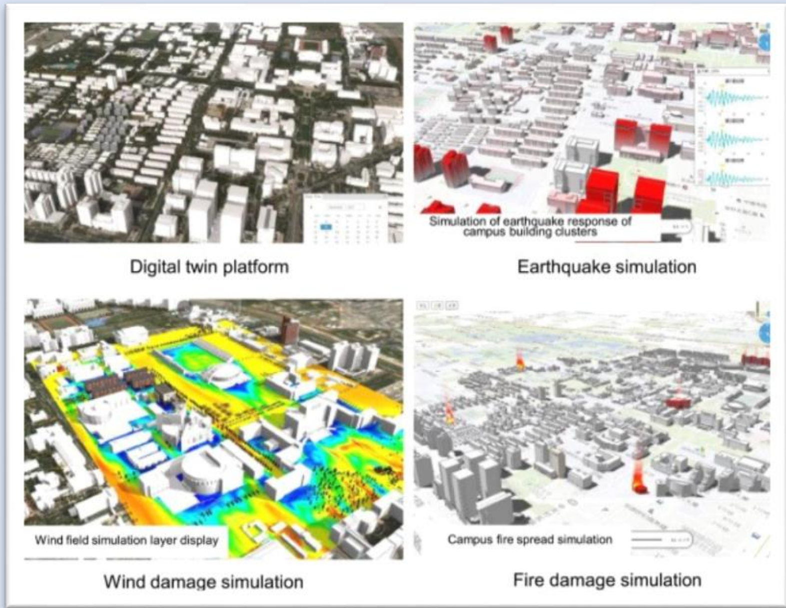



*Figure: Various types of disaster scenario simulations using digital twin technique. Source"https://www.linkedin.com/pulse/digital-twin-based-disaster-resilience-simulation-smart-reddy-ie1if/*

- **Predictive Analysis**: Digital twins can find systemic weaknesses and cascade effects by simulating an unlimited number of what-if scenarios prior to disaster, so weak spots can be reinforced selectively.
- **Optimization of Response:** The emergency evacuation plans, resource mobilization, and first responder plans can be tested and updated in the simulation. This virtual practice makes sure that the plans are sound and efficient, without wasting valuable time and lives in case of a real-life situation.
- **Build Back Better:** The digital twin becomes an anchor in the immediate aftermath of a disaster to estimate damage in a short time span and design rebuilding scenarios based on build-back-better principles, making the rebuilt infrastructure more resilient than it was initially.

Advancements like digital twins are now an imperative rather than merely an option. Digital twins offer an effective common operating picture. They convert the complicated data into clear images, which promote cooperation between the policy makers, engineers, and the community. It is through the invention of a living digital reflection of our physical world that we are given the ability to predict disaster, strengthen our systems, and work on a future that is naturally safer and more resilient to all.

# Integrating Disaster Risk Reduction into the Global Stocktake of the Paris Agreement

**Biplab Pal**

The Global Stocktake (GST) employs a three-phase framework every five years, integrating Disaster Risk Reduction (DRR) into all three phases. United Nations Office for Disaster Risk Reduction's (UNDRR) submission to the first GST highlighted the importance of DRR metrics and data in establishing progress on disaster risk reduction and climate adaptation. Integration occurred through technical input from UNDRR and monitoring with the Sendai Framework, which confirms DRR-related metrics, systems, information, and frameworks. DRR is considered in the revised assessment linked to mitigation, adaptation, and support.

The integration occurs through specific streams of technical dialogue during the GST. As referenced in the United Nations Framework Convention for Climate Change (UNFCCC) technical dialogue system, the DRR input is part of the adaptation and loss-and-damage workstreams, and the aggregated participation is providing informative input into climate resilience and progress indicators from the Sendai Framework. UNDRR analyses Member States' information and submits analytical input to the GST process, aligning with the High-Level Political Forum on Sustainable Development and other UN processes. Data from the Sendai Framework Monitor directly connects to the GST assessment.

The integration of seven global DRR targets from the Sendai Framework informs GST assessment in India. The methodology document for the National Disaster Management of India outlines disaster risk reduction indicators in terms of hazards, vulnerabilities, exposures, and capacities. Key integrated indicators include early warning systems, disaster risk-related deaths, and progress in implementing the national DRR strategy.

### Technical assessment integration:

The GST's technical assessment component now systematically incorporates DRR through synthesis reports that include disaster risk data alongside climate data. According to the World Resources Institute analysis, a basic framework for aggregating national adaptation progress to the global level ensures clear links to related global monitoring efforts, including the Sendai Framework. The integration ensures disaster loss databases and risk assessments are included in Phase 1 information collection, while Phase 2 technical dialogues systematically address disaster preparedness, early warning systems, and loss and damage mechanisms.

### Financial and support integration:

DRR integration extends to climate finance assessment within the GST. The process now evaluates mobilization of resources for building disaster risk reduction capacity alongside climate adaptation finance. According to the Center for Climate and Energy Solutions analysis, adaptation finance assessment in GST must be scaled up significantly, and DRR integration helps identify specific support needs for disaster-resilient development. The means of implementation assessment in GST now includes technology transfer and capacity building for disaster preparedness, ensuring that climate support addresses both mitigation and comprehensive risk management.

### Outcome integration for enhanced climate action:

The Global Green Climate Change Outcome Phase integrates DRR and improved nationally determined contributions (NDCs) to revise climate goals based on collective learning. This integration is crucial for improving disaster risk management. Reporting on the GST helps connect with the UNFCCC (UNDRR) through the Sustainable Development Goals (SDGs) to identify potential data gaps and inform future climate resilience planning.

The Paris Agreement's accountability function is transformed from a climate-only assessment to a climate-disaster risk assessment system by incorporating DRR metrics into the Global Stocktake. This system uses UNDRR technical input, Sendai Framework monitoring data, and DRR metrics to assess global progress in climate resilience, emission reductions, and disaster risk consequences. Each 5-year assessment offers systematic improvement opportunities for addressing climate change and disaster risk.

# A New Dawn for Humanitarian Aid: Blockchain for Disaster Relief Transparency

**Disha Roy**

Natural disasters such as earthquakes, floods, and wildfires strike suddenly, with increasing frequency and intensity, leaving behind widespread devastation and urgent humanitarian needs. Relief efforts often attract massive global donations from individuals, corporations, and governments. However, these efforts are frequently slowed by inefficiency, corruption, and lack of transparency, eroding trust among donors and beneficiaries. Traditional aid systems, with their many intermediaries, are vulnerable to fraud and delays.

To overcome these challenges, blockchain technology is being explored as a transformative solution. As a decentralized and tamper-proof digital ledger, blockchain records every transaction securely and transparently, from donation to final aid delivery. Platforms like the Blockchain Enabled Charity Process (BECP) allow donors to track their contributions in real time, ensuring accountability and minimizing misuse. Such transparency enhances trust, as seen in debates surrounding the 2015 Nepal earthquake, where blockchain could have helped verify whether relief funds were used appropriately for food, shelter, or medical aid.

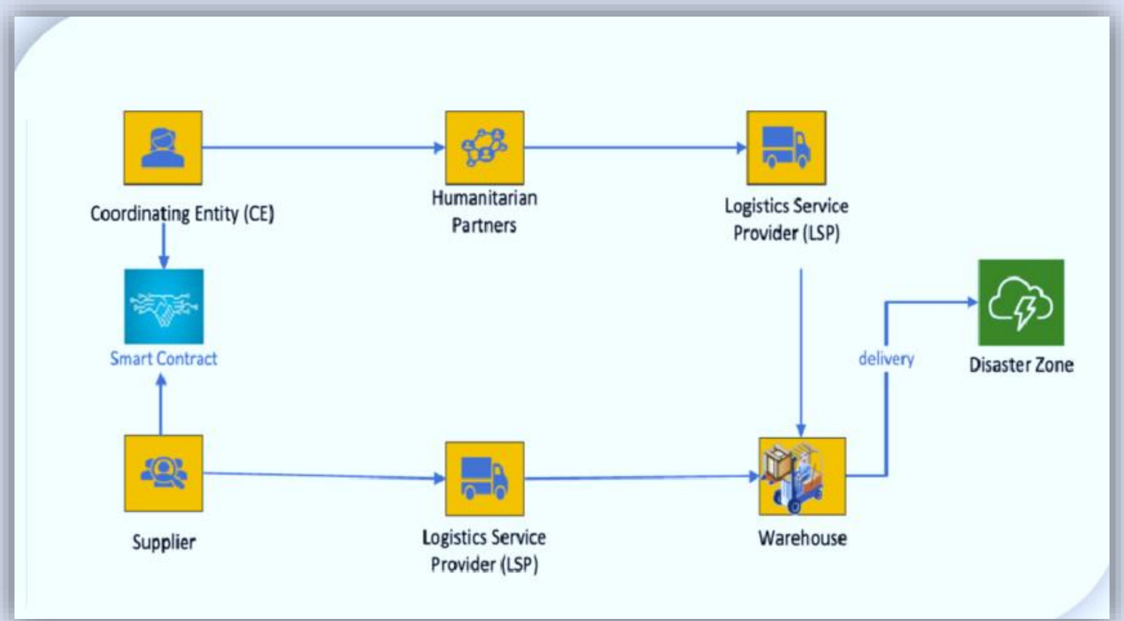



*Figure: Blockchain-Based traceability system for enhanced humanitarian supply chain management. [Source: Saad et al. 2023]*

Real-world applications highlight blockchain's promise. The UN World Food Programme's Building Blocks project used blockchain in Jordanian refugee camps, enabling Syrian refugees to redeem food vouchers through iris scans, eliminating middlemen, reducing costs, and ensuring aid reached recipients securely. Similarly, the UN Refugee Agency has used stablecoins to deliver emergency funds directly to displaced families in areas lacking banking infrastructure. Initiatives like the Kare Survivor Wallet in the U.S., supported by the Algorand Foundation, further demonstrate how blockchain-based digital identities and direct transfers can cut delivery times by up to 70% and administrative costs by over 50%.

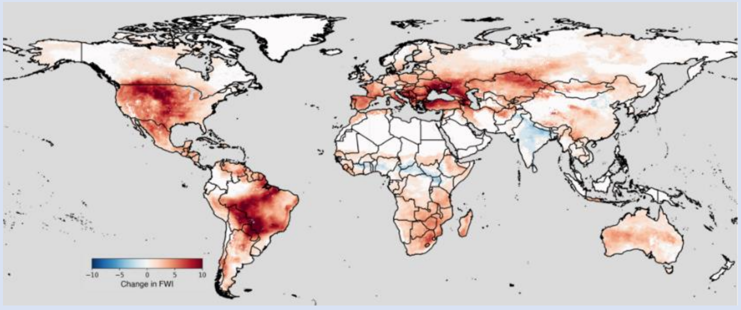
Despite its advantages, blockchain faces hurdles, including limited internet connectivity in disaster zones, data privacy concerns, and high energy consumption. Yet, as the technology advances, it holds the potential to reshape humanitarian aid. Tools such as smart contracts could automate disbursements once conditions are met, while digital identities could empower displaced individuals to access essential services.

While not a complete solution, blockchain offers a powerful means to create a disaster relief system that is faster, more transparent, and more trustworthy, ensuring that every act of generosity makes a meaningful impact.

# Intensification of Climate Extremes and Compound Disasters

**Srinjoy Roy**

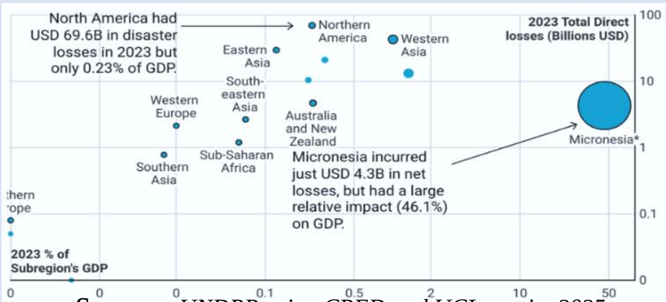
Extreme weather events are intensifying and often overlapping. Scientists report that warming has “likely increased the chance of compound extreme events” – for example, more frequent heatwaves occurring together with droughts. A NASA study finds that if global warming hits 2°C, “more than a quarter of the world’s population could experience an additional month of severe heat stress” each year, while heat plus drought could “combine dangerously” (for example, in the Amazon) to boost wildfire risk. Researchers warn these overlapping extremes could inflict “significant damage to communities and economies”.




**Sources:** *https://www.nasa.gov/centers-and-facilities/ames/nasa-study-reveals-compounding-climate-risks-at-two-degrees-of-warming/)*

Recent events illustrate this trend. In 2023, the UN’s weather agency noted that climate change made both a severe Horn of Africa drought and an April heatwave in the western Mediterranean “at least 100 times more likely”. In late April, Spain, Portugal, and Morocco endured record-breaking 37–41°C heat *on top of* a years-long drought, “exacerbating the lack of water” and devastating crops. In East Africa, successive seasons of drought and extreme heat have pushed communities toward famine.

Compound climate events pose serious health risks. As the planet warms, more people face deadly heat: the World Health Organization notes that climate change has made heatwaves longer and more intense, and that nearly 489,000 heat-related deaths occur worldwide each year (2000–2019 data). For instance, Europe’s summer 2022 heatwave alone caused an estimated 61,000 excess deaths (and past waves in 2003 and 2010 each killed tens of thousands). Smoke from wildfires is another hidden danger: the tiny particles travel far and can inflame lungs and hearts. Indeed, medical studies show that extreme weather raises heart risks – for example, after Hurricane Sandy (2012), New York City saw elevated cardiovascular deaths for up to a year afterward. In short, heat, pollution, and disaster-related stress combine to cause illnesses and deaths well beyond the immediate crisis.




**Sources:** *UNDRR using CRED and UCLouvain, 2025*

The financial toll of overlapping disasters is enormous and growing. UN reports show the average annual cost of weather and climate disasters rose from ~$70–80 billion in 1970–2000 to about $180–200 billion in 2001–2020. Including indirect costs (health care, lost income, ecosystem damage), disasters now cost roughly $2.3 trillion globally every year. Just in 2023, insurers estimated around $250 billion in worldwide losses, roughly equal to the GDP of a medium-sized country. Even rich countries suffer big hits (for example, North America faced about $69.6B in losses in 2023), but small economies are hit hardest. The chart below shows that Micronesia lost $4.3B in 2023 – a staggering 46% of its GDP – while North America’s larger $69.6B was only 0.23% of its GDP. UN experts warn that without better planning, these rising costs and debts could destabilize even major economies.

In conclusion, climate extremes are getting worse, and compound disasters are increasing. These issues challenge us more than ever. Their impact on human health and the global economy highlights the urgent need for action. We need a two-part strategy. First, we must quickly reduce greenhouse gas emissions to limit future warming. Second, we need to invest in strong infrastructure, health systems, and disaster preparedness to protect communities.

# AI Malfunctions and Technological Disasters in Autonomous Systems

**Trisha Ghosh**

AI malfunction occurs when an AI system act unpredictably due to bugs, poor design, or adversarial manipulation. it can lead to significant safety issues; regulation plays an extra attention to human and data safety to avoid such technological disaster. As notable an example of technological disaster, Tesla Autopilot In crashes in 2023 can be stated, the car was operating on Autopilot and collided with a stationary fire truck in California; the accident caused one death. Tesla's overreliance on camera-based systems without adequate lidar or radar redundancy is why the AI misinterpreted static obstacles. In 2020, there was a significant issue with algorithmic bias in the UK's passport photo system. The UK's automated passport photo checker rejected 22% of applications of dark-skinned women due to training data skewed toward lighter skin tones. The system misinterpreted shadows on darker skin as "closed eyes" or "poor background contrast." Patriot Missile Fratricide in 2003 During the Iraq War, a U.S. Patriot missile defence system failed to intercept an incoming missile that caused 28 deaths. A software error caused time-tracking inaccuracies during prolonged operation. The airline's chatbot invented a bereavement fare policy, leading a passenger to book an invalid ticket in 2018.


**Figure:** *Hazards across multiple domains remind us of the risks in managing complex systems, from biological to nuclear, and now, AIs. Organizational safety is vital to reduce the risk of catastrophic accidents*

A tribunal ordered compensation to reject Air Canada's claim that the chatbot was a "separate legal entity." With the expansion of artificial intelligence (AI) in general and in self-driving cars in the United States, there is an increasing need for new hazard analysis approaches to determine how AI contributes to accidents. The original Swiss Cheese model cannot address accidents where AI is a possible causal factor. The Taxonomy for AI Hazard Analysis (TAIHA) is proposed that introduces layers focusing on the oversight, design, maintenance, and testing of AI; case studies situated in the self-driving domain demonstrate how TAIHA can be used to better understand how AI contributes to accidents. To mitigate these gaps, people need to include more regulatory involvement, as well as the company needing to appoint senior lead test engineers, who will be the new first-line actors in any autonomous system operation.

In summary, AI malfunctions occur due to deficiencies in design, data, and testing or reveal critical safety gaps in autonomous systems. The proposed TAIHA provides a structured framework to deconstruct AI-specific contributory factors, as demonstrated in automotive case studies for safety purposes. Mitigating these risks needs a shift beyond technical fixes, which requires rigorous validation protocols, multi-layered governance for accountability, and the formal integration of specialized oversight roles to ensure AI deployment.

# Cultural Heritage at Risk: Safeguarding Identity in the Time of Disaster Crisis

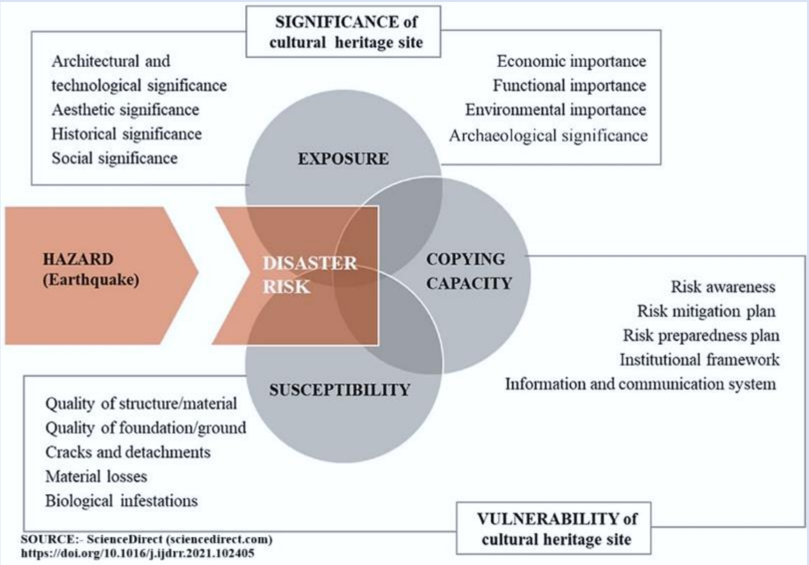
**Abhijit Paul**

*"Our heritage and ideas, our code and standards, the things we live by and teach our children are preserved or diminished by how freely we exchange ideas and feelings" - Walt Disney*

In human society, the term heritage is a type of product which is selected by the people of the society, not all legacies are past generations' "Heritage" it's sometimes tangible and sometimes intangible, it's a benefit of a group or society.

World Heritage sites can be classified into three main categories: (i) Natural Heritage, (ii) Cultural Heritage (which includes artefacts, monuments, archaeological sites, various temples, and cultural landscapes), and (iii) Mixed Cultural and Natural Heritage. During disasters such as earthquakes, landslides, and tsunamis, older buildings and human settlements, along with significant cultural monuments, are particularly vulnerable. These structures often lack the resilience needed to withstand such events, resulting in considerable damage to important artefacts and sites.

**Protection Strategies:** In the emergency time their many strategies are taken for protecting Cultural Heritage during the time of conflict or disaster, in the time of disaster the process of build up and make the Brick wall can protect the old structure, Monument, Buildings so it can minimize the blast damage, which objects are movable like some antic coin, a sculpture or other things which carry the heritage that objects can be transfer one place to another during the conflict time.




**Sectorial Support:** During times of human-made disasters, explosions and detonations can damage the walls of Monuments and ruin archaeological artefacts. To safeguard heritage sites, it is crucial to have support from specific sectors that can help preserve these locations. Certain sectors that contribute to early recovery during critical moments are extremely beneficial for protecting heritage. At times, cultural workers may devise strategies to stabilise situations of conflict or disaster.

**The Heritage Conserving Process:** The local and national governments are planning to conserve and protect the older, more vulnerable heritage sites. They can rebuild ancient temples and monuments, which can sometimes help prevent disasters. An effective approach to conserving heritage and old traditions is involving the community and its members, as local people have greater knowledge about cultural heritage and traditions. By preserving traditional rituals and cultural skills, along with the people of the culture, if a significant disaster strikes that could entirely destroy the heritage and culture site, the preserved rituals will aid in restoring the culture.

The International Conference "Protecting Heritage: From Crisis to Peace" was held on 6-7 May 2025 at Villa Barton in Geneva, Switzerland. Europa Nostra participated in this event, which was organized by ALIPH, the International Alliance for the Protection of Heritage in Conflict Areas. The conference focused on peace-building and sustainable development, emphasizing the importance of recognizing cultural heritage as a vital component in responding to crises.

# Crowdsourced Data, Citizen Science, and Community-Driven Disaster Risk Mapping

**Abinash Dhibar**

Disasters, whether they occur suddenly or develop gradually, pose threats to lives, infrastructure, and local ecosystems. Successful disaster preparedness relies on timely local data and the active participation of individuals who are exposed to these risks. Recently, grassroots initiatives that merge citizen engagement with digital tools have filled gaps in official data and have made planning more attuned to local conditions.

Crowdsourced reporting transforms those affected into real-time sensors. In the event of floods, earthquakes, or storms, residents can share geotagged images or brief reports using mobile applications and social media. This immediate, localized feedback provides response teams with situational awareness they might otherwise be lacking, especially in areas where government oversight is limited. In regions with restricted resources, such reports can significantly impact the speed of response, preventing delays.

Citizen science emphasizes the collection of structured observations by non-experts, which aid scientific evaluation. Volunteers may document daily rainfall measurements, observe river levels, or track erosion over an extended period. These datasets enhance the spatial and temporal range accessible to researchers while fostering local comprehension of hazard dynamics. When everyday individuals supply systematic observations, the resulting data may prove more valuable for modelling and planning than isolated anecdotes.

Community mapping transforms both reporting and observation into a spatial representation. Through low-tech approaches like participatory mapping workshops or more advanced platforms such as OpenStreetMap, neighbourhoods can outline evacuation routes, safe shelters, and sites that pose local hazards. These maps frequently incorporate knowledge that official records lack—such as seasonal flooding paths, buildings prone to leaks during heavy downpours, or informal markets that obstruct access during emergencies. A practical example is CoastSnap, a tool that aggregates repeated photos from fixed locations to monitor shoreline changes, illustrating how community contributions can become solid environmental evidence.

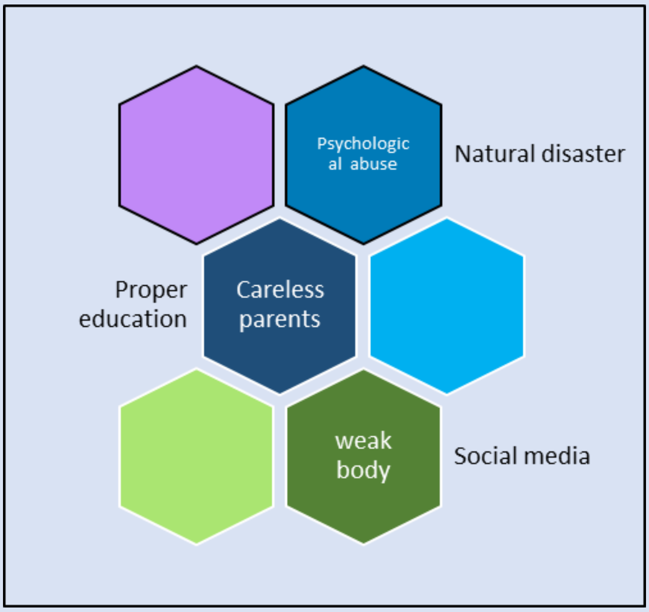

These approaches make disaster awareness and planning more democratic by involving those most affected. At the same time, they face real limits. Volunteer reports can be uneven in accuracy or coverage, and digital methods may exclude people without smartphones or internet access. To address such problems, many projects combine community inputs with professional validation: volunteers flag events, and analysts cross-check them with satellite images, GIS databases, or targeted field checks.

Overall, these participatory approaches represent a meaningful shift in disaster risk management. In short, participatory mapping and citizen-driven data collection are powerful complements to formal monitoring. They bring local knowledge into planning, improve the timeliness of information, and strengthen connections between communities and decision-makers. For these efforts to be reliable and inclusive, projects must invest in training, simple verification workflows, and ways to include people who are offline or hard to reach. When done carefully, community-led data can make disaster planning more practical and more just.

# Children and Youth as Agents of Disaster Resilience

**Ananya Basak**

Disaster resilience refers to the capacity of communities, processes, and nations to respond to and recover from disasters, minimizing their effects on lives, livelihoods, and infrastructure. Children and young people constitute about 50% of the world's population, which makes them particularly vulnerable groups in the context of Disaster Risk Reduction (DRR).




Children encounter disasters at various times and locations, experiencing both natural disasters such as floods, droughts, storms, and earthquakes, as well as man-made disasters that include psychological abuse and inadequate access to emergency shelter, water, food, and medical support. The influence of digital platforms and social media, combined with issues like physical weakness, insufficient education, neglectful parenting, and low public awareness, further complicates their circumstances. These challenges create numerous negative situations in their school lives, making it difficult for them to adapt to society. Consequently, children and youth face a wide range of issues, and their lack of proper education exacerbates their vulnerability during times of disaster.

In 2020, Typhoon impacts in Vietnam affected 2.5 million children, while approximately 960 million children worldwide were affected by COVID-19. Additionally, in April 2024, around 14,500 Palestinian children lost their lives due to ongoing conflicts. Each year, an estimated 175 million children and youth are impacted by natural disasters such as floods, droughts, earthquakes, cyclones, severe storms, and heatwaves.

Disaster-prone situations, including cyclones, floods, landslides, and droughts, are also prevalent in our country and significantly impact children and youth. Furthermore, poor education and economic challenges remain major issues for these young individuals.

**Way to prevent disasters:** Spreading the benefits of education to children is crucial for mitigating the impacts of disasters. Children should be warned before disasters occur. Parents must prioritise their children's safety. Public awareness through TV, radio, and social media plays a vital role in disaster preparedness. It is essential to protect children in safe locations during a disaster. Technology can help predict disasters in various areas. The government should implement various strategies to adequately protect children and youth, thereby reducing the likelihood of disaster impacts.

**Policy:** (a) Global disaster policy is guided by the Sendai Framework for Disaster Risk Reduction (DRR) 2015-2030. (b) The Child Centric Disaster Risk Reduction (CCDRR) Centre India collaborates with UNICEF, ensuring active participation of children and youth in DRR and climate action efforts nationwide. (c) UNICEF engages children through education, preparedness, and resilience programs. (d) Grassroots projects play a vital role in fostering community involvement and enhancing disaster resilience.

Children should always stay vigilant, and precautions must be taken to prevent them from encountering danger due to negligence. In today's world, parents have become much more aware of their children's needs. The rate of incidents involving children has diminished compared to previous years. The influence of education on children is steadily increasing, helping them understand the ramifications of disasters. Through advancements in technology, disaster forecasts can be made in different regions, which greatly decreases the occurrence of disasters and helps keep children and young people attentive. Various strategies can be employed to address such issues.

# Critical Infrastructure Interdependencies and Cascading Failures in Disaster Scenarios

**Ananya Das**

In a disaster scenario, critical infrastructure (CI) refers to the essential systems and resources necessary for society to function properly. Safeguarding these infrastructures is vital to ensure public health, sustain human activity, maintain good living standards, ensure safety, and support economic security.

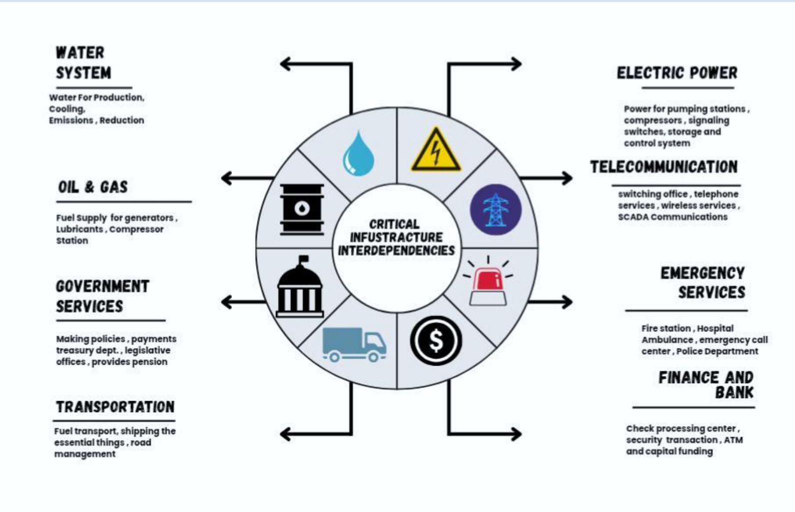
Due to the high level of interdependence among these systems, CI sectors rely on one another to exchange services. Thus, the failure of one sector can lead to disruptions and a cascading impact on others. Below are the different types of important components of critical infrastructure:

**Energy and Utilities:** The energy sector supplies natural gas, oil, and electricity, which are essential for the operation of nearly all other critical systems. This includes power plants, transmission lines, substations, and pipelines.

**Water System:** This system provides the fresh drinking water necessary for survival and maintains wastewater systems essential for public health and sanitation. Key components include water treatment plants, dams, and reservoirs.

**Transportation System**: A robust transportation network is required to move emergency supplies and evacuate people from vulnerable areas. This includes roads, bridges, railroads, airports, and seaports.

**Communications & IT:** These are crucial for informing the public and coordinating emergency responses. This component includes internet infrastructure, data centers, telecom networks, and operational technology.




**Financial Services**: The funding for disaster recovery and economic stability relies heavily on the infrastructure of banking and financial markets. This encompasses stock exchanges, banks, and various payment systems.

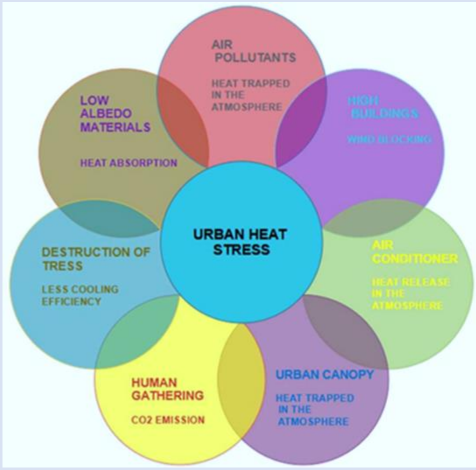
Cascading failure occurs when one component of a system fails due to the failure of another component on which it relies. This mechanism can cause a local disturbance to spread unexpectedly throughout a system, ultimately leading to a failure on a global scale. A notable example is the 2011 Fukushima Daiichi Nuclear Power Plant incident. On March 11, a 9.0 magnitude earthquake struck Japan, triggering a series of malfunctions. The earthquake devastated the electricity grid, forcing the plant to rely on backup generators. About 50 minutes later, a 15-meter tsunami inundated the facility, rendering the generators inoperable and resulting in a total station blackout. Without electricity, the cooling systems failed, leading to partial meltdowns, hydrogen explosions, and the overheating of fuel that ultimately destroyed the reactor structures. Over 100,000 people were evacuated due to radioactive materials being released into the air and ocean. The Fukushima incident serves as a stark reminder of how a series of infrastructure failures can escalate into a catastrophic nuclear accident with long-lasting consequences.

In conclusion, resilience and preparedness for disasters depend on understanding and addressing these interdependencies. Policymakers and emergency managers can reduce systemic vulnerabilities by investing in adaptive technologies, enhancing redundancies, and mapping critical connections. Understanding cascading failures promotes more coordinated, cross-sectorial disaster responses and informs risk assessments and early warning systems. Ultimately, creating resilient infrastructures ensures the continuity of vital services, saves lives, and maintains socioeconomic stability in the face of complex and unpredictable disasters.

# Urban Heat Stress as an Under-Addressed Disaster Risk

**Bidhan Mondal**

Urban Heat Stress is a human-induced phenomenon where city temperatures rise to extreme levels, creating an unhealthy environment. The process of urbanization leads to the absorption of significant heat by materials like cement and asphalt in roads and buildings, which then gradually release it into the atmosphere, causing temperature increases. Furthermore, the absence of trees and water bodies, along with the presence of factories, vehicles, and the use of air conditioning, contributes to Urban Heat Stress. In May 2024, Kolkata experienced an average temperature of 40°C, and West Bengal recorded 21 days of heat waves. Urban Heat Stress constitutes an Unaddressed Disaster Risk because there is no early warning mechanism, heat impacts the body progressively, making it difficult for people to recognize, urban planning mistakes contribute to the issue, and severe outcomes like fatalities are uncommon. Concrete structures trap heat and hinder air circulation, preventing proper airflow. Overpopulation leads to air pollution, which intensifies heat retention in the atmosphere and exacerbates global warming. The ongoing destruction of trees and forests, along with the decline of the urban canopy, continues to elevate urban heat stress. The consequences of urban heat stress are expected to worsen significantly in the future.




## The Impact and Mitigation of Urban Heat Stress

Urban heat stress has emerged as a major environmental and public health challenge in modern cities due to rapid urbanization, dense infrastructure, and declining green cover.

**Human Health Impacts:** Prolonged exposure to high temperatures leads to heat-related illnesses such as heatstroke, dehydration, and heat exhaustion. Vulnerable groups—particularly the elderly, children, and outdoor workers—face a higher risk of mortality. Additionally, prolonged heat exposure increases the likelihood of cardiovascular and respiratory diseases, reducing overall public well-being.

**Environmental Impacts:** Urban heat stress elevates ambient air temperatures, intensifies water scarcity, and contributes to the loss of urban biodiversity. The depletion of groundwater levels and disruption of ecological balance further worsen environmental degradation. Moreover, the growing use of energy-intensive cooling systems amplifies global warming and raises the city’s carbon footprint.

**Socio-Economic Impacts:** High temperatures increase electricity consumption for air conditioning and refrigeration, leading to higher energy costs and a greater financial burden on urban households. Productivity and work efficiency decline as discomfort rises, particularly in outdoor and informal sectors. Consequently, the overall cost of living and urban vulnerability increase.

**Mitigation Strategies:** Sustainable urban design and planning are key to mitigating heat stress. Expanding green spaces, planting shade trees, developing vertical gardens and green roofs, and restoring traditional water bodies help cool urban environments naturally. Promoting renewable energy, electric vehicles, and public transport can reduce emissions and heat generation. Urban zoning policies, reflective roofing materials, and heat-resistant construction technologies can further enhance resilience. Public awareness campaigns emphasizing hydration, rest, and heatwave preparedness are essential to protect citizens.

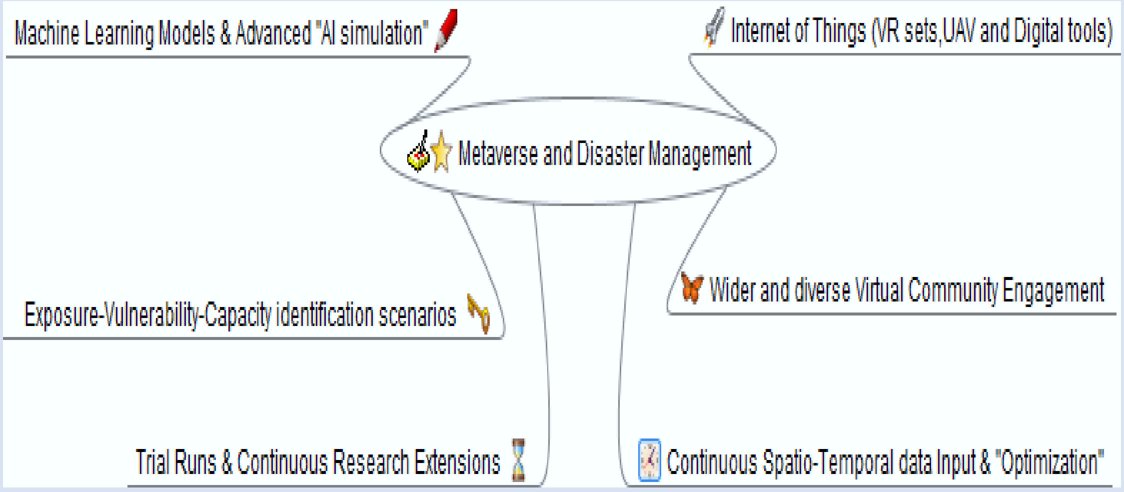
In conclusion, addressing urban heat stress through integrated ecological planning and community participation is vital for safeguarding human health, conserving biodiversity, and ensuring sustainable urban living.

# Metaverse & Virtual Reality Simulations for Disaster Training & Awareness

**Biprorshi Ghosh**

*….In our virtual world, we can simulate on-demand any number of what-if scenarios to test the robots and the factory's workflow. Long-tail situations that might never happen in the physical world can be simulated and trained on in the virtual world. - **Jensen Huang, CEO of NVIDIA** at NVIDIA GTC, 2021.*

The vast array of an interactive digital platform, the namesake being from the portmanteau "Meta" meaning beyond and verse in context of a space, like internet; the metaverse is a word largely known to mostly tech-savvy or ones engaged in that field as a buzzword, albeit the concept sparked something greater. In the wider scale, thought at first, virtual video games were popular at a relatively smaller scale, until the official launch of meta's (previously Facebook) "Facebook Horizon" in 2019 and its subsequent popularity.Tech-oriented large multinational firms like Google, NVIDIA, Microsoft, Apple etc. to name a few has developed it's test versions of the concept as of now, showing it's break taking developmental path in this age of technology and AI taking roles beyond labs, analytics and large scale management of resources. In this regard, wider fields like Disaster Managements are having a novel moment to implement these frameworks. Use of metaverse, especially of virtual reality (Other than the broader "Mixed Reality" and "Augmented Reality'') where the whole interactive platform is in a virtual world, interacted by entering into it can be a viable option for training of volunteers and staffs for hazard preparation, albeit in cases of extreme requirement as an alternative.




According to a US based Market Research Firm Polaris MR, the economic market for the whole metaverse industry can be forecast by valuing the global metaverse market at $107.01 billion in 2024, with projected growth to $4,798.77 billion by 2034. Especially, MIT has its own application called "RescuEye" from MIT Solve, that applies UAV like drones and application in simulation modelling to predict, analyse and respond to hazards. Developments has being ongoing with the integration of research institutions and corporate specialized in the field, like NVIDIA's Omniverse and Unity Technology's Game Engines in running models by feedings input of continuous spatio-temporal data and optimizing them in simulation runs.

Digital communities are a key part in this process where they use exiting open forum platform or unique ones to discuss, disseminate and train models, people, and generate awareness in this point at a wider level. With lower barriers of entry by using IoT for physical-movement based interactions by "avatars" and using Virtual reality tools like VR sets, and in using exiting smartphone based systems like mixed reality application and popular opens source platforms like meta in this case.

But keep in mind, the huge amount of initial cost intensified a barrier in various sectors. Also, the technical know-hows of using digital platforms and non-implementation of robust security apparatus like blockchain to digitally track every case can jeopardise the situation, along with a simple lack of the dimension of truly identifying the problems of vulnerabilities in a broader and holistic scale in an "unguarded digital wilderness it seems". This truly requires robust plans, frameworks and continuous trials for the betterment forseen.

# Financing Resilience: Green Bonds, Loss and Damage Fund, and disaster risk reduction (DRR) Investments

**Debanjana Das**

The escalating frequency and intensity of natural disasters across the globe are negatively impacting both the society and economy thereby increasing the vulnerability of communities. The increasing rate of disasters over time can no longer be considered as an isolated event, but rather has emerged as a systemic threat, requiring fundamental changes in the way global risks are identified and managed. These fundamental changes are needed, as they seek to transform the economy into a low-carbon and climate-resilient economy and also shift our focus from a reactive disaster response to proactive systemic resilience.

The process of disaster mitigation is an integrated approach that leverages strategic coordination and financial investment across every stage of the disaster cycle to build a stable future. However, contrary to the intuition that post-disaster spending is more effective, evidence consistently shows that proactive financial investment made before a disaster is far more effective at reducing loss and damage. For instance, a research demonstrates that every dollar spent on preparedness can save up to $13 in future losses, proving that

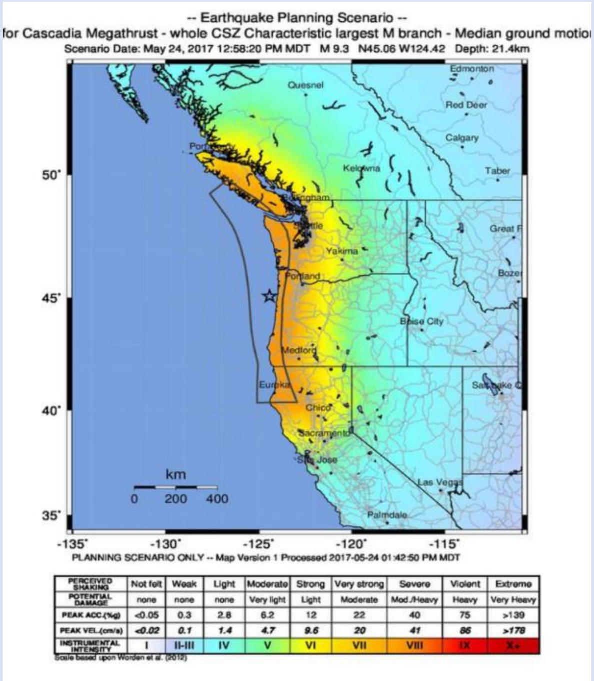
"**Resilience is not a cost, but a catalyst for growth**"

The concept of resilience, originated by the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, implements the concept of the triple divident of resilience by reducing the resilience gap through the effectiveness of capacity adoption. It is worth noting that the framework, which is composed of policy governance and a continuum of financial tools, creates a strategic blueprint, the core of which is the three pillars that represent the components and provide the structure of a three-tier system. The strategic framework is at the highest level of this three-tier structure, which encourages public-private collaboration to adopt integrated risk assessment strategies and build financial funds by determining the country's long-term macro fiscal policy. The second layer of this structure is the central component that includes proactive prevention, private capital mobilization and post impact response, which will operate in a continuous complementary cycle across the disaster timeline. As the first pillar of this layer, disaster risk reduction is proactively aimed at prevention, and risk reduction and capacity building are carried out in the pre-disaster phase based on the principle of the 'triple dividend of resilience'. Mobilizing private capital, as the second pillar of the same level, essentially provides the long-term financing needed to implement the first level. The implementation of this pillar involves attracting private investment on special terms through instruments such as green bonds to maintain the supply of capital for various resilience-enhancing projects. Post-impact response has emerged as the third pillar of the level, which plays a direct role in dealing with the crisis after a disaster. In this context, the loss and damage fund compensates for the unavoidable losses of vulnerable countries through grant-based financial assistance after a disaster. The last layer of the three-tier structure is mainly based on supporting mechanisms, of which contingent financing, global funds, and partnerships are particularly notable as financial tools. Implementing this overall framework requires a wide range of stakeholders with distinct, distinct roles, including the public sector, private sector, local communities and civil society, along with international organizations and bodies. Ultimately, it can be said that it is effective as a complementary approach to the UN Sustainable Development Goals (SDGs).

# Geo-hazards of the Future: Mega-Earthquakes, Super-volcanos and Tsunamis

**Manaswita Guha**

Earth as a dynamic planetary system, is perpetually shaped by the multifaceted interaction of the intrinsic geodynamic processes and extrinsic environmental forces. Among all the geodynamic processes, geohazards are considered as the most profound manifestation of this dynamism. Geohazards are natural processes emerging from the lithosphere, hydrosphere and atmosphere having the capability to cause panoramic destruction and disruption of social equilibrium. Earthquakes, volcanos, and tsunamis have been imperative in sculpting the Earth's surface, nevertheless their occurrence on an unprecedented scale manifest as mega-earthquakes that ruptures entire tectonic boundaries, Super volcanos that can alter the global climate and tsunamis that defy borders and devastate the coastlines. These catastrophic events occur due the disproportionate power concentrated within the subduction zones, where one tectonic plate is forced beneath another. These geohazards challenge not only our scientific understanding but also our resilience as a global society. Therefore, to anticipate and mitigate their impact requires integrating knowledge from geophysics, seismology, volcanology, and plate tectonics. Thereby building an interdisciplinary framework that deciphers Earth's most powerful forces.




Earth's most energetic seismic events are the mega-earthquakes, they occur due to the convergence of the two plates, the oceanic plate being denser thrusts under the continental plate, due to friction the interface become locked. Over decades or centuries these locked faults harbor immense strain until it can no longer endure, ultimately leading to an unforeseen and violent rupture. This concurrent, large-scale vertical displacement of the seafloor, which disturbs the entire water column above it, is the fundamental mechanism responsible for the generation of tsunami. One such zone that possesses such is the Cascadia Subduction Zone. Even though it exhibits low seismicity currently but the historical geological evidences say otherwise. It has been observed that in last 10,000 years this region produced at least 19 great megathrust earthquakes and is capable of a staggering magnitude of 9.0+ event. The vigorous shaking produced from such event leads to widespread catastrophic devastation.

Super volcanos represent a different yet equally formidable threat. A super volcano can produce an eruption with a Volcanic Explosivity Index (VEI) of 8, which is termed as "Super-eruption". Such eruptions eject more than 1,000 cubic kilometers of magma, ashes, and gases, making them unimaginably powerful than a typical volcanic eruption. Super volcanos are considered extreme geohazards due to their global impact like pyroclastic flows and ashfall which can obliterate landscapes across thousands of kilometers. They emit enormous volumes of Sulphur dioxide and volcanic ash in the stratosphere. This leads to "Volcanic Winter" responsible for a sharp global temperature drop due to sunlight blocking aerosols. Some super volcano systems across the globe are Yellowstone Caldera (USA), Toba Caldera (Indonesia), Taupo Volcanic Zone (New Zealand), Aira Caldera (Japan) etc. While the reoccurrence intervals of mega-earthquake, super volcanos and tsunamis are difficult to predict and their geological inevitability is well established. Thus, the study for future geohazards does not solely rely on the retrospective geological evidences but in the advancement of predictive modeling, satellite geodesy, and early warning systems. These tools are essential in preparing societies to mitigate risks, adapt and develop resilience against such "low frequency and high impact" geohazards.

## RISK-INFORMED DEVELOPMENT: ALIGNING SDGs, DRR, AND CLIMATE AGENDAS

**Nabanita Kundu**

Risk−Informed Development (RID) is a strategic approach to planning and decision–making that systematically integrates an understanding of potential risks, such as climate change, conflict, and economic instability, into all stages of development process. RID is consistent with the Sustainable Development Goals (SDGs), Disaster Risk Reduction (DRR), and the climate agenda, where climate and disaster risk assessment for sustainable infrastructure is an integral part of development planning and decision–making processes. The main goal of Risk–Informed Development (RID) is to build resilient communities and societies by integrating risk–related knowledge into development planning.

There is a clear interconnection between these agendas where climate play a crucial role. These interconnections are — 1) RID integrates disaster risk management and climate change as vital elements of development planning and budgeting, rather than separating them, 2) by identifying and addressing risks, countries build resilience, which enables them to achieve the SDGs by preventing damage from disasters and climate extremes that threaten development achievements, 3) The Sendai Framework is a global agreement that works towards the goal of 'Disaster risk reduction', which is a key part of risk-based development. This framework emphasizes building resilience and preventing new risks, in line with the broader goal of sustainable development. Climate change is a primary driver of risk, and steps are taken to reduce climate change risks using a risk-informed approach, ensuring that climate adaptation efforts are consistent with development goals.

### The result of applying these Agendas are —

1. **Enhanced Resilience:** Integrating hazard assessment with development to build capacity and resilience within communities.

2. **Improved Efficiency and Effectiveness:** Silent rise, risk-informed development targets the non-governmental sector, which more consistently aligns with this approach, redoubles efforts and makes intelligent use of financial and human resources.

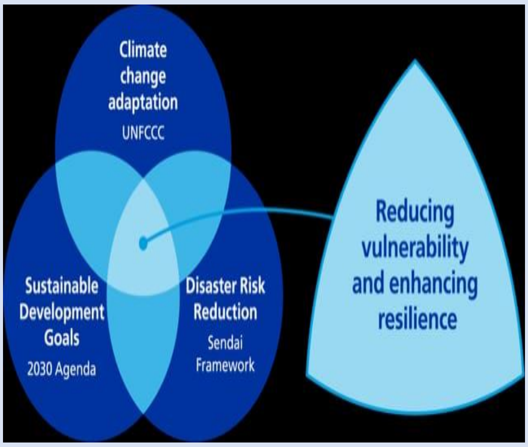



Figure source: UNDRR

3. **Achieving the Sustainable Development Goals (SDGs):** Accelerating progress towards the SDGs in this step-by-step matter ensures that development is not disrupted due to disasters and climate change, further qualifying the 2030 Agenda for sustainable development.

4. **Holistic Planning and Implementation:** Long-term vision, sustainable approach and development planning within individual organizations, progress and disaster risk management.

5. **Better Coordination:** An interdisciplinary approach between different campaigns and coordinated efforts of different stakeholders is crucial to implement the results.

***"Risk Reduction must be integrated into the DNA of policies and investments if actions are to be sustainable and resilient in the face of current and future risk"— UNDRR.***

# Elderly Populations and Age-Sensitive Disaster Risk Straggles

**Samima Khatun**

The older people are often the ones who suffer the most during the natural disaster. Especially during a disaster emergency situation they lack the ability of coping with the situation. As a result, older people are often severely impacted by adverse impact of any disaster and suffer health issues. In recent time, COVID 19 pandemic situation has depicted the complexities of such sufferings. Thus, it is important for communities to be aware and develop prior plans to cope up the situation for safeguarding the elder ones.

***"It is essential for older adults to maintain social connections as a part of disaster preparedness. Being prepared is not only stockpiling resources like food and medicines and water. You also need to pay attention to the social connections."— Ichiro Kawachi, Ph.D., Harvard T.H. Chan School of Public Health***

### The reasons why the elderly are affected by disasters:

**1. Lack of early warning:** The elderly are sometimes at risk for not speaking up about the disaster. Their tolerance decreases and they got sick. They lack of capacity and right to information often lead them to high disaster risk.

**2. Inadequate medical system:** The elderly are more sensitive when they are at disaster risk, and if the disaster damage is greater, the risk cannot be minimized with inadequate medical infrastructure and facilities.

**3. Stress and loneliness:** Often the elderly people are not provided with enough care, and their opinions are not well regarded in modern society. All these factors harm their mental health condition during or after disasters.

For an example; in 2019, affected 703 million of the global population was older than 65 years of age.

### Age-sensitive disaster risk strategies:

**1. Preparedness**: There is an urgent need to prioritize elderly people and their basic necessities in disaster emergency situations. Awareness must be raised among health and humanitarian sectors. Various guidelines need to be adopted (e.g. emergency medical care, nutrition, protection, gender-based codes, participatory evaluations and programs). Also, helping disaster affected elderly communities could aid into rebuilding strength and capacities.

**2. Emergency response and review:** Participatory assessment should target all age groups, including those with established assessment tools for people with certain medical conditions. Assessments should include information on health status, social support services, medical and nursing needs, caregiving responsibilities, and access to basic living needs (including food and healthcare).

Promoting consultation on inter-agency and inter-sectoral policies and programmes for building consensus, commitment and capacity to address the needs of older persons in disaster and humanitarian crises could immensely help in disaster risk reduction. Collaborating with the Ministry of Health to establish mandates and legislation could ensure adequate care provided to older persons along with implementing a human rights framework. In addition, developing options for increasing access to affordable health services for older persons, including the implementation of subsidized medical and drug programmes are of urgent requirements. Advocating for funding options and humanitarian assistance for safeguarding the old people in emergencies and conflicts will help in minimizing the disaster risk. Overall, the above plans and strategies might improve preparedness and could ensure safety for the elderly people.

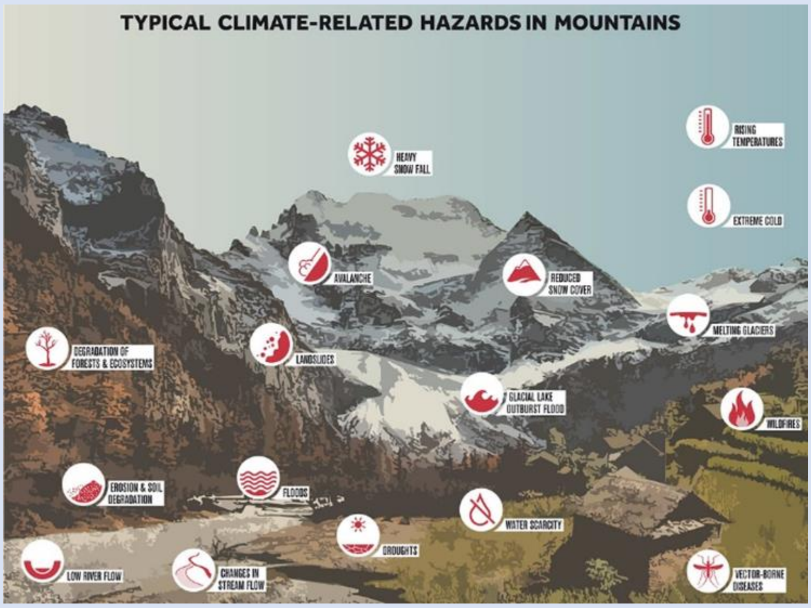
# Disaster risk in high altitude mountain regions and mitigation strategies

**Soumita Biswas**

Although high-altitude mountain ranges rank amongst some of the more aesthetically pleasing regions within Earth's biosphere, their inherent beauty makes them particularly sensitive to ecological disasters. Their steep slopes, unstable geology, and unpredictable weather make these areas fragile, and climate change has only exacerbated these challenges. For example, glaciers in the Himalayas have lost more than 40% of their ice since the mid-20th century. This rapid melting is not simply a matter of loss; it heightens the risk of avalanches, flash floods, and the formation of unstable glacial lakes that can burst at any time, threatening millions of people downstream.

These mountains are often referred to as the "water towers of the world", supplying fresh water to approximately 1.3 billion people across Asia. This makes their stability crucial not only for the mountain communities but also for overall water security, contributing to the ecological balance of the entire continent. Among the most significant risks in these regions are landslides, which are mainly caused by heavy monsoon rains, earthquakes, deforestation, and illegal human activities such as unregulated road construction that disturb fragile slopes. In India, around 12% of the land is highly susceptible to landslides, with the Himalayan belt being particularly vulnerable.

Earthquakes pose a constant threat; the devastating Nepal earthquake of 2015, measuring 7.8 on the Richter scale, resulted in the loss of over 9,000 lives, highlighting how catastrophic seismic activity can be in densely populated mountain areas. Glacial lake outburst floods (GLOFs) are becoming increasingly common as well. These occur when melting glaciers create fragile lakes that can suddenly burst, releasing massive amounts of water and causing floods. The 2013 disaster in Kedarnath, Uttarakhand, serves as a tragic reminder of these risks, as heavy rainfall combined with glacial flooding led to thousands of deaths and widespread destruction.



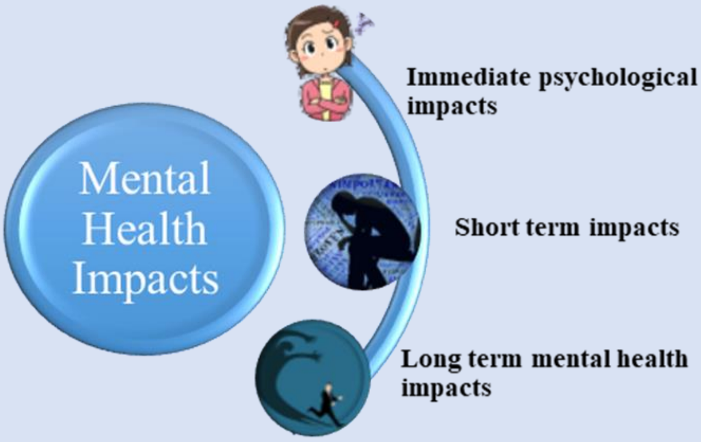

Avalanches pose another layer of threat, especially in snowbound areas like Kashmir, where more than 60 people lost their lives within days due to sudden snow slides in 2020. This illustrates how rapidly changing weather conditions can turn deadly at high altitudes. While these hazards are primarily natural, human actions have aggravated the situation. Unmanaged tourism exerts immense pressure on vulnerable ecosystems, deforestation weakens natural barriers against erosion, and rapid urban growth in valleys and mountainous areas heightens exposure to various risks.

To address these challenges, solutions must come from multiple directions. Early warning systems for earthquakes, avalanches, and glacial activity can save many lives, but local communities must also be prepared through awareness programs and first-aid training. On a larger scale, sustainable development is key; this includes implementing earthquake-resistant buildings, stabilizing slopes through afforestation, and restricting settlements in high-risk areas to reduce long-term vulnerability. Protecting forests helps regulate water flow and mitigates landslide risks, while promoting responsible tourism can create a balance with economic benefits. Additionally, traditional practices such as controlled grazing and mindful resource management can complement modern scientific approaches to enhance resilience.

# Mental Health Impacts of Climate and Disaster Trauma

**Sumi Roy**

Natural disasters can significantly affect mental health, both in the short term and the long term. The impact varies based on the type of disaster, individual experiences, social support systems, and any pre-existing mental health conditions. Common consequences include a broad spectrum of emotional and psychological challenges. Climate and disaster trauma refers to the psychological, emotional, and physiological distress that individuals experience as a result of climate-related events such as wildfires, floods, droughts, and hurricanes, as well as other natural disasters like earthquakes and tsunamis. This trauma can manifest as either short-term or long-lasting effects and may stem from direct exposure to disasters, witnessing destruction, or even the anxiety surrounding potential future events.




There are several ways in which climate change contributes to disasters. Elevated temperatures can lead to drought, wildfires, and health issues such as heat stroke and dehydration. Warmer oceans can intensify cyclones, hurricanes, and typhoons. The melting of glaciers and polar ice raises the risk of flooding, coastal erosion, and saltwater intrusion, which can devastate farmland and freshwater sources. Changes in rainfall patterns can result in some regions experiencing excessive rainfall that causes flash floods and landslides, while others suffer from insufficient rain, leading to prolonged droughts and food insecurity. Furthermore, extreme weather events like storms, cyclones, and hurricanes are becoming progressively more destructive. Hotter, drier conditions create an environment more conducive to wildfires, making forests and grasslands increasingly susceptible to ignition. These wildfires can obliterate homes, ecosystems, and release harmful smoke into the atmosphere.

**There are several mental health Impacts of climate and disaster trauma:**

- **Immediate psychological impacts:** Shock, confusion, panic, difficulty concentrating and emotional numbness. Grief and loss from losing loved ones, homes, or livelihoods right after the event.
- **Short-term impacts:** Nightmares, anxiety and depression, hopelessness, loss of purpose and sleep disturbances. Disruption of social support networks due to displacement.
- **Long-term mental health impacts:** Eco-anxiety and climate anxiety reflect a persistent worry about environmental degradation and the threat of future disasters. Chronic depression and a sense of demoralisation are especially prevalent among those who experience repeated disasters. Children raised in areas prone to these events often internalise feelings of fear and insecurity. In farming communities facing climate-induced livelihood losses, such as droughts and crop failures, there is a noticeable increase in the risks of suicidality and self-harm. Socially, the impacts of these crises include displacement, the erosion of cultural identity, and discrimination in new regions. The resilience of communities can break down as repeated disasters strain traditional coping mechanisms. Vulnerable populations, particularly children and adolescents, are notably more sensitive to stress and its long-term developmental effects. Indigenous communities, too, face significant challenges, grappling with cultural loss alongside the trauma inflicted by environmental changes.

Climate change has a profound impact on children and young people, affecting them not only through physical health issues but also socially, psychologically, and developmentally. Given that their bodies and minds are still developing, they are particularly vulnerable to both the direct and indirect consequences of a warming planet, and they are likely to bear these burdens longer than any other generation. Many young individuals experience eco-anxiety, a persistent fear of environmental catastrophe. Some contend with climate grief, mourning the loss of species, landscapes, and a sense of a stable future. Children who endure hurricanes, floods, or wildfires may develop depression or anxiety as a result, and long-term displacement and interruptions in their education can further exacerbate their distress.

# Role of Synthetic Aperture Radar in Disaster Assessment

**Suvarun Nag**

Disasters, whether natural or anthropogenic, often lead to widespread destruction and threaten the lives and livelihoods of affected communities worldwide. Accurate and timely disaster assessment is vital as it helps coordinate effective relief efforts, minimize additional damages, and plan long-term recovery and rebuilding strategies. In recent years, Synthetic Aperture Radar (SAR) has emerged as an important tool in the realm of remote sensing, offering unique advantages far beyond what traditional imaging methods are capable of. While optical systems are heavily dependent on bright and clear skies, SAR can produce high-resolution images in any weather condition and also during night time. It is therefore especially useful during the occurrence of disasters when, apart from the clouds, heavy rains and darkness also affect the normal way of observation. Conventional optical satellites often fail when clouds or bad weather block visibility. In contrast, SAR works in the microwave spectrum, which allows it to pass through clouds and atmospheric disturbances and also penetrate vegetation cover to an extent. This means it can still gather crucial information during emergencies, giving relief teams dependable data when it is most needed.

One of the best examples where SAR technology has proven to be exceptionally useful is in the case of flooding. Radar signals reflect off water surfaces, which makes it possible to detect and map flooded areas even when thick vegetation or clouds block normal visibility. This facilitates the quick generation of flood maps, which are crucial for guiding rescue workers, determining safe zones and planning evacuation routes. Following cyclones or storm surges, SAR imagery helps to track coastal erosion, assess damage to infrastructure, and monitor changes in water levels, all of which are essential for effective rapid response and recovery efforts.

In case of earthquakes or landslides, Interferometric SAR (InSAR) can detect ground shifts in centimeters, either before or after it occurs. This information is essential in determining the extent of earthquake damage and assessing aftershock probabilities. In landslide prone regions, SAR can provide early warnings through slope and soil stability assessment, which is critical in preventing the loss of life and damage to property.

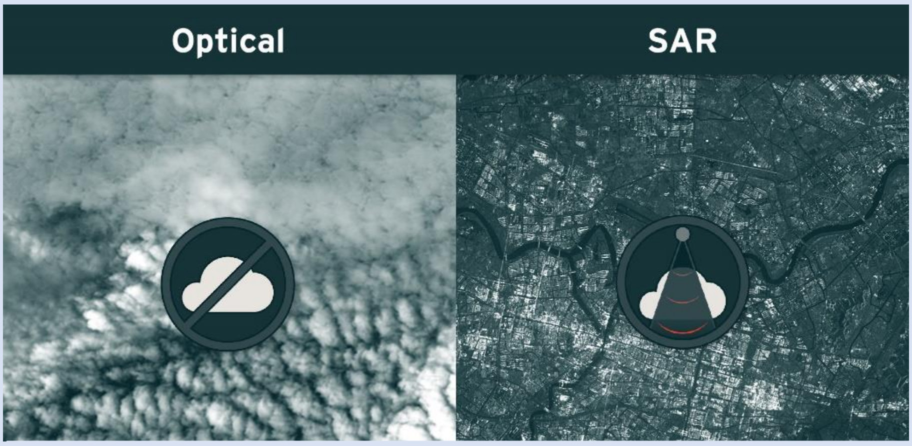



*Fig: Difference between optical remote sensing systems and Synthetic Aperture Radar (SAR) (Source: ursaspace.com)*

In urban environments, Synthetic Aperture Radar (SAR) is crucial for detecting structural changes with high accuracy, helping in instant identification of collapsed buildings, transportation failures, and interruptions to essential services. This helps authorities prioritize emergency responses by directing services to critical locations like hospitals and affected areas. It also monitors land use, vegetation, and water bodies, providing critical insights that support sustainable recovery and strengthen urban resilience. These efforts enhance community safety, reduce risks, and support the maintenance and planning of resilient infrastructure, enabling quicker recovery and rehabilitation.

Overall, SAR technology has revolutionized disaster assessment and management. Its ability to operate under adverse conditions makes it an essential component of modern disaster response systems. SAR helps in fast disaster response, but is also useful in the long run as it builds resilience and guides better recovery and preparedness for future hazards.

# Wildfire Risk Reduction in a Warming World

**Tanushree Bag**

Since the Industrial Revolution in the 1800s, there has been a rapid increase in population growth. This surge has led to excessive urbanization and significant environmental pollution from vehicles, which are key contributors to rising greenhouse gas levels. The burning of fossil fuels releases large amounts of $CO_2$ into the atmosphere, intensifying the greenhouse effect and contributing to global warming. Gases such as $CO_2$, $CH_4$, $N_2O$, and CFCs trap heat from sunlight, further warming the lower atmosphere.

Currently, climate change is profoundly affecting the environment. Deserts are expanding, ice in polar regions and glaciers is melting, leading to rising sea levels. Increased frequency of extreme weather patterns has resulted in excessive drought, particularly in arid and semi-arid regions, dry conditions that foster devastating wildfires. Consequently, ecosystems are disrupted, the environment degrades, and biodiversity declines. Wildfires typically arise from both natural and human-made causes. While natural factors like lightning, dry weather, and plentiful flammable vegetation can fuel fires, climate change enhances these conditions with strong winds that exacerbate the situation. Human activities—such as campfires, careless smoking, and faults in electrical power lines—also significantly contribute to severe wildfires. Additionally, urbanization leads to forest destruction, and practices aimed at pest control can leave trees dry and flammable, creating further wildfire risks.

Wildfires have devastating effects on forest vegetation and wildlife, leading to the destruction of ecosystems and threatening human lives. The aftermath of these fires releases excess carbon from burned vegetation into the atmosphere, worsening air pollution and contributing to greenhouse gas emissions. This exacerbates the ongoing cycle of climate change, highlighting the urgent need for wildfire prevention strategies to safeguard lives, property, and ecosystems.

While wildfires can sometimes be triggered by natural occurrences, human activities are often the main culprits. In a warming world, wildfires are viewed not just as natural events but as critical threats that require proactive measures. Efforts to mitigate wildfire risks now emphasize public awareness and participation, comprehensive policy planning, the use of advanced equipment, responsible housing management, and the avoidance of hazardous activities, like smoking and burning dry leaves. Together, these strategies aim to significantly reduce the risks associated with wildfires and protect both people and the environment.

The UNEP report points out Portugal as a good example for governing wildfire risk which was a man driver behind the Landscape Fire Governance Framework (AGIF 2023). The need for such Victoria's Wildfire Management overlay (WMO) is becoming increasingly apparent as climate change contributes to the growing frequency and intensity of bushfires in Australia.

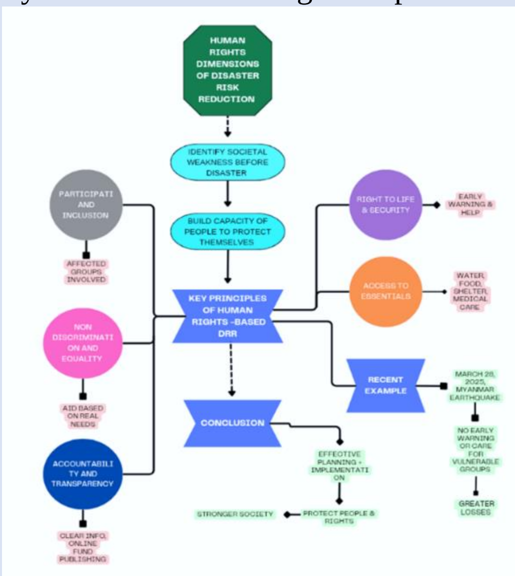
# Human Rights Dimensions of Disaster Risk Reduction

**Uma Bala**

"Prevention is better than cure" reflects the principles of Disaster Risk Reduction (DRR). Through DRR, it is possible to reduce the loss of human lives and property from major disasters such as cyclones, earthquakes, floods, and droughts. For example, in 2004, the Indian Ocean Tsunami and, in 2010, the Haiti Earthquake caused significant damage. In contrast, the application of DRR during the 2013 Cyclone Phailin greatly minimised the extent of the destruction.

However, in a disaster situation, do people only lose their lives and property, or do they also lose their rights? Take the example of an earthquake. Why did tall buildings in developed cities remain standing while the mud houses of poor villagers collapsed? The reason lies in the vulnerability of the poor, who often live in less secure locations. They lack the financial resources to construct strong homes, do not receive early warnings, and may not have proper systems in place to access help.

In DRR, the Human Rights Dimension emphasises identifying societal weaknesses before a disaster strikes and addressing these issues. As a result, when a disaster occurs, its impact is less harmful to everyone involved. Human rights extend beyond just food, water, shelter, and dignity; they also involve building the capacities of all individuals so they can protect themselves.




**The basic principles of a human rights-based approach to disaster risk reduction include:**

- ***Participation and Inclusion:*** Affected communities, especially individuals with disabilities, the elderly, and children, should be actively involved in all stages of DRR.

- ***Non-Discrimination and Equality:*** DRR initiatives must be developed based on principles of non-discrimination and equality. Aid, financial distribution, and capacity building should be based on actual needs, not influenced by race, gender, religion, disability, or social status.

- ***Accountability and Transparency:*** Governments have a responsibility to provide clear information and publish details of disaster relief funds online to keep everyone informed. Additionally, if emergency shelters are unsafe, individuals should have the ability to file complaints against the government or relevant authorities.

- ***Right to Life and Security:*** The government must ensure that people can live safely by providing early warnings and necessary assistance.

- ***Access to Essential Services and Resources:*** During and after a disaster, arrangements must be made to ensure everyone can access drinking water, food, medical care, shelter, and proper sanitation.

Efforts are being made to implement DRR through various policies and programs that are crucial for protecting human rights and saving lives.

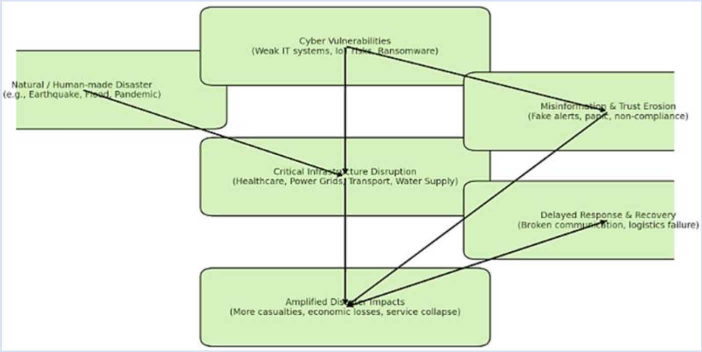
However, on March 28, 2025, a 7.7 magnitude earthquake struck central Myanmar, where there were no early warnings and no provisions for drinking water, food, medical care, or special assistance for vulnerable groups, leading to greater human loss. It is clear that it is not only about having policies in place, but also about effective planning and proper implementation, which are essential for protecting people from disasters and upholding their rights. Only then can our society truly thrive.

# Cyber-security Threats as Disaster Multiplier

**Sanku Mondal**

In the modern digital age, disasters are no longer confined to natural hazards such as earthquakes, floods, or pandemics; they also include cyberattacks that disrupt critical infrastructure, data integrity, and essential services. The convergence of cyber risks with traditional disasters has created a new paradigm in disaster risk reduction (DRR), where cybersecurity threats act as disaster multipliers. This means that cyber vulnerabilities can amplify the impacts of natural or human-made hazards, increase systemic risks, and hinder effective response and recovery operations.

Critical infrastructure systems, including energy grids, healthcare networks, transportation systems, water supply, and communication channels are increasingly interconnected through digital platforms and the IoT. While this integration improves efficiency and monitoring, it also expands the surface area for cyberattacks. For example, a flood or earthquake may damage physical systems, but simultaneous cyberattacks on power grids or communication networks can paralyze response teams, delay relief operations, and escalate the magnitude of the disaster. Such cascading effects illustrate how cybersecurity threats intensify vulnerability during crises. One prominent example is in healthcare systems. During the COVID-19 pandemic, hospitals became prime targets of ransomware attacks. Cyber intrusions not only jeopardized sensitive patient data but also disrupted life-saving equipment, laboratory processes, and vaccine supply chains. Here, the disaster—public health emergency—was compounded by cyberthreats, amplifying both human and economic losses. Similarly, cyberattacks on water treatment plants or nuclear facilities during extreme weather events could create compound risks, leading to contamination, radiation leakage, or widespread service breakdowns.




The concept of ‘disaster multiplier’ also extends to the erosion of trust in institutions and data. In times of crisis, accurate and timely information is vital. Cyberattacks that spread misinformation, manipulate emergency alert systems, or compromise government databases can mislead populations, reduce compliance with evacuation orders, and trigger social unrest. Such disruptions magnify the chaos of a disaster, prolong recovery, and increase the likelihood of secondary hazards, such as panic or market instability.

Scientific literature emphasizes the need for integrated risk assessment that treats cyber risks and traditional hazards as interconnected. The Sendai Framework for Disaster Risk Reduction (2015–2030) underscores the importance of understanding systemic risk in a globally connected world. Cybersecurity thus cannot remain a siloed issue of IT management; it is a fundamental component of resilience planning. Investments in robust encryption, redundancy in communication systems, and cyber hygiene training for emergency responders are essential strategies to mitigate cyber-amplified disasters. Moreover, scenario-based simulations combining physical hazard models with cyber-threat models can improve preparedness. For example, simulating the impacts of a hurricane coinciding with a coordinated cyberattack on telecommunications can reveal hidden interdependencies and guide contingency planning. Public–private collaboration is also crucial, since much of the critical infrastructure is operated by private entities. Developing real-time cyber threat intelligence sharing platforms and embedding cybersecurity into disaster drills can substantially reduce compound risks.

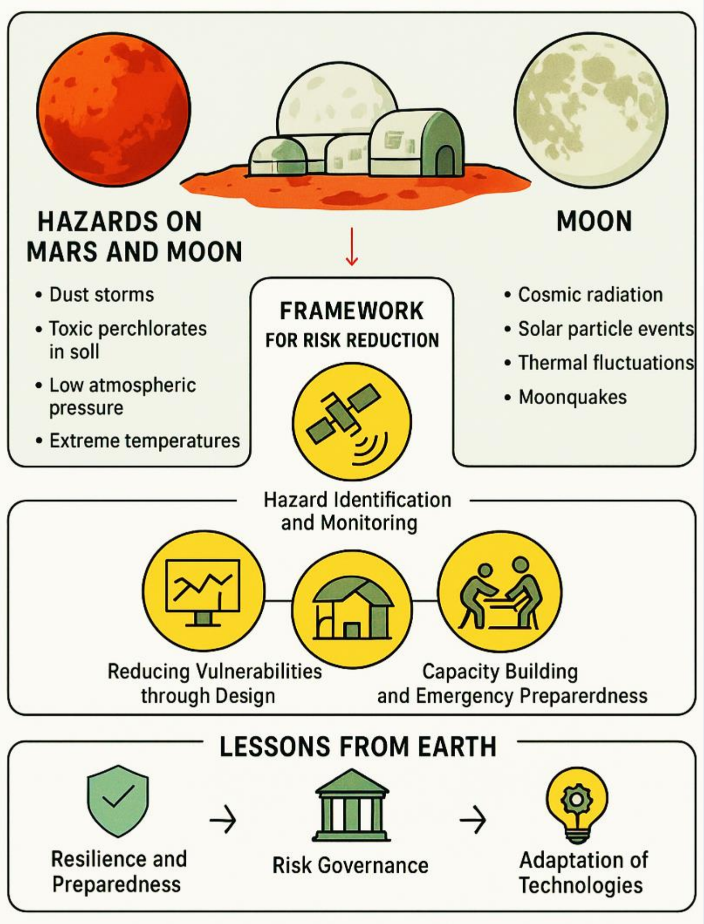
Overall, cybersecurity threats act as disaster multipliers by amplifying vulnerabilities, disrupting critical services, and compounding the social and economic impacts of disasters. Addressing these risks requires a holistic framework that integrates cyber resilience into disaster management. As societies become more digitized, recognizing and mitigating cyber-disaster interlinkages will be essential to safeguard human security, maintain trust, and ensure rapid recovery in times of crisis.

# Disaster Risk Reduction in Space: Safeguarding Future Settlements on Planet Mars and Moon

**Sinjini Lahiri**

Humanity's ambition to establish settlements on the Moon and Mars, driven by initiatives such as NASA's Artemis program and private ventures like SpaceX, raises critical challenges of survival in harsh extraterrestrial environments. Among these challenges, Disaster Risk Reduction (DRR) emerges as a cornerstone for ensuring the safety, resilience, and long-term sustainability of off-world colonies.

**Hazards on the Moon and Mars:** Both planetary bodies present unique natural and technological hazards. The Moon is exposed to intense cosmic and solar radiation, lacks atmospheric protection, and undergoes drastic temperature shifts between day and night. "Moonquakes," though less frequent than earthquakes, can destabilize structures. On Mars, hazards are amplified by planet-wide dust storms lasting months, toxic perchlorates in soil, extremely low atmospheric pressure, and average temperatures near –60°C. The absence of magnetic fields on both worlds makes radiation exposure one of the most critical risks.




**Framework for DRR:** Developing effective DRR strategies involves three interconnected dimensions: hazard identification, vulnerability reduction, and capacity building.

- ***Hazard identification and monitoring:*** Early-warning systems, proven invaluable on Earth, must be adapted for space. Radiation detectors, seismic monitoring, and atmospheric models of Martian dust storms will be essential. Orbital satellites can provide continuous surveillance, while artificial intelligence can support predictive modeling and real-time risk assessment.
- ***Reducing vulnerabilities through design:*** Engineering resilience is key. On the Moon, habitats shielded by regolith or located underground can protect against radiation. On Mars, 3D-printed structures using local soil may withstand dust storms and reduce dependence on Earth's resources. Pressure control, redundant life-support, and thermal regulation must be embedded in settlement design. Modular, repairable structures will ensure flexibility in responding to localized damage.
- ***Capacity building and emergency preparedness:*** Settlers must be trained in crisis management, including medical care, repairs, and evacuation. AI-driven decision-support tools and autonomous robotic responders can enhance disaster response. Emergency shelters with independent oxygen and power reserves are vital for short-term survival during catastrophic failures.

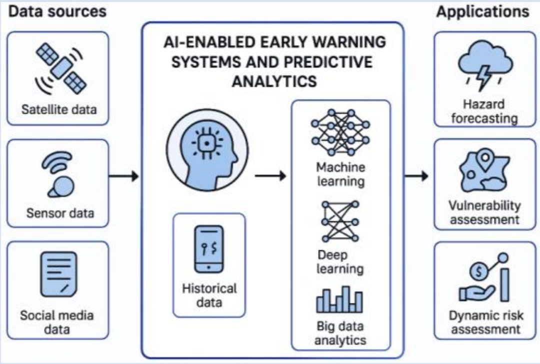
**Lessons from Earth:** The Sendai Framework for Disaster Risk Reduction (2015–2030) provides guiding principles for resilience, preparedness, and risk governance. Strategies such as earthquake-resistant engineering, cyclone shelters, and early-warning systems on Earth can be adapted to extraterrestrial contexts. Importantly, inclusive resilience, ensuring equitable access to safety measures for all settlers, will be essential to maintain stability in isolated colonies. As humanity moves toward interplanetary colonization, disaster risk reduction must be central to planning. The extreme hazards of Mars and the Moon demand innovations in monitoring, resilient engineering, and preparedness. DRR will not only safeguard survival but also enable sustainable and secure human expansion into space.

# AI–Enabled Early Warning Systems and Predictive Analytics in Disaster Risk Reduction

**Sneha Saha**

The increasing frequency and intensity of natural disasters under the influence of climate change have made Disaster Risk Reduction (DRR) a global priority. Traditional early warning systems, though effective to some extent, often face challenges such as delayed detection, insufficient accuracy, and limited capacity for large-scale data integration. In this context, Artificial Intelligence (AI) has emerged as a transformative tool for enhancing early warning systems and predictive analytics, enabling proactive and more effective disaster management strategies.

AI-enabled early warning systems leverage machine learning, deep learning, and big data analytics to process vast and heterogeneous datasets collected from satellites, remote sensors, drones, weather stations, and social media platforms. Unlike conventional methods, AI models can detect hidden patterns, correlations, and anomalies in real time, providing more accurate forecasts of hazards such as floods, cyclones, droughts, landslides, and wildfires. For instance, convolutional neural networks (CNNs) are widely applied for satellite image interpretation to detect early signs of wildfire spread, while recurrent neural networks (RNNs) and long short-term memory (LSTM) architectures are used for predicting rainfall variability, river discharge, and storm surges with higher temporal resolution.




Predictive analytics, powered by AI, extends beyond forecasting hazards to assessing vulnerabilities and potential impacts. By integrating socio-economic, demographic, and infrastructural datasets, AI can identify high-risk zones and populations most susceptible to disaster impacts. This facilitates targeted preparedness and resource allocation. For example, predictive models can estimate the probability of building collapses during earthquakes based on structural data, or anticipate food and water shortages following droughts by linking climate and agricultural datasets.

Another significant advantage of AI-enabled systems is their adaptability and continuous learning capability. Unlike static statistical models, AI algorithms improve with additional data, refining predictions over time. This adaptability is particularly crucial in contexts of climate change, where historical baselines are shifting, and disaster patterns are becoming less predictable. Furthermore, integration with IoT devices enhances real-time monitoring, allowing for dynamic risk assessments and rapid response strategies.

However, the deployment of AI in disaster risk reduction is not without challenges. Issues such as data scarcity in developing regions, algorithmic bias, and lack of transparency in AI models (the 'black box' problem) can limit reliability and acceptance. Moreover, ethical considerations, including privacy and equitable access to early warning information, must be addressed to ensure inclusivity. Strengthening interdisciplinary collaborations among AI experts, disaster scientists, policymakers, and local communities is essential for creating effective and socially responsible AI-driven DRR systems.

Overall, AI-enabled early warning systems and predictive analytics represent a paradigm shift in disaster risk reduction. By enhancing accuracy, timeliness, and impact assessment, they contribute to building resilient societies capable of anticipating, preparing for, and mitigating the consequences of disasters in an increasingly uncertain world.

# Resilience in Informal Settlements: Community-led Innovations in DRR

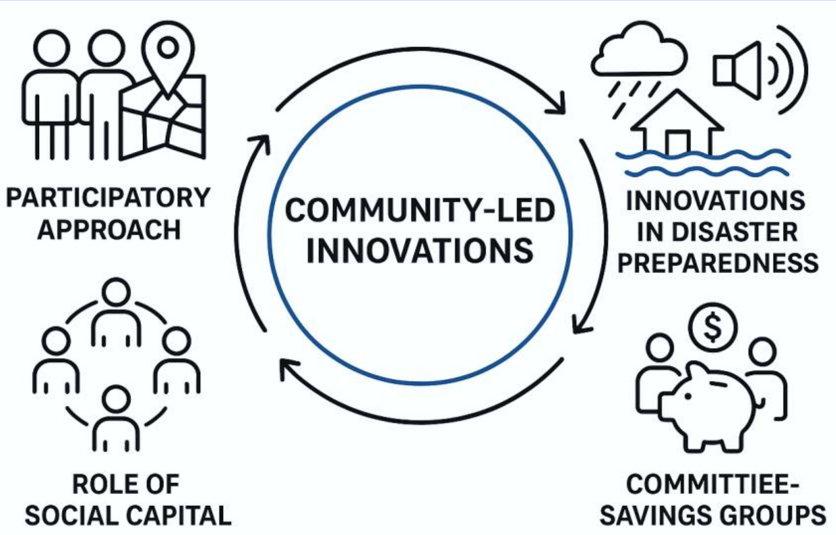
**Soumik Mukherjee**

Informal settlements, often referred to as slums or unplanned urban areas, represent some of the most disaster-vulnerable environments worldwide. Characterized by poor infrastructure, insecure land tenure, high population density, and inadequate access to basic services, these settlements are disproportionately exposed to floods, fires, landslides, and disease outbreaks. Climate change and rapid urbanization further intensify these risks, making disaster risk reduction (DRR) in informal settlements both urgent and complex. In recent years, community-led innovations have emerged as a crucial dimension of resilience building, as top-down strategies alone have often proven inadequate in addressing localized vulnerabilities.

One of the defining features of community-led resilience is its participatory and context-specific approach. Residents possess intimate knowledge of their environment, hazards, and coping mechanisms. Grassroots organizations and neighborhood committees frequently lead initiatives that range from hazard mapping and early warning systems to participatory upgrading of drainage, sanitation, and housing structures. For example, participatory risk mapping allows communities to identify flood-prone zones, unsafe pathways, and fire hazards, which can then inform targeted interventions with municipal support. Such initiatives strengthen social capital and encourage collective action, which are themselves vital components of resilience.

Innovations in disaster preparedness often arise from resourcefulness under constraints. In flood-prone settlements, communities have developed low-cost floating devices for children, raised storage platforms for household goods, and locally designed rainwater harvesting systems. Similarly, in areas susceptible to fires, informal settlement dwellers have organized volunteer firefighting brigades and installed simple but effective community alarm systems using whistles, mobile phones, and neighborhood watch groups. These grassroots solutions, though modest in scale, significantly enhance local response capacities before external aid arrives.

Community savings groups and cooperatives also play a transformative role in resilience. By pooling resources, residents finance incremental housing improvements, construct shared infrastructure such as raised walkways, or maintain emergency funds for post-disaster recovery. Partnerships with local NGOs, universities, and city governments amplify these efforts, providing technical expertise, micro-finance, and policy recognition. This co-production of resilience blurs the boundary between formal and informal governance, demonstrating that sustainable DRR requires both bottom-up initiative and institutional support.




Importantly, resilience in informal settlements is not limited to physical measures. Social networks, cultural practices, and collective memory of past disasters shape adaptive behavior. Women, youth, and marginalized groups often emerge as leaders in organizing disaster drills, promoting environmental stewardship, and sustaining community kitchens during crises. Their involvement challenges the notion of communities as passive recipients of aid, reframing them as proactive agents in shaping safer futures.

# Inclusive Resilience: Gender, Disability, and Indigenous Knowledge in DRR

**Sanchari Sarkar**

Disaster risk reduction (DRR) is no longer viewed solely through the lens of physical infrastructure and technological interventions; instead, it encompasses social, cultural, and ecological dimensions. Inclusive resilience emphasizes the importance of engaging all segments of society, particularly marginalized groups such as women, persons with disabilities, and indigenous communities, whose knowledge, experiences, and adaptive capacities are often overlooked. A comprehensive approach to DRR must therefore recognize diversity, address structural inequalities, and integrate traditional wisdom with modern practices.


**Gender and DRR:** Women are disproportionately affected by disasters due to entrenched socio-economic inequalities, restricted access to resources, and culturally prescribed roles. For example, in many communities, women are primary caregivers and responsible for securing water, food, and shelter. These responsibilities increase their exposure during crises, yet they also equip women with unique perspectives and skills critical for community survival. Evidence from disaster-affected regions highlights that when women actively participate in planning, preparedness, and response, outcomes are more effective and sustainable. Women-led organizations often play pivotal roles in mobilizing local networks, disseminating information, and advocating for risk-sensitive development. Thus, promoting gender-responsive DRR requires empowering women through leadership opportunities, access to early warning systems, capacity building, and integration of their voices in policymaking.

**Disability-inclusive DRR:** Persons with disabilities (PwDs) face layered vulnerabilities during disasters—physical, informational, and institutional. Barriers such as inaccessible shelters, inadequate communication of warnings, and lack of disability-sensitive evacuation planning can exacerbate risks. However, viewing disability solely as vulnerability is limiting. Many PwDs have developed strong coping mechanisms, problem-solving skills, and community linkages that can contribute meaningfully to resilience. Inclusive DRR frameworks, as emphasized by the Sendai Framework for DRR (2015–2030), call for universal design in infrastructure, accessible communication tools, and active consultation with disabled persons' organizations. Integrating disability perspectives into preparedness and response ensures equity while enriching community resilience with diverse strategies of adaptation and survival.

**Indigenous knowledge and cultural resilience:** Indigenous communities often live in ecologically sensitive areas where modern infrastructure is limited. Yet, they possess centuries-old knowledge systems rooted in close observation of local ecosystems, weather patterns, and resource management. Such knowledge has guided sustainable practices, like elevated housing in flood-prone regions, rotational farming to reduce land degradation, and the use of native plant species for slope stabilization. During the 2004 Indian Ocean tsunami, for instance, some indigenous groups in the Andaman and Nicobar Islands recognized early environmental warning signs and evacuated to safer grounds, demonstrating the life-saving potential of indigenous knowledge. Incorporating these practices into formal DRR planning fosters culturally appropriate strategies and strengthens trust between communities and authorities.

Building inclusive resilience demands a shift from top-down approaches to participatory models. Policies must address intersecting vulnerabilities, such as being a disabled woman in a rural indigenous community, through intersectional frameworks. Education, community training, and cross-generational knowledge sharing enhance adaptive capacity. Furthermore, partnerships between governments, NGOs, academia, and local communities are vital for co-creating solutions that merge modern science with traditional wisdom.

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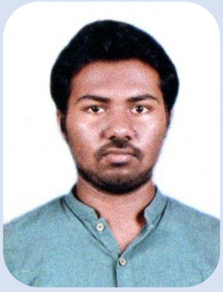

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