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GREEN CLIMATE FUND

ADAPTATION PLANNING FOR INDIA'S WATER SECTOR UNDER CLIMATE CHANGE

COMPENDIUM OF PROCEEDINGS OF THE TWO-DAY NATIONAL WORKSHOP

Editors:

Dr. Surjeet Singh •

Dr. Deepak Singh Bisht •

Ms. Aindrila Ghosh •

Organised by :

NATIONAL INSTITUTE OF HYDROLOGY, ROORKEE

D/O Water Resources, RD & GR; Ministry of Jal Shakti,
Government of India

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Disclaimer

The views, opinions, and analyses presented in this compendium are those of the individual experts, panellists, and moderators who participated in the Two-Day National Workshop *"Adaptation Planning for India's Water Sector under Climate Change"* during 21-22 Aug, 2025. These views are personal to the contributors and **do not necessarily reflect the official position, policies, or perspectives of the National Institute of Hydrology (NIH), Roorkee**. The Institute shall not be held liable for any interpretations, conclusions, or recommendations expressed in this publication.

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PREFACE

The National Institute of Hydrology (NIH), Roorkee, had the privilege of organizing the **Two-Day National Workshop on "Adaptation Planning for India's Water Sector under Climate Change" during 21–22 August 2025**. The workshop brought together eminent experts, policymakers, researchers, practitioners, and representatives from national institutions to deliberate on the emerging challenges and strategic priorities for climate adaptation in the water sector. Over the course of two days, **seven technical sessions** were convened, spanning themes such as flood risk reduction, drought resilience, glacial lake outburst floods (GLOFs), rainfall-induced landslides, cyclone-resilient infrastructure, coastal flooding and sea-level rise, and importantly a dedicated session on Gender Equality, Disability, and Social Inclusion (GEDSI) in water-sector adaptation.

This compendium presents a structured documentation of the rich discussions, perspectives, and recommendations offered by the moderators and panellists across all sessions. Their insights reflect decades of collective experience of experts in hydrology, climate science, disaster risk reduction, community resilience, and policy design. As India advances towards the formulation of its **National Adaptation Plan (NAP)** -a process guided by global adaptation mandates under the UNFCCC and the Paris Agreement- the knowledge captured here is both timely and essential. It contributes to strengthening adaptation planning, enhancing institutional capacities, and informing evidence-based decision-making at national and sub-national levels.

The compendium is intended to serve as a **knowledge resource for researchers, government agencies, technical working groups, practitioners, and young professionals** engaged in climate-resilient water management. It conveys key risks, sector-specific vulnerabilities, and potential adaptation pathways that can support national and regional planning processes. Through informed dialogue and cross-disciplinary engagement, the workshop reinforces NIH's commitment to advancing scientific understanding and supporting national efforts in developing climate-resilient water resource strategies.

I express my deep appreciation to the **Centre for Cryosphere and Climate Change Studies (C4S), NIH**, for taking the lead in organizing this national workshop and for their immense contributions throughout the process. Their dedicated efforts ensured the successful conduct of all sessions and the meaningful participation of experts from across the country.

I also extend my sincere thanks to the **editors of this compendium**, whose meticulous work in documenting the proceedings has played a vital role in preserving the ideas, insights, and recommendations shared during the workshop. Their commitment to accuracy and clarity has enabled this knowledge to be made accessible for wider use.

On behalf of NIH, I further acknowledge the Ministry of Jal Shakti for its continued guidance and the Ministry of Environment, Forest and Climate Change (MoEF&CC) and United Nation Development Program (UNDP) for their collaboration and support in strengthening India's adaptation agenda.

It is my hope that this compendium will inspire continued dialogue, foster interdisciplinary collaboration, and contribute meaningfully in the development of climate-resilient water systems in India. The challenges posed by climate change are multifaceted, yet through collective effort and informed planning, we can build a more secure and sustainable future for our water resources.

Dr. Y.R. Satyaji Rao
Director, National Institute of Hydrology, Roorkee

ACKNOWLEDGEMENTS

The editors acknowledge with appreciation the contributions of all individuals and institutions involved in the successful conduct of the **Two-Day National Workshop on "Adaptation Planning for India's Water Sector under Climate Change"** and in the preparation of this compendium.

We extend our formal thanks to all **moderators, esteemed panellists, and rapporteurs** for their substantive technical inputs across the workshop's thematic sessions. Their domain expertise, evidence-based perspectives, and active engagement were critical in shaping the deliberations documented herein. The insights provided by these distinguished professionals have materially enriched the quality and depth of this compendium.

The editors gratefully acknowledge the support of the **United Nations Development Programme (UNDP)** for sponsoring the project and for its continued collaboration in advancing national climate adaptation processes. We also recognize the role of the **National Water Mission (NWM)**, **Department of Water Resources, River Development & Ganga Rejuvenation (DoWR, RD & GR), Ministry of Jal Shakti (MoJS)** in providing strategic direction and in facilitating NIH's engagement in the broader national adaptation planning framework.

We place on record our sincere thanks to **Ms. Archana Verma, IAS, Additional Secretary and Mission Director, NWM,MoJS** for her guidance and for entrusting the **National Institute of Hydrology (NIH)** with the responsibility of serving as the *anchoring institute* for the preparation of the **India's National Adaptation Plan for Water Sector**. Her confidence in NIH and her continued encouragement have been instrumental in enabling focused and coordinated technical contributions from the Institute.

The editors further express their gratitude to **Dr. Y.R. Satyaji Rao, Director, NIH** for his leadership, sustained support, and administrative facilitation throughout the organization of the workshop and the development of this compendium. His direction provided the institutional framework necessary for the effective execution of this activity.

Finally, the editors acknowledge all participants, collaborating institutions, and supporting staff whose involvement contributed to the successful completion of this initiative. This compendium reflects the collective commitment of the scientific fraternity, policymakers, and stakeholders towards strengthening climate-resilient water sector planning in India.

Editors

ADAPTATION PLANNING FOR INDIA'S WATER SECTOR UNDER CLIMATE CHANGE

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Inaugural Ceremoney







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Photo Courtesy: National Institute of Hydrology





INAUGURAL ADDRESS

DAY 01
21 AUGUST, 2025



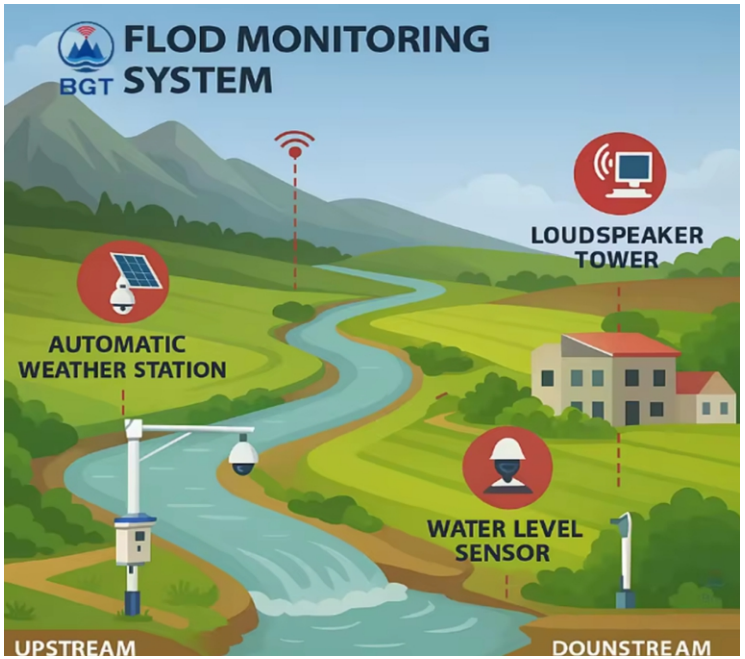
Dr. Y.R. Satyaji Rao
Director, NIH Roorkee

The 02-Day National Workshop on "Adaptation Planning for India's Water Sector under Climate Change" convenes with a clear mandate: to foster sustainability and resilience in India's water systems through inclusive, actionable strategies. The discourse emphasizes the necessity of a 'common-man-friendly' approach to adaptation planning—one that demystifies technical knowledge and translates research into everyday relevance for citizens. This orientation seeks to dissolve the divide between scientific inquiry and lived experience, ensuring that adaptation frameworks are not only expert-informed but also accessible and empowering to the general public. Central to the dialogue is the call for universal participation: every individual, regardless of age, gender, or ability, holds a stake in climate resilience and must be encouraged to contribute meaningfully.

Climate change, while beyond human control, demands a proactive and collective response through robust adaptation mechanisms. The workshop positions itself as a collaborative nexus, integrating science, policy, and community engagement to co-create a resilient ecosystem. It champions interdisciplinary dialogue and participatory governance as the cornerstones of climate adaptation in the water sector.









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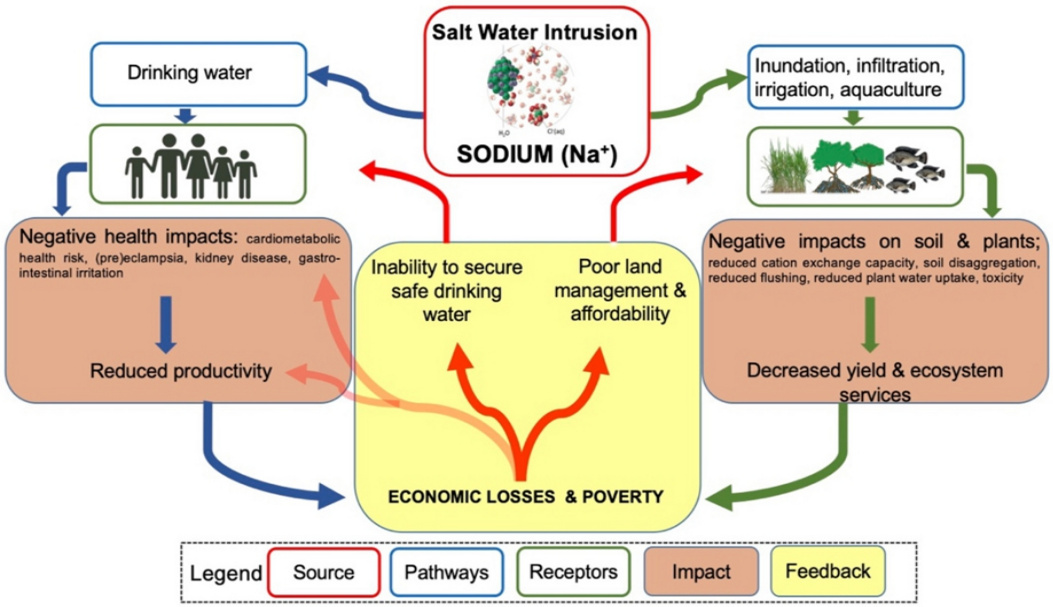
DAY 01
21 AUGUST, 2025

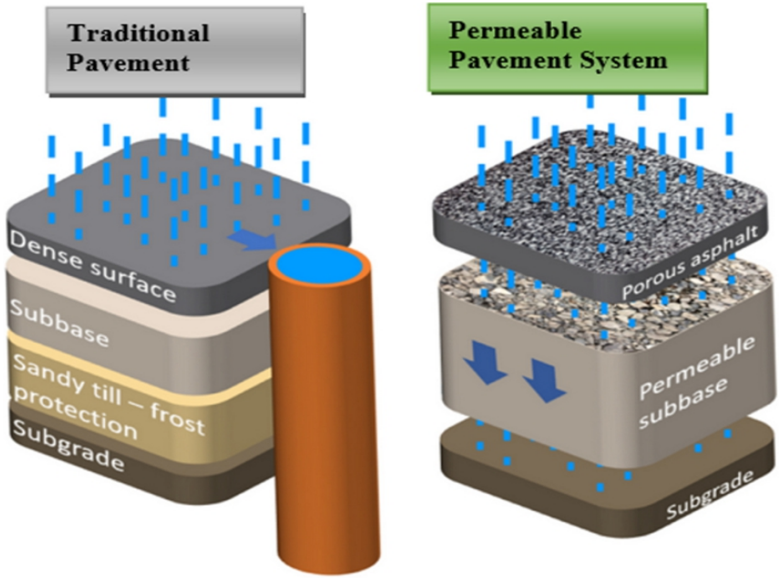


Mrs. Ruchika Drall
Deputy Secretary, MoEF&CC

The National Adaptation Plan (NAP) will be a dynamic and future-oriented framework shaped by the foundational principles of the Paris Agreement (2015) and the United Nations Framework Convention on Climate Change (UNFCCC). Designed for phased implementation over the next decade, the NAP outlines strategic timelines—short-term (2025–2028), mid-term (2025–2030), and long-term (2025–2035)—to adapt to evolving climate realities. Central to its vision is the recognition of critical vulnerabilities in India's water sector, including erratic monsoon patterns, increasing frequency of extreme weather events such as floods, droughts, cyclones, and glacial lake outburst floods (GLOFs), saline intrusion, and stark regional disparities in water availability. In response, the plan articulates four overarching goals for adaptation planning, supported by eleven prioritized strategies. Among these, the most urgent include enhancing climate data systems and early warning mechanisms, fortifying climate-resilient infrastructure, promoting sustainable water governance, and deepening community-level engagement.

The NAP positions itself not merely as a policy document but as a transformative blueprint for resilience, equity, and ecological stewardship in the face of climate uncertainty.


Salt Water Intrusion
SODIUM (Na+)
Drinking water
Inundation, infiltration, irrigation, aquaculture
Negative health impacts: cardiometabolic health risk, (pre)eclampsia, kidney disease, gastro-intestinal irritation
Reduced productivity
Inability to secure safe drinking water
Poor land management & affordability
Negative impacts on soil & plants; reduced cation exchange capacity, soil disaggregation, reduced flushing, reduced plant water uptake, toxicity
Decreased yield & ecosystem services
ECONOMIC LOSSES & POVERTY
Legend
Source
Pathways
Receptors
Impact
Feedback


Traditional Pavement
Dense surface
Subbase
Sandy till – frost protection
Subgrade
Permeable Pavement System
Porous asphalt
Permeable subbase
Subgrade


(Source: google images)





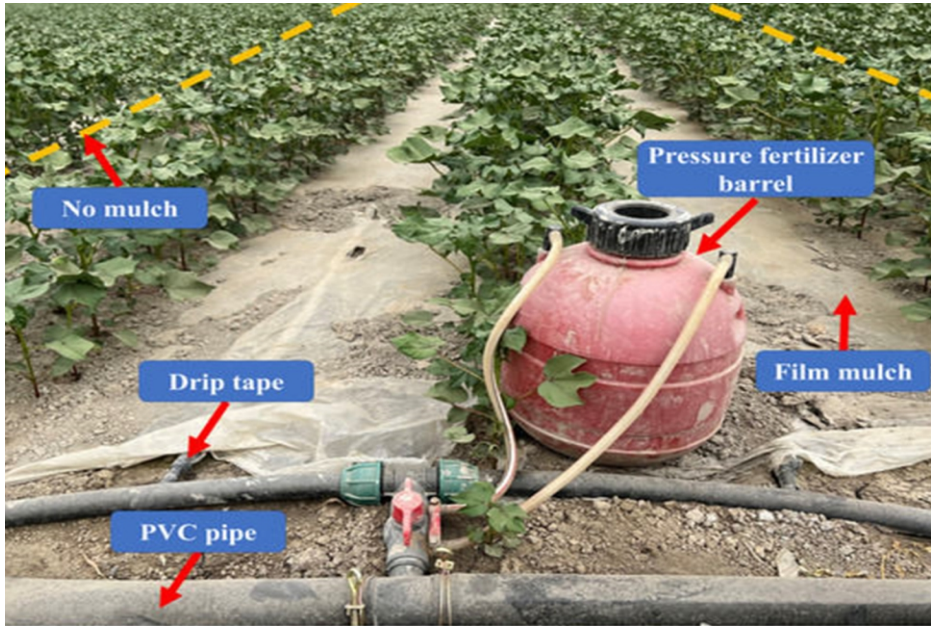
DAY 01
21 AUGUST, 2025



Sh. Shiv Mohan Dixit
Advisor (Tech), NWM

India's water sector confronts escalating stress driven by climate change, rapid industrialization, and population growth. Since officially entering the category of water-scarce in 2011, the nation faces a widening gap between freshwater demand and availability—projected to reach 843 billion cubic meters (BCM) by 2025 and 1180 BCM by 2050, while only 1126 BCM remains usable due to systemic losses and limitations. The National Adaptation Plan (NAP) positions itself as a strategic instrument to bridge this gap through the integration of cutting-edge technologies, community empowerment, and policy innovation.

Intensifying climate phenomena—such as extreme weather events, droughts, urban heat islands, coastal salinity, and groundwater depletion—pose multidimensional risks to food security, public health, and economic stability. A mere 1% shift in monsoon patterns can reduce agricultural GDP by 0.34%, underscoring the fragility of climate-linked systems. Adaptation strategies under NAP include real-time hydrological monitoring, coastal salinity tracking, urban planning with flood-resilient infrastructure like permeable pavements, artificial recharge structures to enhance groundwater storage, and basin-level integrated water resource management informed by climate projections. These efforts are complemented by national initiatives such as Atal Bhujal Yojana, Jal Shakti Abhiyan, Jal Sanchay Jan Bhagidari initiative, Aquifer Mapping, and PMKSY, collectively advancing the vision of a climate-resilient India.









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INAUGURAL ADDRESS OF CHIEF GUEST

DAY 01
21 AUGUST, 2025



Dr. Kamal Lochan Mishra
IAS, ED, OSDMA

An enabling environment is fundamental to the successful development and implementation of India's National Adaptation Plan (NAP), demanding a synergistic collaboration across technological innovation, evidence-based policy-making, forward-looking research, political will, and agile administrative frameworks. Climate adaptation and disaster management must be deeply rooted in community-based approaches, where local knowledge, lived experiences, and participatory decision-making shape practical and sustainable solutions. This bottom-up engagement ensures that interventions are not only technically sound but socially accepted and contextually relevant.

To meet the scale and urgency of climate challenges, research must evolve beyond controlled laboratory settings and embrace large-scale, field-applicable models that reflect the complexities of real-world ecosystems and governance structures. Scientific insights must be tailored to administrative feasibility, aligning technical expertise with operational realities to ensure effective implementation. This calls for a shift in mindset—from theoretical precision to practical impact.

Several exemplary models of integrated climate-resilient development illustrate this approach. Computerized fortified pressurized irrigation systems combined with plastic mulching have demonstrated remarkable crop productivity using minimal water, especially in water-stressed regions. Recirculated Aquaculture Systems (RACS) enable high-yield pisciculture with limited water resources, leveraging continuous aeration and nutrient recycling to maintain optimal conditions. Climate-controlled poultry farms offer robust business models that withstand climatic fluctuations, while environment-controlled button mushroom cultivation showcases adaptive agricultural innovation in response to changing temperature and humidity patterns.

Two standout disaster management interventions further reinforce the value of scalable, resource-efficient solutions. In one case, drip irrigation supported by two bore wells successfully irrigates 40 acres of land in areas with poor surface water availability, maximizing productivity through precision water delivery and mulching. In another, a RACS setup utilizes a single bore well to sustain 10 aquaculture ponds: each measuring 45m × 16m × 1.5m with 24×7 aeration and nutrient recycling, covering 2 acres and exemplifying circular water use.

These models underscore the transformative potential of climate-smart technologies and integrated planning. They highlight how resource optimization, administrative alignment, and community engagement can converge to build resilience at scale. The imperative is clear: "If we can't adapt, we may be extinct." Research must be reoriented to serve the realities of governance, climate vulnerability, and the urgent need for inclusive, scalable, and actionable solutions.


02-Day National Workshop
on
Adaptation Planning for India's Water
Sector under Climate Change
(21-22 Aug 2025 – Hyatt Place, Haridwar, Uttarakhand)
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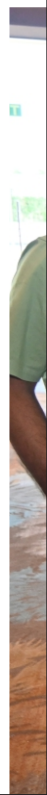












GREEN CLIMATE FUND
02-day National Workshop
on
'ADAPTATION PLANNING FOR INDIA'S WATER SECTOR UNDER CLIMATE CHANGE'
21-22 AUGUST, 2025
ADAPTING TODAY FOR A RESILIENT TOMORROW
National Institute of Hydrology
D/o Water Resources, River Development & Ganga Rejuvenation
Ministry of Jal Shakti, Government of India

DAY 01

Technical Session 1

- Integrated Strategies for Flood Risk Reduction and Adaptive Water Governance

Technical Session 2

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Technical Session 3

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DAY 02

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ADAPTATION PLANNING FOR INDIA'S WATER SECTOR UNDER CLIMATE CHANGE

COMPENDIUM OF PROCEEDINGS OF THE TWO-DAY NATIONAL WORKSHOP

DAY 01

21 AUGUST, 2025

TECHNICAL SESSION 01



INTEGRATED STRATEGIES FOR FLOOD RISK REDUCTION & ADAPTIVE WATER GOVERNANCE





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Prof. Sharad Kumar Jain
Ex-Director, NIH Roorkee,
Visiting Professor, IIT Gandhinagar

Dr. Anil Kumar Lohani
Former Scientist 'G' & Head SWHD, NIH Roorkee

Prof. Dhanya C. T.
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IIT Delhi

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Vice President, RMSI, Noida

Shri Pranav Shukla
Deputy Director, Central Water Commission, New Delhi

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Dr. Mohit Prakash Mohanty
Assistant Professor, Water Resources Development & Management,
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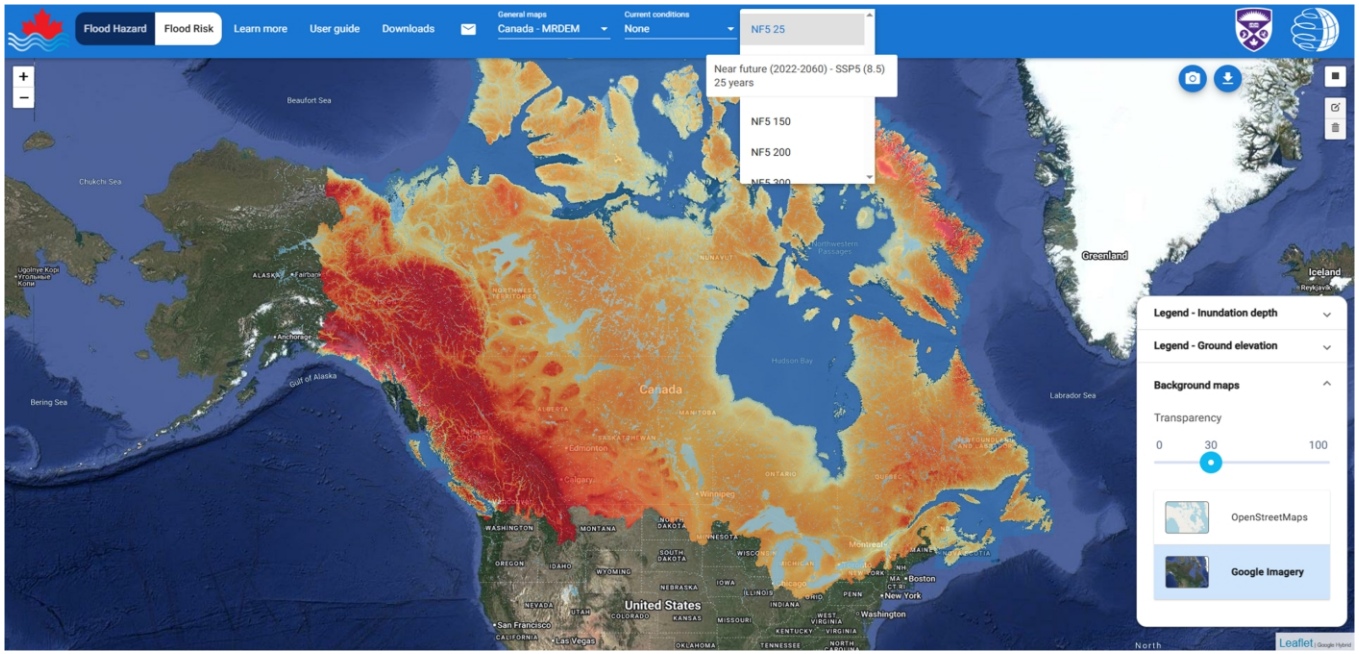
Dr. Somyaranjan Sahoo
Scientist 'B', Surface Water Hydrology Division, NIH Roorkee





(Reference: Mohanty, M. P., & Simonovic, S. P. (2022). A comprehensive approach for floodplain mapping through identification of hazard using publicly available data sets over Canada. Water, 14(14), 2280)



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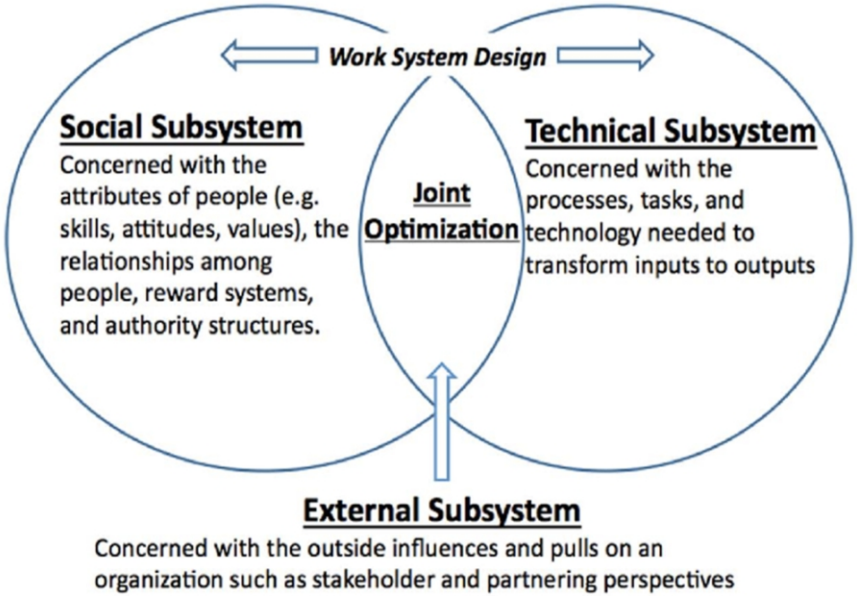


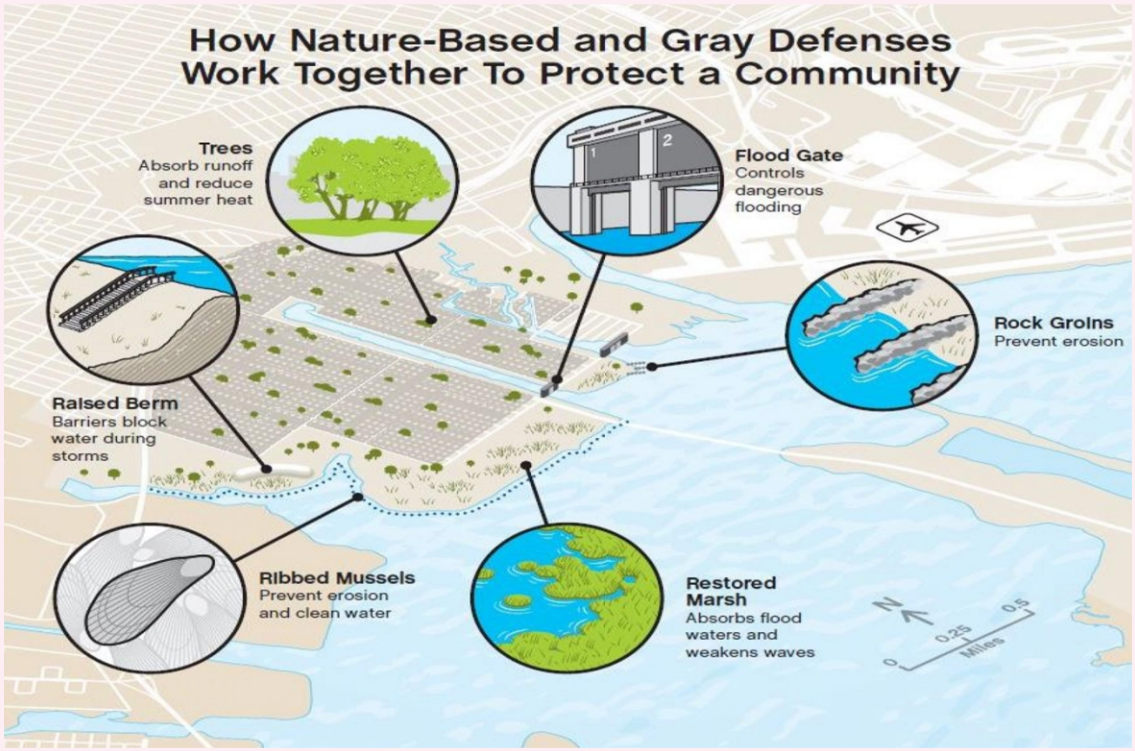


Dr. Mohit Prakash Mohanty

Assistant Professor,
Water Resources Development & Management, IIT Roorkee

Flood disasters remain one of India's most destructive hydro-climatological extremes, inflicting recurring losses to life, agriculture, infrastructure, and livelihoods across vast and varied geographies. Historical events such as the 2015 Chennai flood catalyzed the development of the country's first nationwide flood forecasting and early warning systems, marking a shift from reactive to anticipatory disaster management. However, building resilience requires more than technical solutions. A balanced "socio-technocratic" approach is essential, one that integrates scientific innovation (e.g., flood modeling, AI/ML prediction, and climate-adjusted hazard mapping) with social inclusion, community-level engagement, and locally adapted planning. Open-access, integrated platforms akin to MANAGE (Multi-Hazard Flood Information System for Coastal Regions) or similar flood-mapping tools can help link historical records with climate-adjusted projections, enhancing transparency and preparedness. Complementing such data-driven systems, deploying sustainable strategies such as Nature-Based Solutions (NBS) and Low Impact Development (LID), rather than relying solely on grey infrastructure, offers long-term resilience and ecological balance. At the same time, strengthening regional hydrological models, improving rainfall forecasting, and building tide and surge prediction capabilities are essential, especially for coastal and Himalayan-fringe regions. Success stories such as Odisha, where coordinated, multi-stakeholder disaster governance has enabled effective mitigation and response, illustrate how reducing fragmentation and encouraging pluralistic collaboration among government, scientists, civil society, and communities can foster a robust culture of disaster resilience.





(Source: google images)



Prof. Sharad Kumar Jain

Ex-Director, NIH Roorkee,
Visiting Professor, IIT Gandhinagar

Nature-Based Solutions (NBS) offer a promising pathway for sustainable water management and flood resilience by aligning interventions with natural processes. Among these, ponds stand out as highly effective tools for water purification and ecological restoration. However, rapid urbanization and unchecked encroachment have led to the disappearance of many traditional ponds—Bangalore alone has lost the majority of its ponds over the past 25 years. A key challenge in scaling NBS lies in maintaining water quality, as many restored or newly constructed ponds face degradation due to waste dumping.

Government initiatives like Mission Amrit Sarovar aim to revive pond ecosystems, yet there remains a pressing need to expand such efforts in urban areas. Successful implementation of NBS at scale requires bridging the gap between scientific planning and consistent political-administrative support. The first step, as recommended, is to halt encroachment on Nature-Based Solutions (NBS) offer a promising pathway for sustainable water management and flood resilience by aligning interventions with natural processes. Among these, ponds stand out as highly effective tools for water purification and ecological restoration. However, rapid urbanization and unchecked encroachment have led to the disappearance of many traditional ponds—Bangalore alone has lost the majority of its ponds over the past 25 years. A key challenge in scaling NBS lies in maintaining water quality, as many restored or newly constructed ponds face degradation due to waste dumping or inflow of polluted water.

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Financial institutions can play a transformative role by promoting flood- resilient investments and enabling risk transfer mechanisms. Creating detailed flood-hazard maps allows for targeted funding and insurance schemes, where premiums are calibrated based on flood risk zones—higher rates for high-risk areas, incentivizing safer development. Strategic regulation of financial flows toward flood-resilient infrastructure ensures that resources are directed where they are most needed.

To discourage settlement in flood-prone zones, a system of reduced compensation or penalty-based probation can be introduced. In addition, loans and financial incentives should be extended to individuals and developers who invest in flood-resilient construction. This dual approach —discouraging risky habitation while rewarding resilient design—can reshape urban planning and foster long-term climate adaptation.

Water bodies and identify suitable locations for new pond development.

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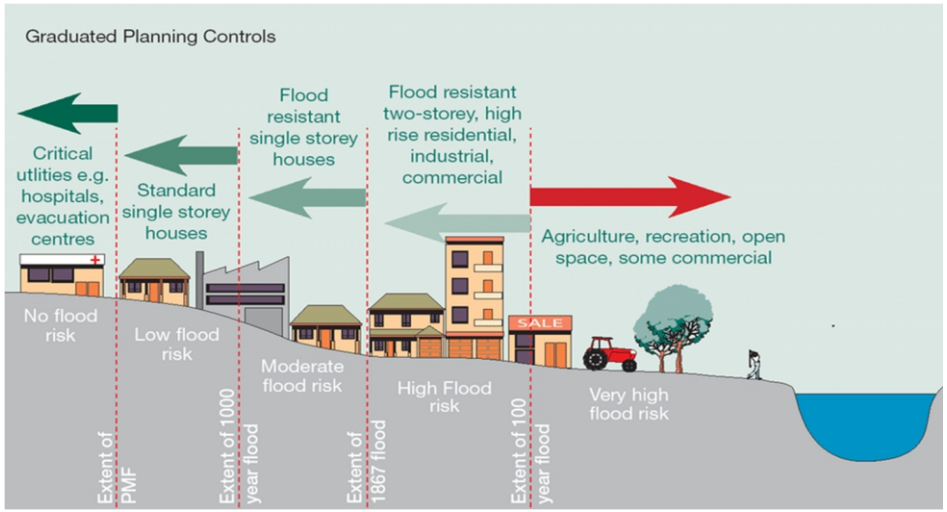
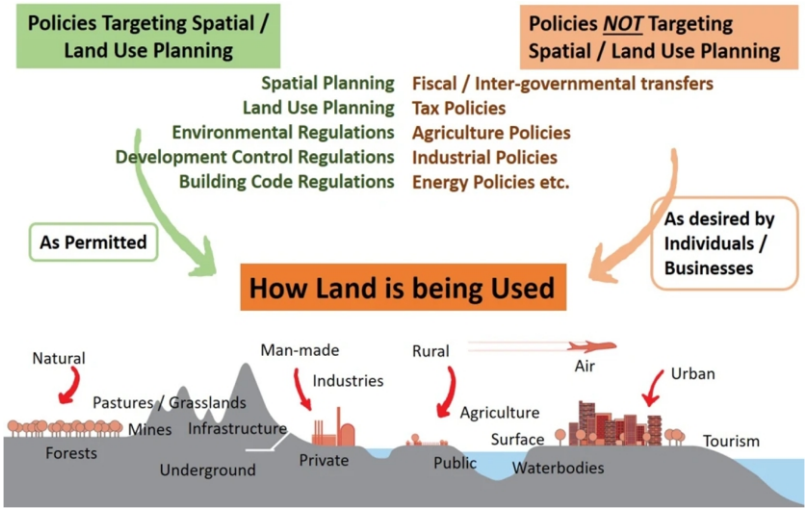
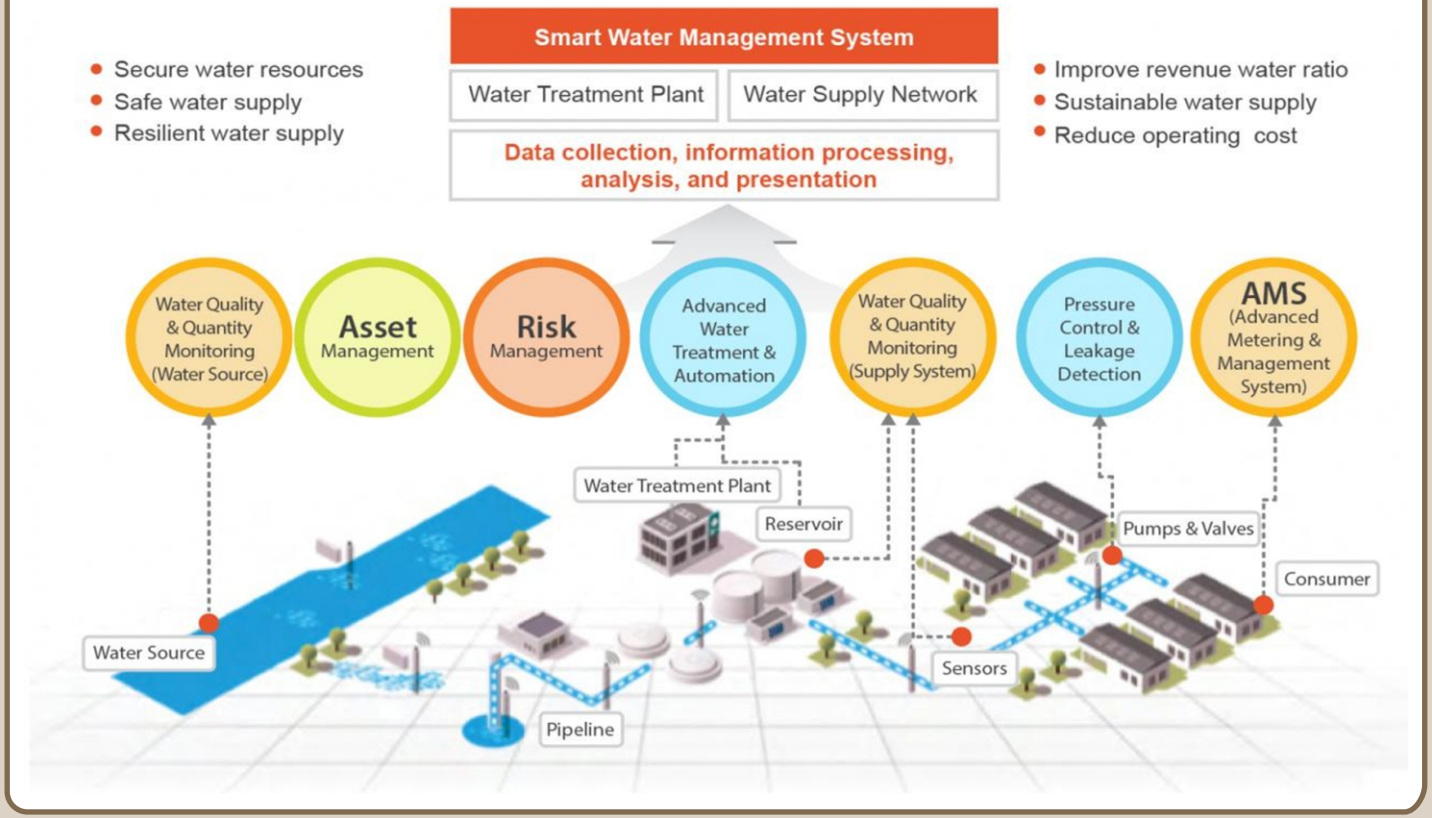






(Source: google images)



Dr. Anil Kumar Lohani
Former Scientist 'G' & Head SWHD,
NIH Roorkee

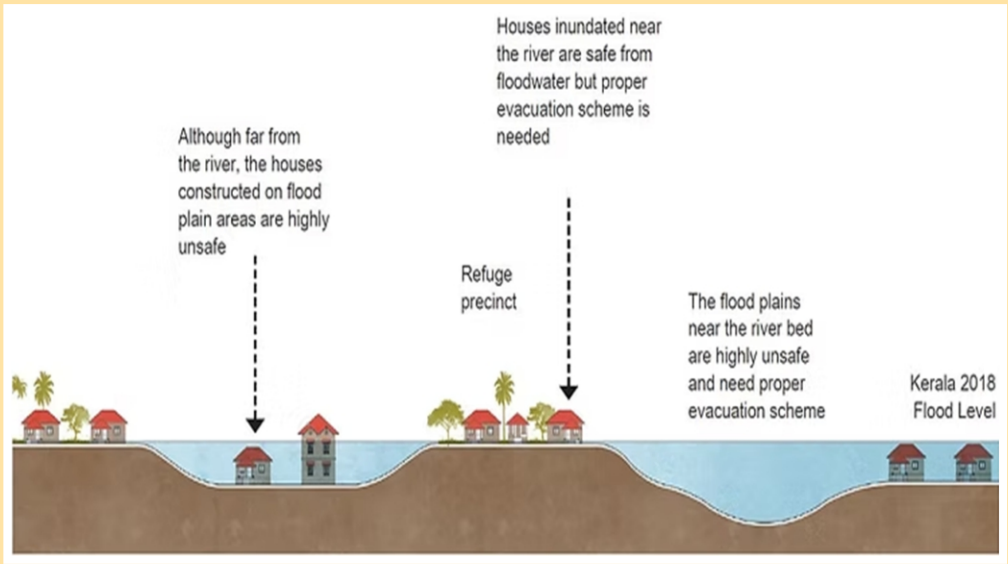
Data gaps continue to pose serious challenges in flood risk management. Despite the availability of large datasets, the core issue lies in fragmented access and inadequate coordination—some authorities possess critical information while others remain excluded. This imbalance often forces practitioners to rely on externally developed equations and models that may not accurately reflect local conditions. A well-defined institutional mechanism is needed to streamline data acquisition, validation, and dissemination. Establishing a centralized data portal would ensure equitable access and promote collaborative decision-making across agencies.

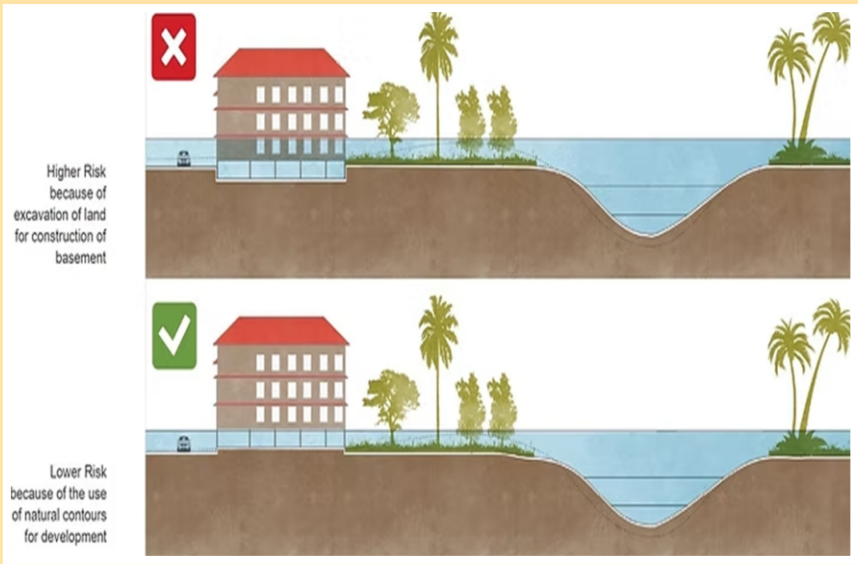
To regulate habitation in vulnerable areas, a Flood Plain Zoning Act, similar to international best practices, should be introduced. Such legislation would provide legal backing for land-use restrictions and guide safe development in flood-prone regions. Housing construction in these areas must prioritize appropriate plinth levels and safe foundation depths, supported by technical guidance from municipal bodies and Water Resources Departments.

Comprehensive Emergency Action Plans (EAPs) should be prepared for floodplain and flood-prone zones, involving coordination among multiple departments and administrative layers. These plans must align with national and international frameworks to ensure consistency, interoperability, and scalability.

Strict adherence to guidelines and effective implementation of government schemes are essential to translate policy into practice. While flooding cannot be fully prevented, its impacts can be significantly mitigated through proactive planning, strategic allocation of resources, and coordinated governance. The focus must shift from reactive responses to anticipatory systems that integrate data, resilient infrastructure, and community preparedness.







(Source: google images)



Prof. Dhanya C.T.
Rama Kanta Chair Professor,
Dept. of Civil & Environmental Engg., IIT Delhi

Floodplain zoning must be made accessible and actionable at the grassroots level to effectively reduce the nationwide severity of flood-related disasters. A three-pronged strategy was proposed to address the challenges:

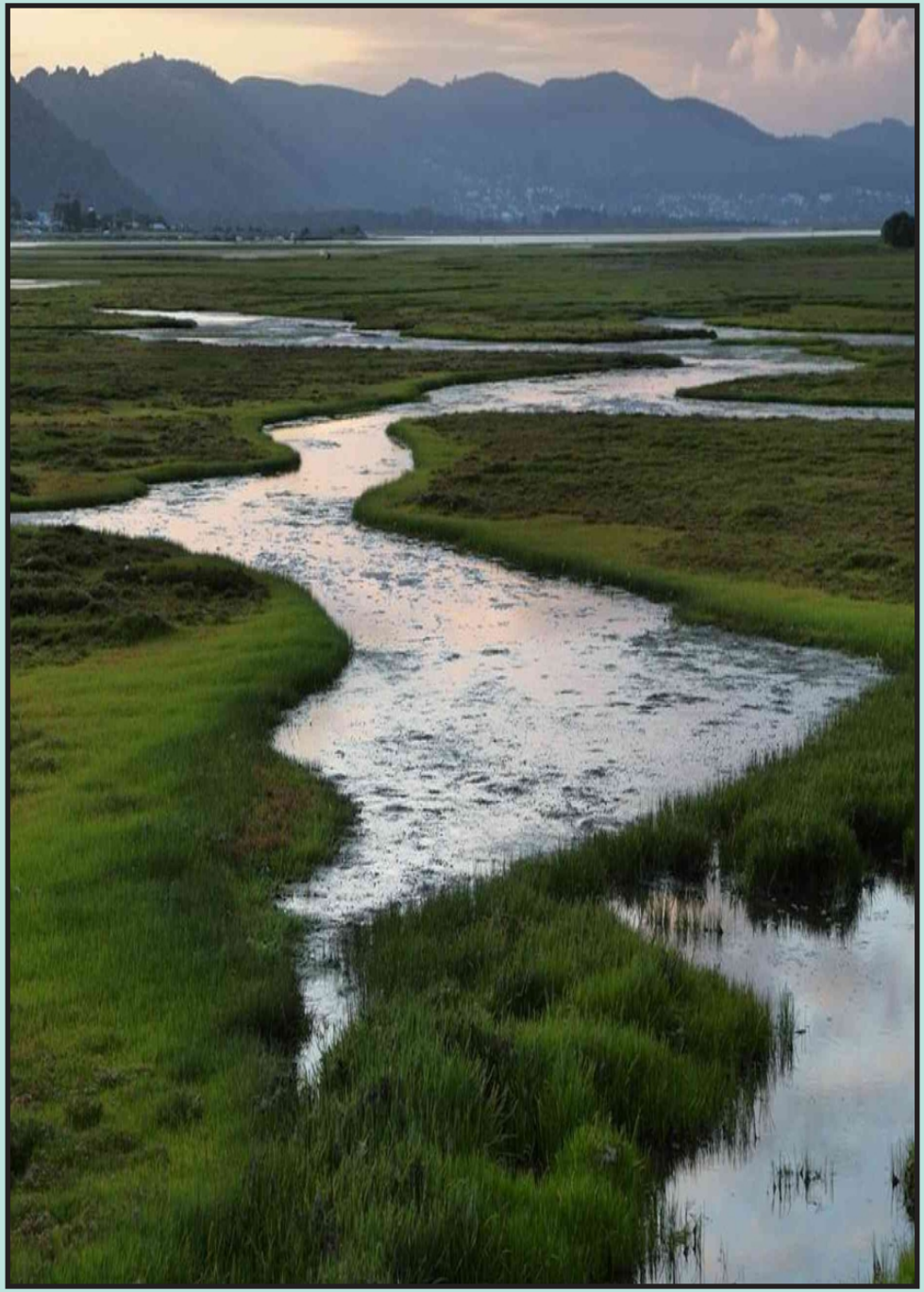
Establishing a Strong Legal Framework: Rather than relying solely on punitive measures, clear guidelines should be embedded within masterplans—urban planning, land use and land cover (LULC) plans, and town development schemes. These should incorporate future climate change projections and classify floodplain zones into low, medium, and high-risk categories.

Integrating Floodplain Zoning into Planning Systems: Zoning must be layered into all relevant planning documents to guide safe development and infrastructure placement, ensuring that flood-prone areas are not misused for residential or commercial purposes.

Ensuring Community Participation: For policies to permeate effectively to the district and block levels, active involvement of local communities is essential. This fosters ownership, enhances compliance, and strengthens integrated disaster management.

She emphasized that solutions to urban flooding already exist and must be scaled with urgency. A notable exercise conducted on 22 June 2024 at IIT Delhi—during a rare 600-year return period rainfall event—demonstrated the value of multi-level interventions. The team proposed a tiered approach to manage routine waterlogging and extreme rainfall, including the design of natural drainage systems that preserved existing infrastructure.

To build resilient urban systems, she advocated for the analysis of both current and projected hydrological data, supported by robust meteorological datasets. Maintenance protocols must be coupled with community engagement to ensure long-term functionality and adaptability. This holistic model—combining legal, technical, and social dimensions—offers a replicable blueprint for urban flood resilience across India.



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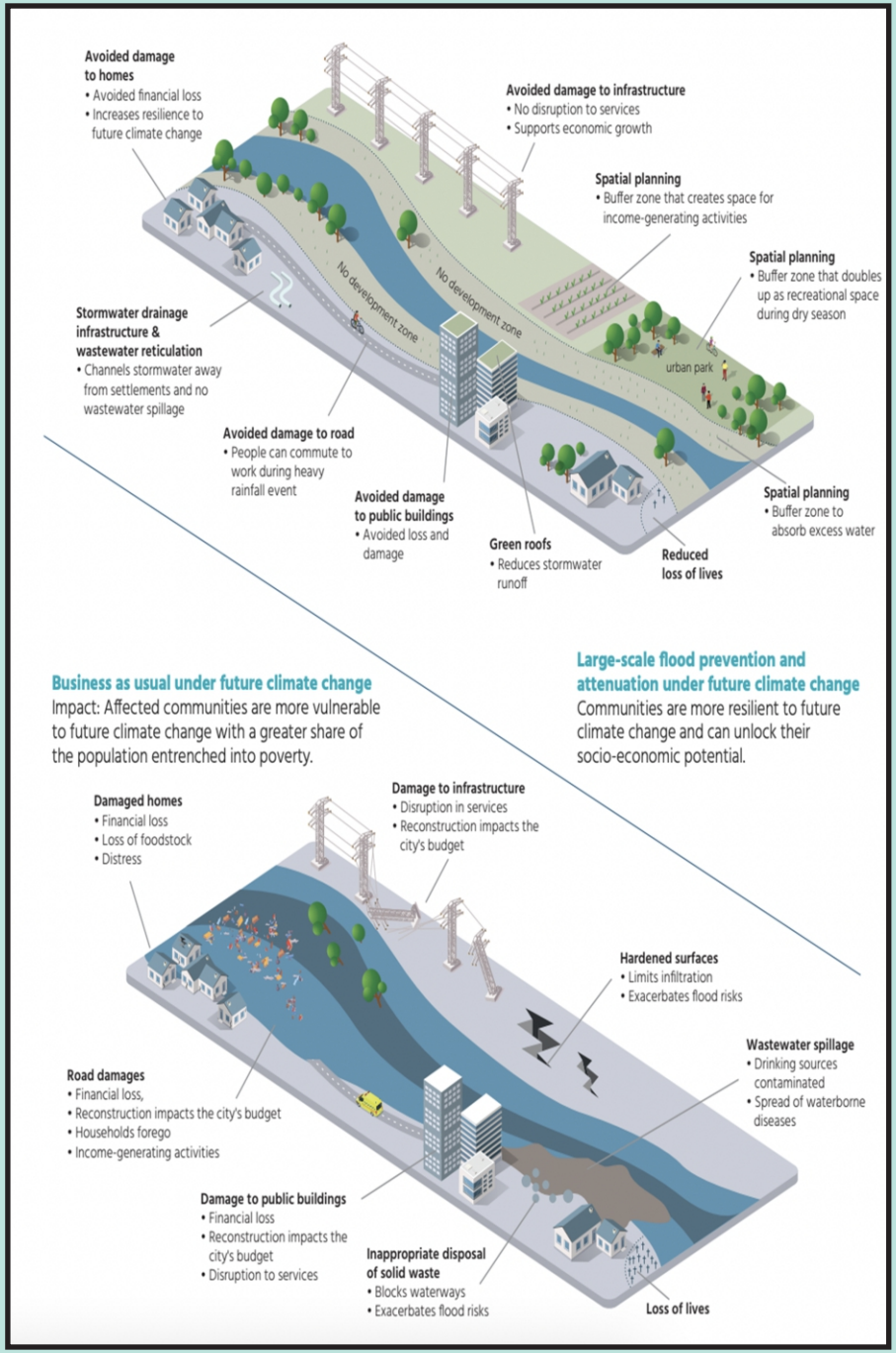




Dr. Pratap Singh
Vice President,
RMSI, Noida

There is no universal adaption strategy for flood resilience which can be implemented in all the regions. Adaptation strategies have to be region-specific, integrating traditional knowledge with modern applications. A key challenge lies in gaining acceptance among vulnerable rural communities, where unfamiliar approaches often face resistance. Drawing from global examples, he highlighted how African countries such as Malawi, Kenya utilize wetlands as natural buffers against flooding—an approach that could be effectively replicated in flood-prone states like Bihar and Assam. These regions would also benefit from AI/ML-based flood warning systems to enhance early preparedness.

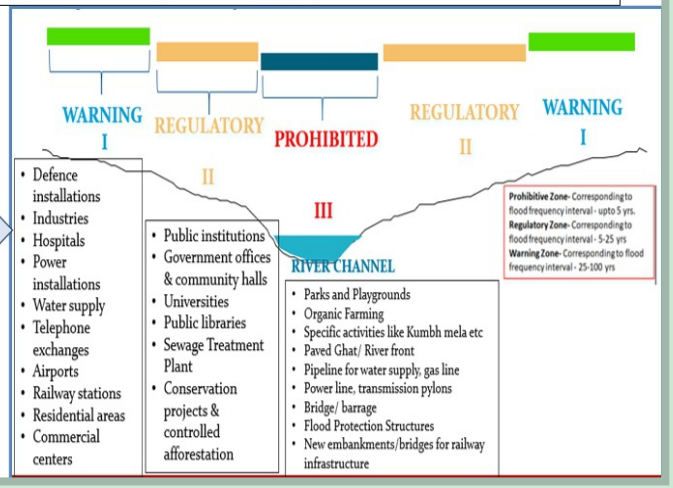
Wetlands, ponds, and lakes—when treated as integral parts of the river system—can significantly reduce the impact of flash floods. He emphasized the need for private sector involvement, but stressed that financial responsibility, including compensation and insurance premiums, should be borne by the government to protect low-income populations, who are often the most affected. A hybrid model led by the government to construct flood-resilient infrastructure could encourage private participation.

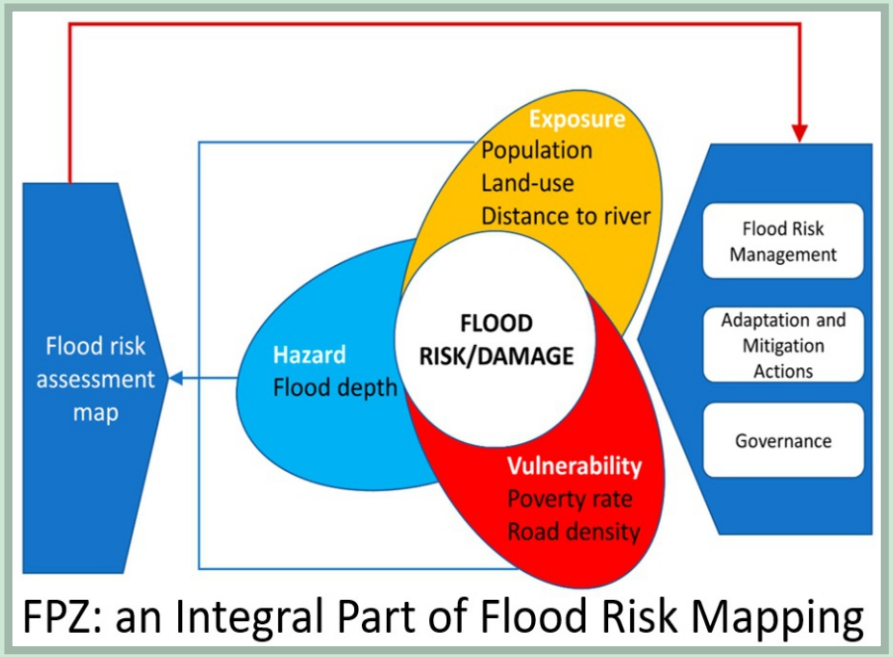
Notably, while frameworks like Nature-Based Solutions and floodplain zoning exist, their practical implementation faces multiple hurdles. Bridging these gaps requires not just technical planning, but also social acceptance, financial support, and institutional coordination.

FLOOD PLAIN ZONING - Guidelines

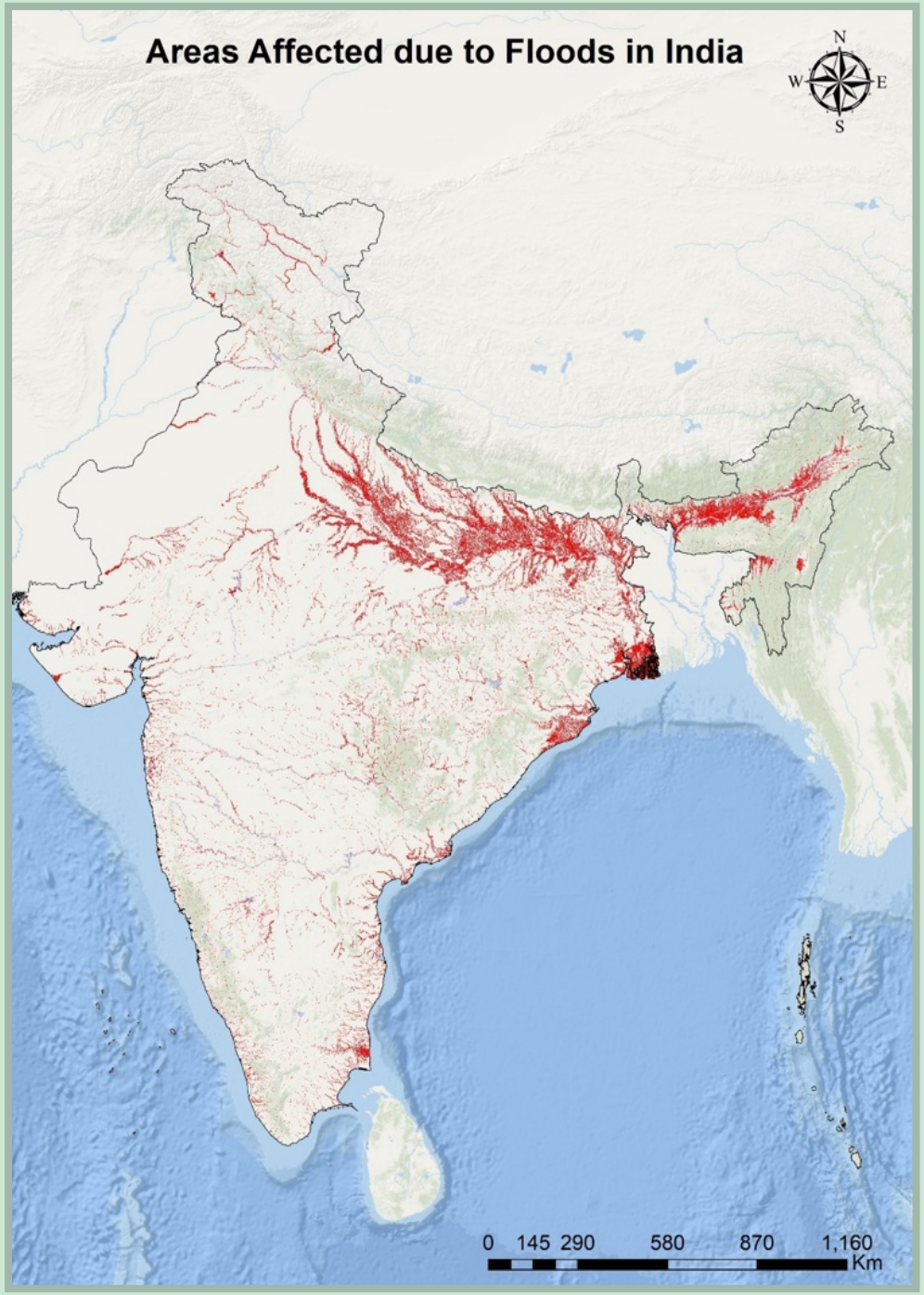
Proposed Zones : Circulated to State Govts. for their views
Prohibited Zone (5 years))
Regulatory Zone (25 years)
Warning Zone (100 years)

Permitted & **Non-Permitted** Activities in each Zone





FPZ: an Integral Part of Flood Risk Mapping



(Photo Courtesy: Sh. Pranav Shukla, CWC)



Shri Pranav Shukla
Deputy Director,
Central Water Commission, New Delhi

The Government's vision for Integrated Flood Risk Management begins with the urgent demarcation of critical, hazard, and floodplain zones—an essential first step before addressing exposure and vulnerability. The concept of Floodplain Zoning (FPZ) dates back to the 1975 model, which has guided states in reducing flood risks. In August 2025, the Central Water Commission (CWC), under the Ministry of Jal Shakti, released updated FPZ guidelines to all relevant ministries and stakeholders. These guidelines classify zones based on return periods—5, 25, and 100 years—into protected, regulatory, and warning zones, with clear definitions of prohibited and permissible activities. The framework is structured for implementation at both state and central levels with distinct responsibilities.

CWC has also advanced national frameworks such as the Sediment Management Guidelines, which address river morphology, and GLOF-related guidelines for project design in glacier lake regions. Monthly monitoring of glacier lakes is underway to reduce outburst risks. The Flood Prone Area Assessment Atlas has revised India's flood-prone area from 40 million hectares to 21.2 million hectares, with state-wise vulnerability mapping. The Central Government is actively identifying state-specific flood challenges—riverine, coastal, urban—and providing tailored support. CWC's two-stage forecasting system includes level and inundation forecasts using satellite and radar data, with efforts to integrate current and future scenarios for improved preparedness.




DR. PRATAP SINGH







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TECHNICAL SESSION 02



DROUGHT RISK MANAGEMENT AND ADAPTATION IN A CHANGING CLIMATE







PANELISTS

Sh. Brijendra Swaroop (IFS)
Executive Director (Projects), NMCG, New Delhi

Dr. Rajesh Kumar Singh
Principal Scientist, IICAR-IISW, Dehradun

Dr. Rajendra Prasad Pandey
Former Scientist 'G' & Head EHD, NIH Roorkee
Visiting Professor; IIT Roorkee

Dr. Ravi Galkate
Scientist 'F' & Head, CIHRC-NIH Bhopal

Sh. Prashant Rai
Regional Director, CGWB, Dehradun

MODERATOR

Dr. Vivek Gupta
Assistant Professor, Civil Engineering Department,
IIT Mandi, Himachal Pradesh

RAPPORTEURS

Dr. Sunil Gurrapu
Scientist 'D', Centre of Cryosphere and Climate Change, NIH Roorkee

Sh. Ruchir Patidar
Scientist 'B', Hydrological Investigations Division, NIH Roorkee









(Source: google images)



Dr. Vivek Gupta
Assistant Professor, Civil Engineering Department,
IIT Mandi, Himachal Pradesh

India is facing increasingly frequent and severe droughts, driven by monsoon deficits, groundwater depletion, climate amplifiers, and economic disruptions. Nearly 96.4 million hectares of land are affected by desertification and degradation, costing the country an estimated ☐3.177 trillion annually. Around 35 million hectares of cropped area suffer damage, resulting in over 33% crop loss, while a quarter of the nation's groundwater assessment units are under significant stress.

To mitigate drought, a balanced approach is needed—managing both water demand and supply. On the demand side, strategies include improving irrigation efficiency, promoting crop diversification, encouraging community water budgeting, and enhancing water conservation in urban and industrial sectors. On the supply side, efforts must focus on rainwater harvesting, groundwater recharge, watershed development, revival of traditional water systems, and creation of new water bodies.

Several government schemes support these efforts. Demand-side initiatives include PMKSY ('Per drop, more crop'), Atal Bhujal Yojana (ABY), Groundwater Regulation under CGWA, and Model Building By-Laws (MBBL). For supply augmentation, schemes such as Jal Shakti Abhiyan (JSA), the National River Linking Project (NRLP), ABY, and various community-led programs are being implemented. Together, these interventions aim to build long-term resilience against drought and secure India's water future.





(Source: google images)



Sh. Brijendra Swaroop (IFS)

Executive Director (Projects),
NMCG, New Delhi

Early Warning Systems (EWS) play a vital role in managing flash floods and glacial lake outburst floods (GLOFs), as demonstrated during the 2023 incident. The operational flow of EWS—warning → percolation → action—must be supported by accurate prediction, which remains a challenge due to data limitations, forecasting model constraints, and ground-level implementation gaps. Strengthening the link between science, policy, and community engagement is key to overcoming these hurdles.

Improving market access and extending the shelf life of perishable crops through local knowledge and technology is equally important for climate resilience. Regulatory frameworks must evolve with broader acceptability, followed by deeper analysis and refinement. Government initiatives such as Atal Bhujal, Jal Sanchay Jan Bhagidhari aim to recharge groundwater at point scale, reduce over-extraction, and enhance base flow in river systems. In both active and passive floodplain zones, recharge enhancement is essential to sustain river health and mitigate flood risks.

These schemes are interconnected, with robust parameters designed to deliver tangible outcomes. A dedicated platform led by the Ministry is needed to bring together climate thinkers—not just for adaptation planning, but for holistic climate action. Public awareness must be prioritized, focusing on climate-resilient structures, tools, and informed decision-making to build long-term resilience at the community level.







(Source: google images)



Dr. Rajesh Kumar Singh

Principal Scientist, IICAR-IISW, Dehradun

The reliability of Early Warning Systems (EWS) hinges on both the accuracy of incoming data and its proper analysis. Data from Automatic Weather Stations (AWS) should be calibrated every 4 to 6 months to ensure validity; only then should it be used for model-based predictions, which can yield near-accurate results when based on verified inputs.

Three key areas were identified for improving agricultural efficiency: enhancing irrigation systems (with current efficiency at just 37%), promoting mulching combined with drip irrigation, and expanding protected agriculture to benefit more farmers. Additionally, cultivating less water-intensive yet high-yield crop varieties is essential in adapting to water stress.

A major barrier to adoption remains psychological—many communities have not yet felt the urgency of water scarcity. Industries must take responsibility by constructing groundwater recharge pits proportional to their extraction, following the principle that water use should match water replenishment. Surface water should be prioritized, with groundwater used only when necessary.

To incentivize sustainable practices, farmers and industrialists contributing to groundwater recharge and gray water reuse should receive financial support. Policy recommendations include expanding canal systems to aid groundwater recharge and flood moderation and increasing the use of Sewage Treatment Plants (STPs) to convert gray water into usable irrigation and industrial water. India generates 27 BCM of gray water annually but treats only 9.8 BCM—yet 1.2 lakh hectares could be irrigated with just 1 million MLD. A guiding thumb rule suggests that 10% of agricultural land should be integrated with water systems to ensure long-term sustainability.





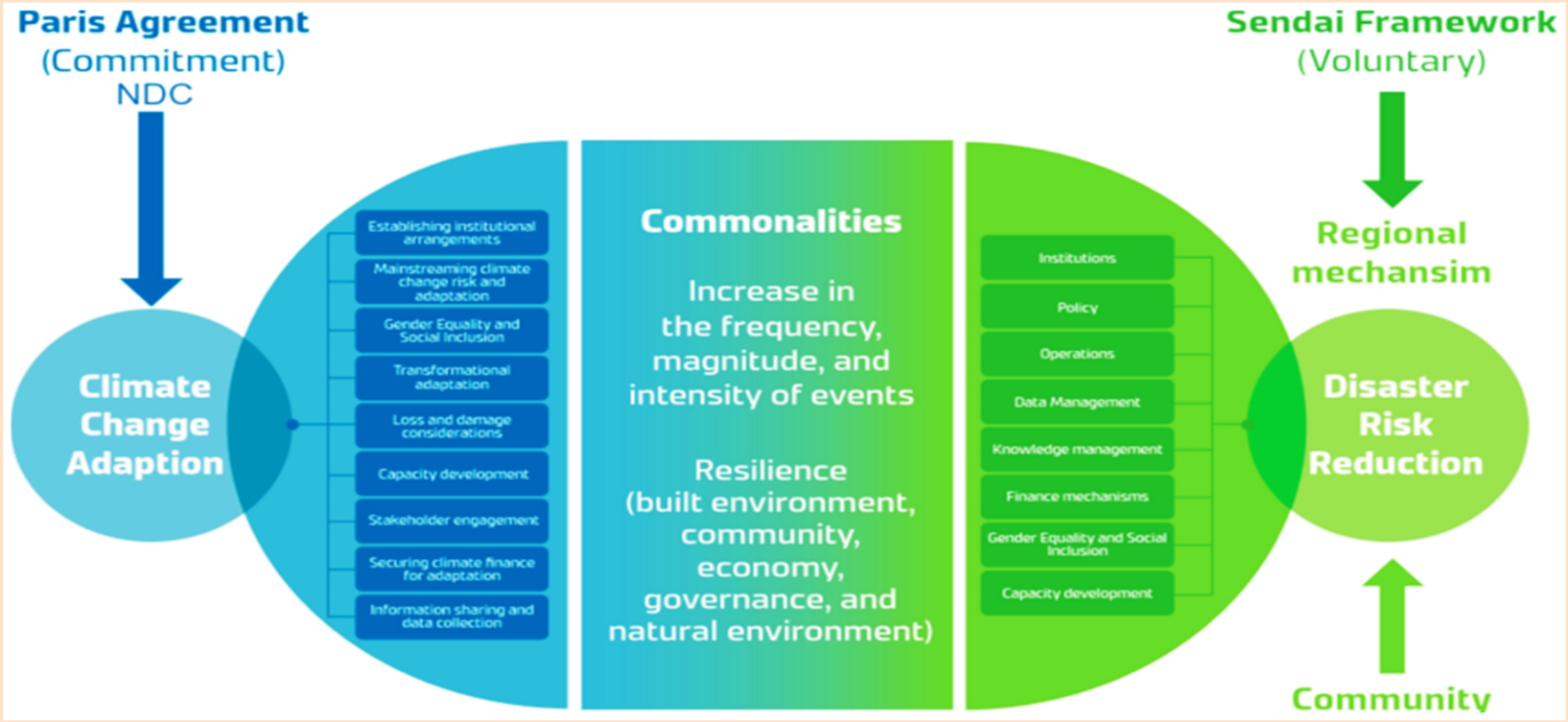
(Source: google images)



Dr. Rajendra Prasad Pandey

Former Scientist 'G' & Head EHD, NIH Roorkee
Visiting Professor, IIT Roorkee

Drought forecasting can be approached through multiple indicators such as rainfall patterns, reservoir levels, and hydrological trends. However, using Early Warning Systems (EWS) for drought monitoring remains complex. Rainfall forecasts typically extend up to a week, and as per IMD, drought conditions may emerge if a region experiences no rainfall for two consecutive weeks under dry conditions. This narrow forecasting window makes timely intervention challenging. Drought vulnerability varies across space and time, influenced by factors like physiography, surface and groundwater potential, land slope, Soil type, land use, crop type and rainfall variability. In 2017, the United Nations Convention to Combat Desertification (UNCCD) outlined three key pillars for drought management: monitoring and early warning from the third week onward, spatial and temporal vulnerability assessment, and structured mitigation planning. Short-term measures focus on immediate relief, while long-term strategies emphasize water conservation through ponds, lakes, biodiversity preservation, vegetation, and environmental restoration—serving both conservation and storage functions. The manual guiding these efforts distinguishes between two core components: the causative factor (rainfall) and the impact factor (availability of water in streams, storage structures such as reservoirs, lakes/ponds and groundwater). Forecasting efforts primarily analyze the causative factor to anticipate drought onset. To strengthen monitoring, Groundwater Drought Index can be employed which offers a more nuanced understanding of subsurface water stress. This index complements surface-level assessments and supports integrated drought resilience planning.







(Source: google images)



Dr. Ravi Galkate

Scientist 'F' & Head,
CIHRC-NIH Bhopal

Accurate and timely data is central to the effectiveness of Early Warning Systems (EWS) and forecasting, especially in drought-prone regions. However, the lack of real-time hydrological data and inconsistencies in existing datasets continue to hinder the reliability of forecasting models and drought monitoring efforts.

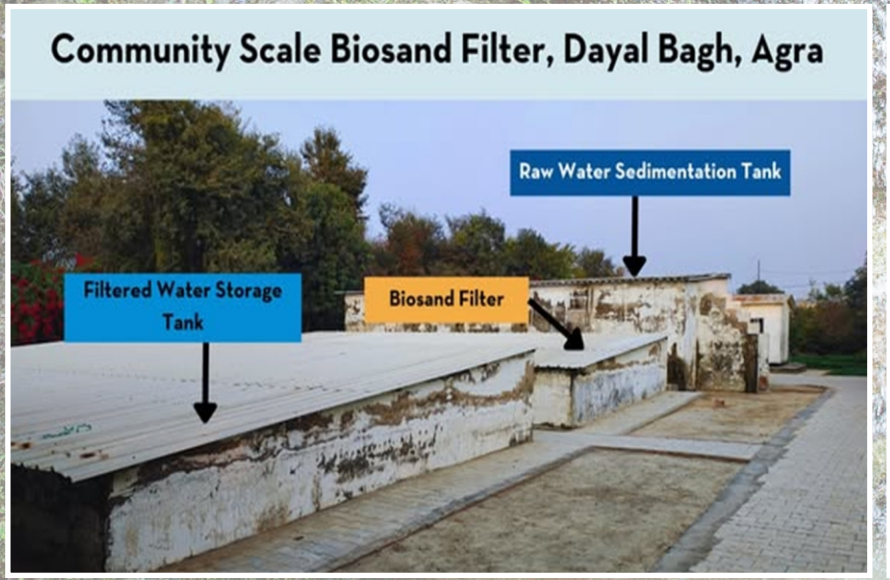
In Madhya Pradesh, the adoption of water-efficient irrigation methods like sprinklers and drip systems remains low—only around 10% of farmers use them, with flood irrigation still dominant. In contrast, states like Maharashtra and Gujarat have embraced these technologies more widely. Water-efficient agriculture, which aims to maximize yield while minimizing water use, is crucial under current climatic stress. To improve adoption, commercial models must be aligned with tangible benefits for farmers, making the transition economically viable and socially acceptable.

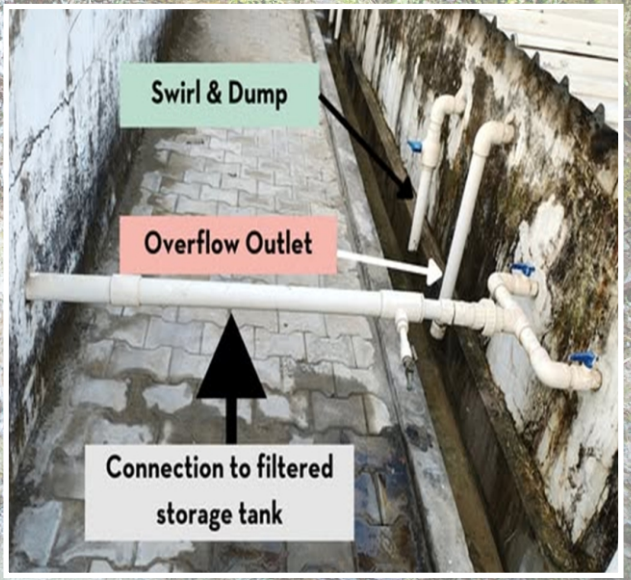
EWS can also be integrated into micro-irrigation systems, offering timely drainage solutions and empowering local artisans. With proper training and workshops, farmers can become proficient in using and maintaining these systems, fostering local expertise and resilience.

A phased approach to drought management is essential. In the short term, planning should focus on integrating EWS with hydrological, meteorological, and climatic parameters, promoting water conservation, ensuring emergency water supply, and encouraging drought-resistant crops. Medium-term strategies include constructing water storage infrastructure, implementing groundwater recharge projects, and strengthening community participation. Long-term planning must incorporate climate projections, comprehensive risk assessments, and ecosystem restoration to build enduring resilience.









(Source: google images)



Sh. Prashant Rai
Regional Director, CGWB,
Dehradun

Farmers remain hesitant to adopt new techniques despite increasing water stress and the continued cultivation of water-intensive crops. Demonstrating cost-effective, long-lasting technologies—rather than short-term annual solutions—is essential to encourage uptake. Current guidelines include block-level groundwater assessments, and industries that rely on groundwater are mandated to conserve it. However, there is a pressing need for a uniform chart to track groundwater usage across industries, with maintenance protocols tailored to local hydro-geological conditions.

The tendency to work in silos must be replaced by a unified data-sharing platform, initiated by the government, to consolidate and democratize access to water-related information. One of the major challenges in India, as in many developing countries, is the collection of real-time data and the need to sensitize ground-level personnel involved in data acquisition and sharing.

Agriculture and urban sectors are the highest consumers of water, yet remain largely uncharged. Installing flow meters in households and introducing minimal water charges can help instill a sense of value and responsibility toward water use. Maintenance of water resource systems must also be prioritized. In regions like Agra, freshwater is used for drinking while saline water is used for bathing and washing—an example of adaptive water use that can be replicated elsewhere.

To ensure long-term sustainability, attention must shift toward managing water-abundant regions with care, as overall water availability continues to decline. Strategic control and conservation in these areas will be key to balancing national water security.


Drought Risk Management and Adaptation in a Changing Climate
DR. RAVI GALKATE
DR. R P PANDEY
DR.PRASHANT RAI








SH.RAJESH KUMAR SINGH
DR.PRASHANT RAI








Drought Risk Management


Drought Risk Management and Adaptation in a Changing Climate




SH. BIJENDRA SWAROOP


'ADAPTATION PLANNING FOR INDIA'S WATER
SECTOR UNDER CLIMATE CHANGE'
21-22 AUGUST, 2025



TECHNICAL SESSION 03



ADAPTATION TO GLACIAL LAKE OUTBURST FLOODS (GLOFs) IN THE HIMALAYAN REGION





PANELISTS

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Former Director, WIHG Dehradun,
JC Bose Fellow, NGRI Hyderabad

Prof. Sanjay Kumar Jain
Former Scientist 'G' & Head WRSD, NIH Roorkee,
Visiting Professor, CoEDMM, IIT Roorkee

Dr. Aparna Shukla
Scientist 'F', Ministry of Earth Sciences, GoI

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Scientist F, WIHG, Dehradun

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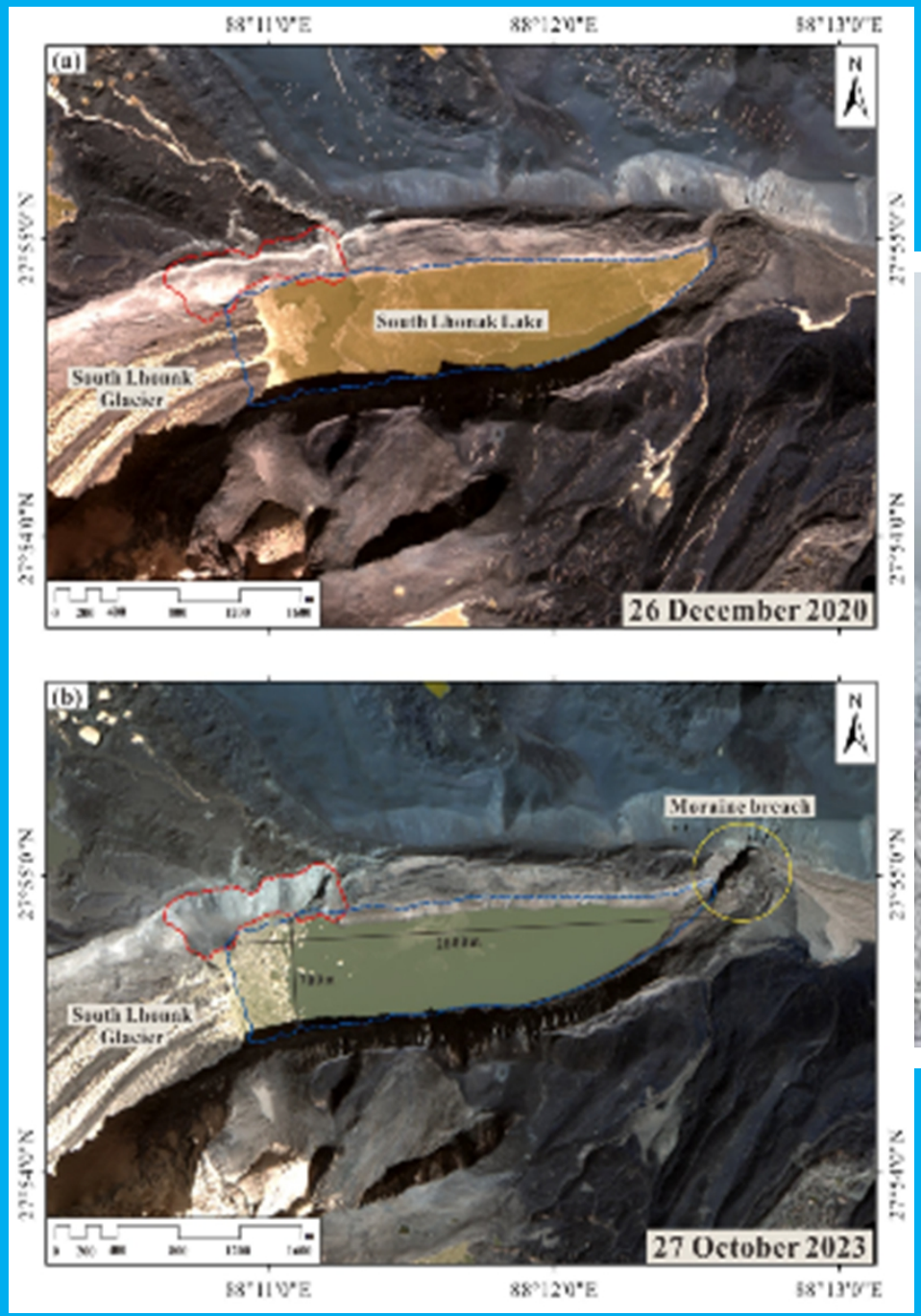
Scientist 'C', Centre of Cryosphere and Climate Change, NIH Roorkee







(Source: google images)

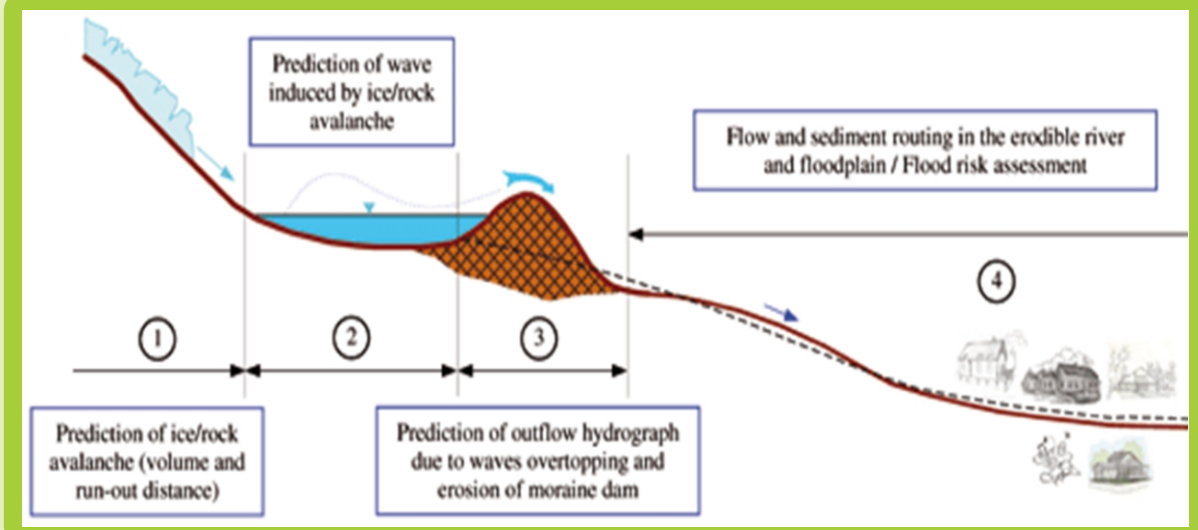


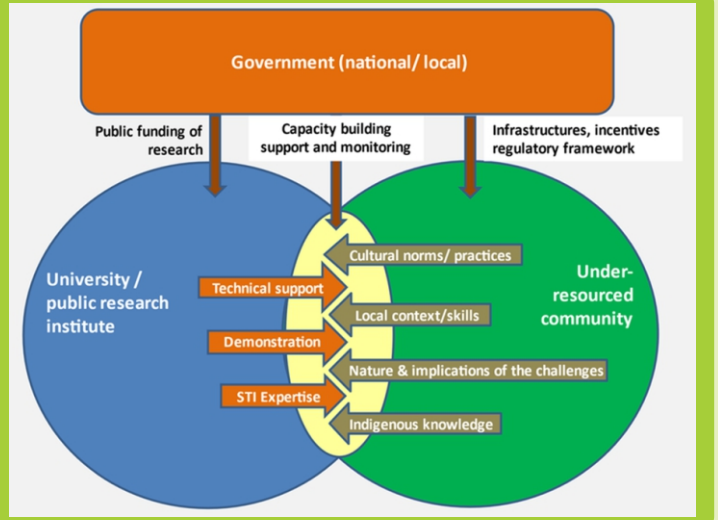
Dr. Bhanu Pratap
Scientist 'D',
National Centre for Polar and Ocean Research (NCPOR), Goa

Glacial melting in the Himalayas directly contributes to the formation of unstable glacial lakes, intensifying the risk of catastrophic downstream disasters. This transformation—from ice to water—may appear benign, yet it triggers devastating consequences through Glacial Lake Outburst Floods (GLOFs). Addressing this threat requires a comprehensive early warning system tailored to GLOF-prone zones. Such a system must begin with rigorous monitoring to identify critical lakes, followed by detailed risk assessments, and culminate in real-time alert mechanisms—such as sirens deployed in vulnerable valleys and inhabited regions—to ensure timely evacuation and local response.

Adaptation to GLOF hazards demands more than technological intervention; it calls for climate-resilient infrastructure that can withstand sudden hydrological shocks. Effective disaster management in the Himalayan region hinges on a fourfold strategy: precise assessment, proactive mitigation, robust early warning implementation, and resilient structural development. This integrated approach empowers communities, safeguards ecosystems, and builds long-term resilience against the accelerating impacts of climate change in high-altitude environments.







(Source: google images)

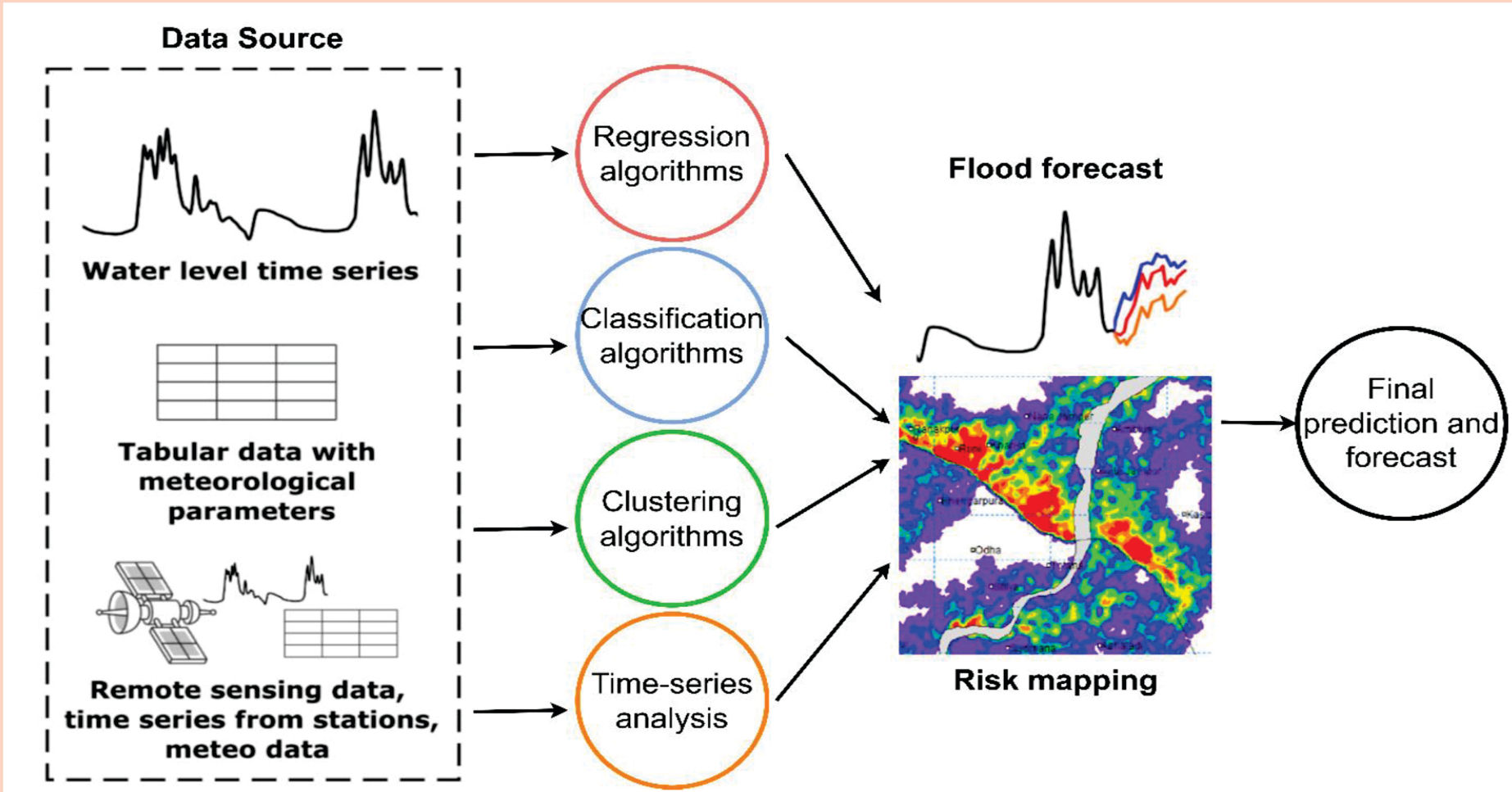


Dr. Kalachand Sain
Former Director, WIHG Dehradun,
JC Bose Fellow, NGRI Hyderabad

Glacial Lake Outburst Floods (GLOFs) represent High Impact–Low Occurrence (HILO) events, akin to tsunamis, yet they receive disproportionately low attention in terms of research, funding, infrastructure, and policy preparedness. This oversight underscores the urgent need for a dedicated framework that prioritizes GLOF analysis and mitigation. A comprehensive strategy begins with four foundational pillars: understanding the detailed characteristics of glaciers, glacier lakes, and GLOF dynamics; analyzing mass and volume changes using advanced technologies such as drone-based surveys slope variations; mapping infrastructure, habitats, and flow directions in vulnerable regions; and assessing seismic activity, anthropogenic pressures, and climatic influences on both glacier and glacial lakes.

Preparedness must evolve from these insights. Critical glaciers and avalanche zones require clear demarcation, early warning systems must be installed to alert downstream communities, and safe relocation plans should be developed for populations at risks. Central and State Governments need to allocate targeted funding for glacier research and disaster management, especially across the 11 Himalayan states and 2 union territories. Mitigation strategies demand state-wise vulnerability assessments based on water and sediment discharge, meteorological data, and slope instability. Engineering interventions—such as syphoning or pumping excess water from glacial lakes—must be paired with environmentally sensitive approaches. Declaration of 'No Construction' zones at riverbanks and floodplains, and relocation of residents from there become essential in anticipation of potential GLOF events.

Integrating meteorological, hydrological and seismological sensors into early warning systems enhances predictive accuracy and response coordination. Establishing a dedicated mitigation team bridges the gap between technical research and community awareness, and ensures adaptation strategies that are not only scientifically sound but also socially inclusive. This holistic approach transforms GLOF preparedness from a reactive measure into a proactive and resilient framework for safeguarding Himalayan communities.





(Source: google images)

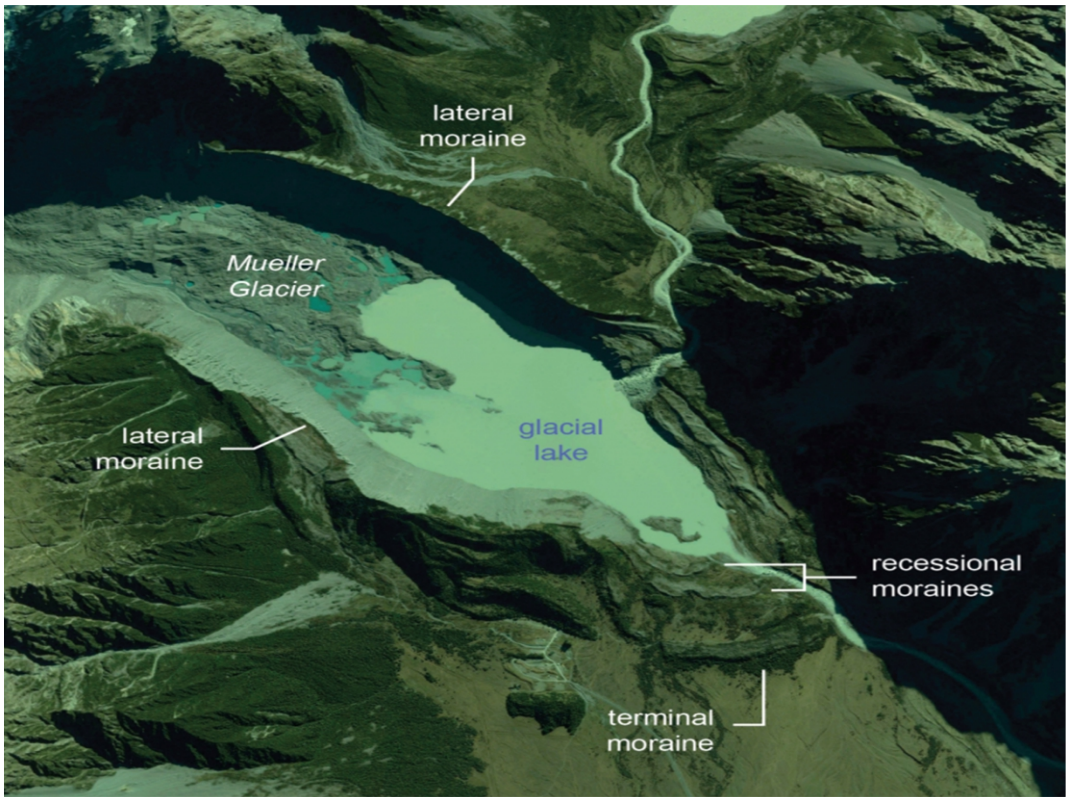


Prof. Sanjay Kumar Jain
Former Scientist 'G' & Head WRSD, NIH Roorkee,
Visiting Professor, CoEDMM, IIT Roorkee

Glacier retreat in the western Himalayas significantly alters runoff patterns, disrupts seasonal water availability, and undermines hydropower generation, deepening the cryosphere crisis across the region. Addressing this vulnerability begins with identifying key parameters and classifying the severity of glacial hazards, followed by targeted modeling of Glacial Lake Outburst Floods (GLOFs) and related events under the most critical conditions. Changes in glacier mass balance, coupled with extreme precipitation in high-altitude zones, intensify the risk of collapses and cascading hazards, demanding a nuanced understanding of the cryosphere's evolving dynamics.

Effective mitigation starts with diagnosing the nature of glacier lake threats—whether through overtopping or overflow—and selecting solutions based on feasibility and context. A structured approach involves categorizing high-priority lakes using standards such as those defined by the Bureau of Indian Standards (BIS), simulating flood levels through advanced modeling, and implementing protective infrastructure tailored to each lake's risk profile. Integrating insights on glacier retreat, flood behavior, and water yield into GLOF studies becomes essential for designing adaptive strategies. This methodology not only enhances regional resilience but also informs broader climate adaptation frameworks for high-altitude ecosystems.





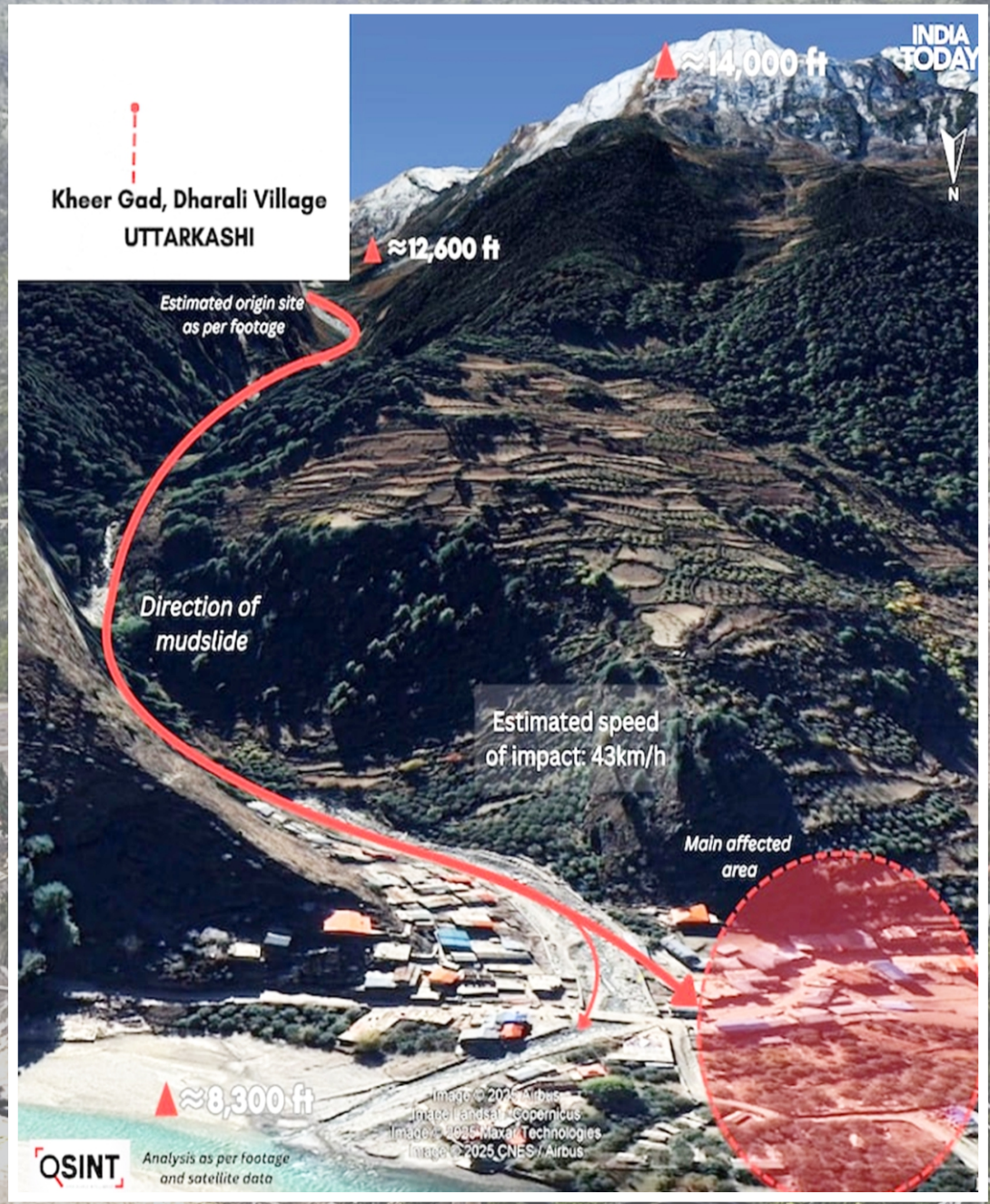
(Source: google images)



Dr. Aparna Shukla
Scientist 'F',
Ministry of Earth Sciences, GoI

The cryosphere in the high-altitude Himalayan region faces an accelerating crisis, warming at a rate significantly higher than the rest of the subcontinent. This rapid temperature rise leads to mass loss and shrinkage across key cryospheric components, including glaciers and snow cover. A dangerous positive feedback loop intensifies the problem: as glaciers morphologically transform, more hanging glaciers emerge, and cryokarst features such as ice cliffs and glacial ponds proliferate. These formations not only accelerate melting but also possess self-reinforcing growth dynamics. Fragile moraine materials accumulate, increasing the risk of breaches and triggering devastating floods. Slope instability, exacerbated by permafrost degradation, contributes to a surge in landslides and rockslides—events exemplified by disasters like Chamoli.

Downstream communities in the Himalayan region now face heightened vulnerability to climate-induced hazards. The combination of increased morainic debris and sudden runoff from extreme weather events and Glacial Lake Outburst Floods (GLOFs) results in flash floods laden with destructive debris flows. Addressing these threats requires a strategic triad: advancing research in mountain meteorology and cryosphere science, fostering international and national collaboration to bridge knowledge and response gaps, and recognizing the transboundary and cascading nature of cryospheric hazards. The Ministry of Earth Sciences has recently funded research-driven projects with focus on risk assessment across all Himalayan states and borders, laying the groundwork for informed action. Building climate-resilient infrastructure and promoting community-based, indigenous approaches emerge as essential pathways to strengthen adaptive capacity and safeguard lives in this fragile mountain ecosystem.







(Source: google images)



Dr. Santosh Kumar Rai
Scientist F,
WIHG, Dehradun

Flash floods in the Himalayan region, often triggered by Glacial Lake Outburst Floods (GLOFs) or cloudbursts, pose a critical threat to communities residing along riverbanks and floodplains—areas increasingly populated due to limited habitable land in high-altitude zones. Balancing human settlement needs with safety imperatives requires strategic spatial planning. A comprehensive mapping of fluvial fans—from upper catchments to lower valleys—serves as a vital tool to guide habitation and land use. These fans, especially those perpendicular to rivers and along nallas, must be strictly designated for agriculture and horticulture, with habitation strongly prohibited to mitigate disaster risk.

Policy frameworks must prioritize the development of robust rainfall and precipitation monitoring networks tailored to mountainous terrains. The principle of "leave the river path always cleared" becomes essential, as the sheer momentum and volume of water during extreme events surpass the capacity of any engineered structure. Learning from past disasters, previously flooded zones should be repurposed exclusively for cultivation, not settlement. To enhance early detection and response, the proposal for a dedicated satellite—'HIMSAT'—focused on the high Himalayan region offers a transformative solution. Continuous satellite-based surveillance would enable timely interventions, safeguard vulnerable populations, and reinforce climate resilience across the fragile mountain ecosystem.






(Source: google images)





Dr. Vaibhav Garg
Scientist/Engineer 'SF',
IIRS Dehradun

Addressing the cryosphere crisis in the Himalayan region requires a multi-pronged strategy rooted in community engagement, technological innovation, and institutional support. Local communities play a pivotal role in identifying newly formed glacier lakes, offering real-time insights that complement scientific monitoring. Installing water level recorders integrated with early warning systems enhances preparedness, while simulation models help delineate vulnerable zones where human habitation must be strictly prohibited to prevent disaster exposure. Government support becomes essential in scaling these interventions. Schemes such as the proposed National GLOF Risk Mitigation Programme can empower states to mitigate losses from Glacial Lake Outburst Floods (GLOFs) and build adaptive capacity.

The development of BIS standards focused on water storage volumes within glaciers marks a critical step toward formalizing risk assessment protocols. Annual monitoring of glaciers, moraines, and other cryospheric elements through Remote Sensing (RS), Geographic Information Systems (GIS), and IoT-enabled Automatic Weather Stations (AWS) ensures continuous surveillance of high-altitude meteorological conditions.

Building resilience also depends on capacity development across scientific and technical communities. Strengthening the skills of scientists, researchers, engineers, and stakeholders, alongside educating local populations, fosters a shared understanding of climate risks and equips regions to respond effectively. This integrated approach transforms cryosphere management from a reactive endeavor into a proactive framework for sustainable mountain development.




02-day National Workshop
on
'ADAPTATION PLANNING FOR INDIA'S WATER
SECTOR UNDER CLIMATE CHANGE'
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21-22 AUGUST, 2025






Adaptation to Glacial Lake Outburst Floods (GLOFs) in the Himalayan Region


DR. SANJAY KUMAR JAIN
DR. VAIBHAV GARG



TECHNICAL SESSION 04

MITIGATING RAINFALL-INDUCED LANDSLIDE HAZARDS IN VULNERABLE TERRAINS









PANELISTS

Prof. Sumit Sen
Head, Department of Hydrology, IIT Roorkee

Dr. Shantanu Sarkar
Director, ULMMC, Dehradun

Dr. Sudhir Kumar
Former Director, NIH Roorkee

Dr. Debi Prasanna Kanungo
Chief Scientist, CSIR-CBRI, Roorkee

Prof. Vikram Gupta
Professor, Sikkim University

MODERATOR

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Assistant Professor, Department of Geology, Doon University, Dehradun

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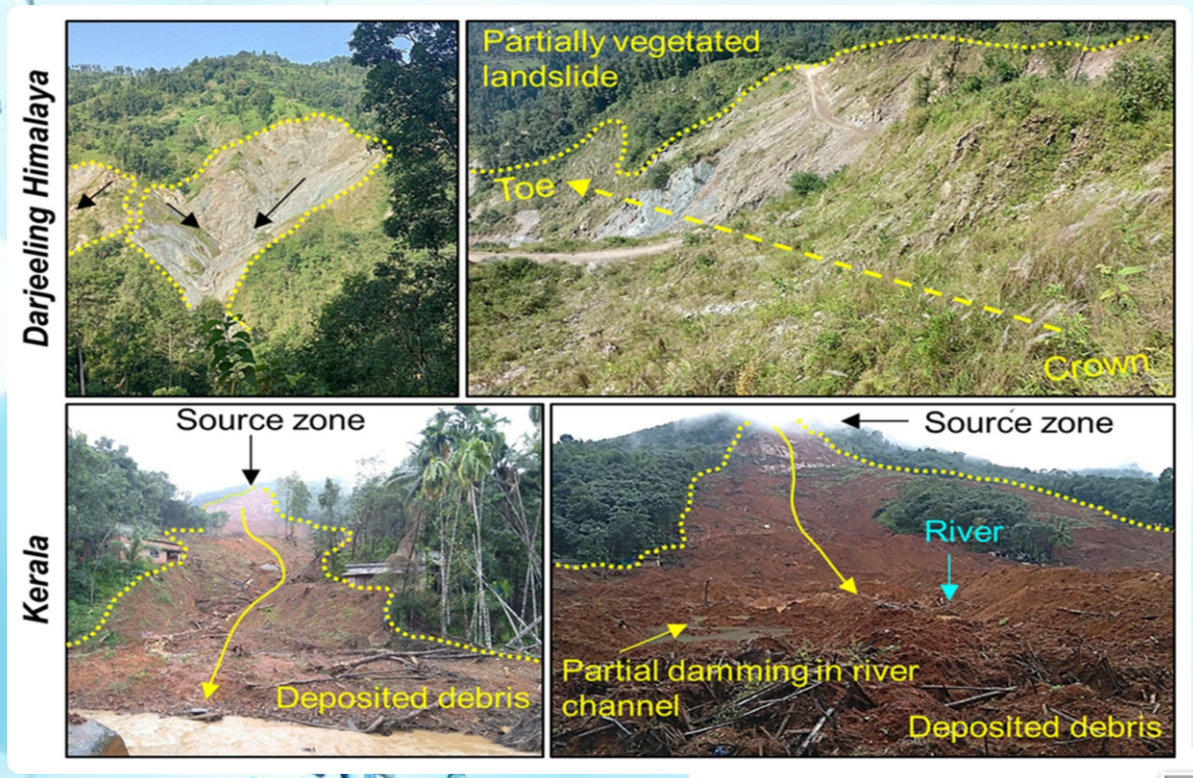
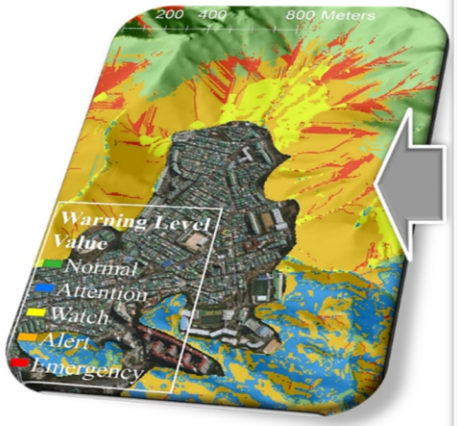
Scientist 'D', Centre of Cryosphere and Climate Change, NIH Roorkee

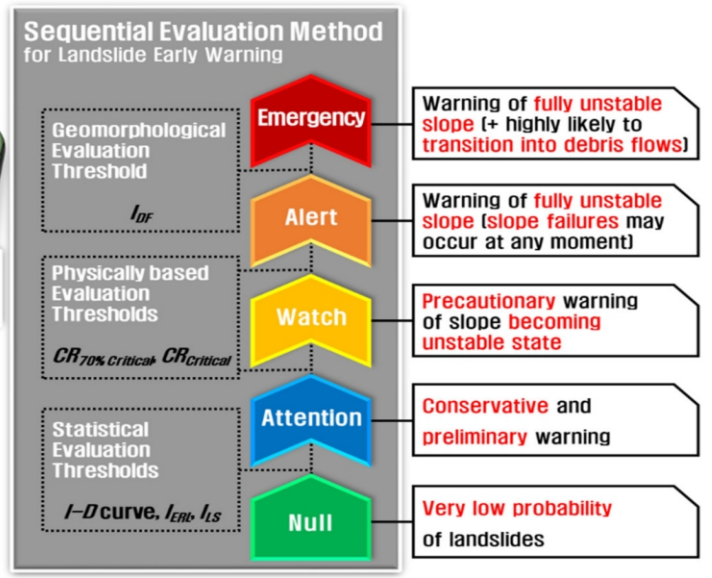
Dr. Nitesh Patidar
Scientist 'B', Ground Water Hydrology Division, NIH Roorkee











(Source: google images)



Dr. Vipin Kumar
Assistant Professor, Department of Geology,
Doon University, Dehradun

Landslide frequency in the Himalayan region has surged since 2005, closely linked to the intensification of rainfall patterns. These rainfall-induced phenomena exhibit significant spatial and temporal variability, governed by factors such as exposure consistency and slope stability. A critical challenge in landslide risk management arises from cognitive biases within communities—particularly optimism bias—which leads to the dismissal of early warnings and underestimation of potential hazards. This behavioral tendency amplifies the cascading effects of landslides, transforming localized events into broader disasters.

Mitigating landslide vulnerability demands a dual approach: rigorous risk evaluation and effective communication strategies that translate scientific forecasts into actionable public awareness. Removing cognitive bias through education and participatory engagement becomes essential to foster a culture of preparedness. By aligning geoscientific insights with community behavior, stakeholders can build adaptive frameworks that not only predict landslide events but also empower populations to respond proactively, reducing long-term risk across vulnerable terrains.





(Source: google images)



Prof. Sumit Sen
Head, Department of Hydrology,
IIT Roorkee

Soil dynamics in the Himalayan region reveal a distinctive hydrological behavior, where gravelly soil promotes higher percolation compared to surface runoff. However, a significant yet under-recognized factor— quick-flow or subsurface flow—plays a critical role in triggering shallow landslides and subsequent debris flows. This rapid subsurface movement, often overlooked due to its complexity and difficulty in quantification, demands focused research and monitoring to mitigate cascading hazards effectively.

Mitigation strategies must prioritize the analysis of soil moisture and water-holding capacity, which directly influence slope stability. While current assessments of rainfall-induced landslides rely on intensity-duration (ID) curves, integrating Differential Thermal Analysis (DTA) curves offers a more nuanced understanding of thermal and hydrological interactions within the soil matrix. Rainfall-triggered landslides, being more frequent than seismic-induced ones, require heightened attention and tailored forecasting models.

Establishing a dense network of high-resolution monitoring stations becomes essential to track system changes and assess susceptibility in real time. Special emphasis on intermittent and ephemeral river systems helps reduce downstream debris-flow impacts, as these channels often serve as conduits for sudden hydrological surges. Enhanced monitoring not only improves localized understanding of extreme events but also strengthens regional forecasting capabilities, enabling proactive disaster management across vulnerable Himalayan landscapes.









(Photo Courtsey: Dr. Shantanu Sarkar, ULMMC)

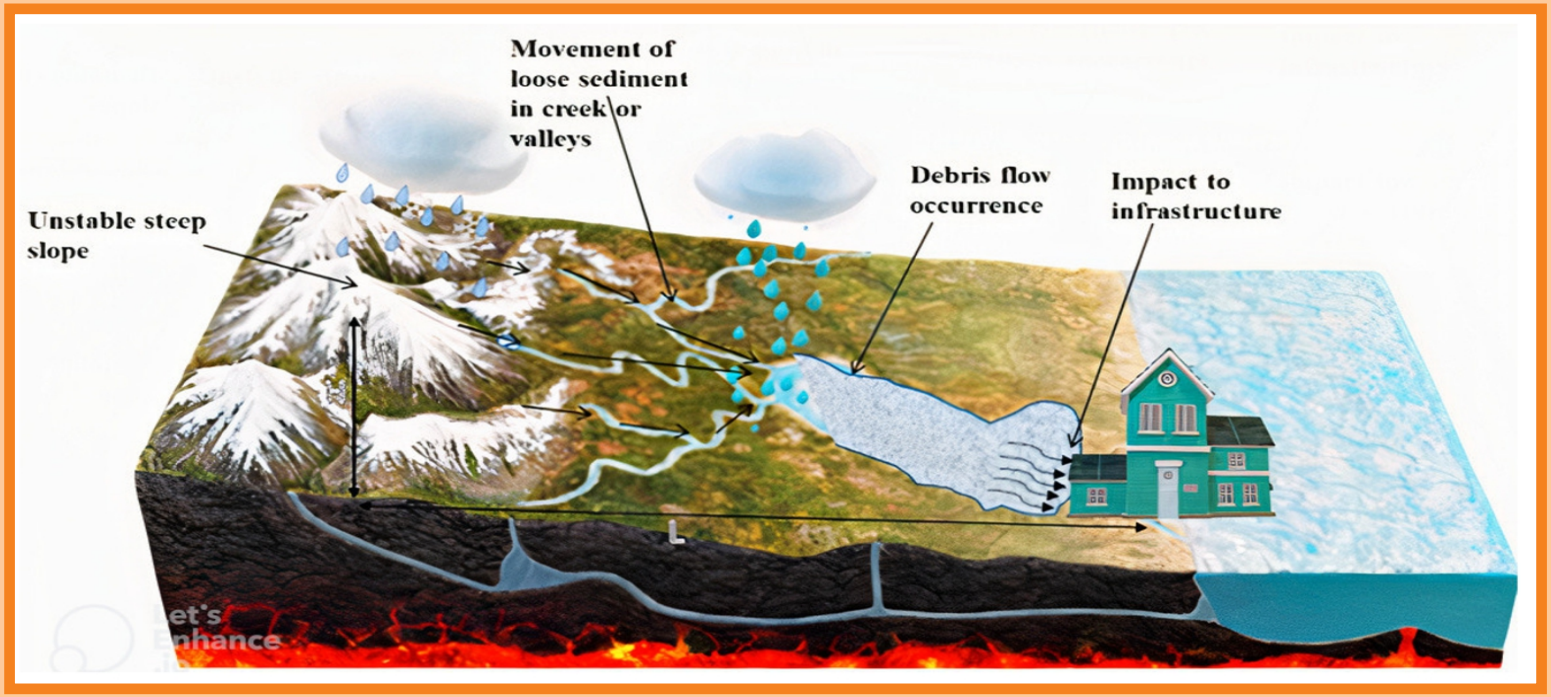


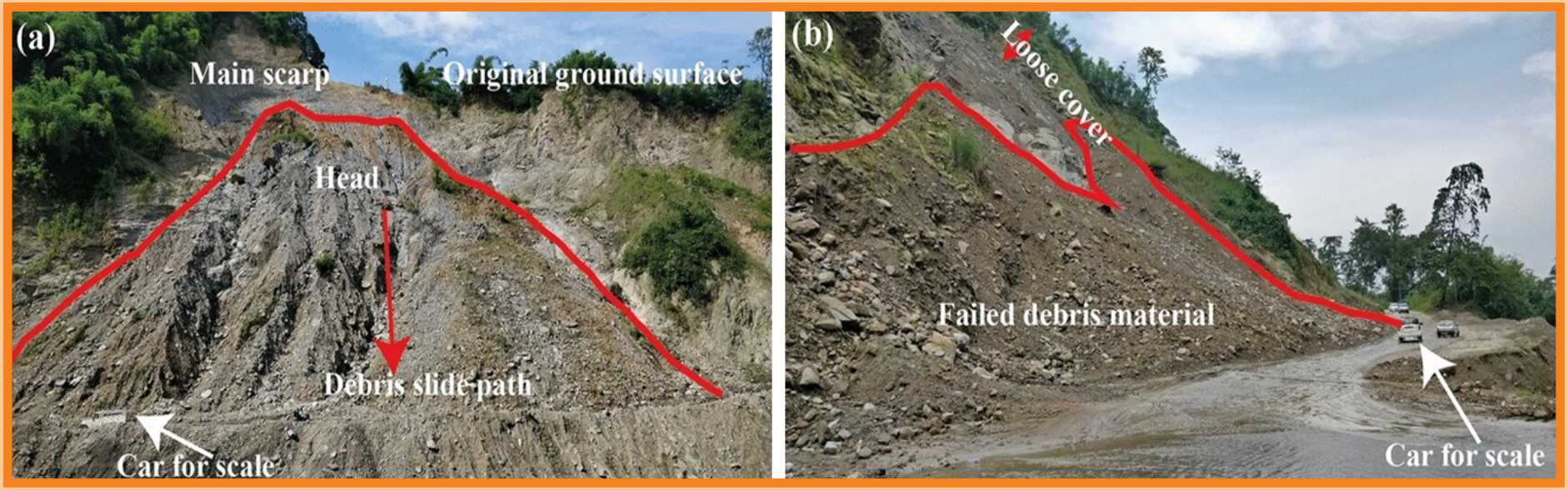
Dr. Shantanu Sarkar
Director,
ULMMC, Dehradun

Risk avoidance emerges as a foundational principle in landslide-prone Himalayan regions, demanding proactive planning and community engagement. Recent initiatives focus on developing geo-databases and conducting block-level awareness programs to educate residents about soil bearing capacity and the geological and geographical characteristics of their terrain. This localized knowledge empowers communities to make informed decisions about land use and settlement.

Dynamic land use planning becomes essential, incorporating detailed mapping of debris channels in relation to population clusters. Such maps guide safe habitation and agricultural practices while minimizing exposure to slope instability. The Uttarakhand Government's installation of hydro-meteorological sensors across vulnerable zones strengthens early warning systems, with densified siren networks enhancing real-time alerts.

Response strategies include building a comprehensive landslide database through systematic mapping and pre- and post-monsoon surveys along critical corridors such as those managed by the National Highways Authority of India (NHAI). These efforts inform the refinement of mitigation measures and infrastructure resilience. To institutionalize this approach, landslide-prone states must establish inter-organizational committees that coordinate research, policy, and implementation. This collaborative governance model ensures that risk avoidance transitions from concept to practice, safeguarding lives and livelihoods in fragile mountain ecosystems.





(Source: google images)

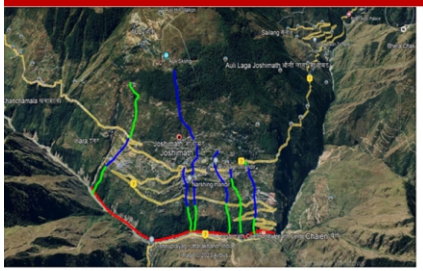


Dr. Sudhir Kumar
Former Director,
NIH Roorkee

Water availability in landslide-prone zones plays a critical role in triggering slope instability, particularly in the context of rainfall-induced landslides. Contrary to common assumptions, rainfall alone does not directly cause landslides; rather, it is the accumulation and infiltration of water within the soil and rock layers that destabilizes slopes and initiates mass movement. Understanding the hydrological mechanisms and subsurface processes becomes essential for developing effective mitigation strategies.

A confident and proactive approach to landslide risk reduction involves targeted investments in monitoring systems, active engagement with local communities, and precise identification of vulnerable sites. Reducing debris accumulation in high-risk zones further enhances slope stability and minimizes cascading hazards. By integrating scientific insight with grassroots participation, stakeholders can build a resilient framework that not only predicts landslide events but also empowers communities to respond effectively, safeguarding lives and infrastructure in mountainous regions.

JOSHIMATH SUBSIDENCE (2023)





Damaged Buildings



Failure in Masonry building



Failure of rubble masonry

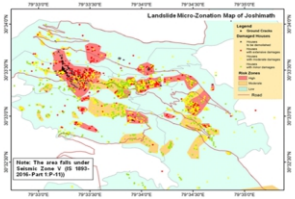


Diagonal shear Failure of Masonry Infill

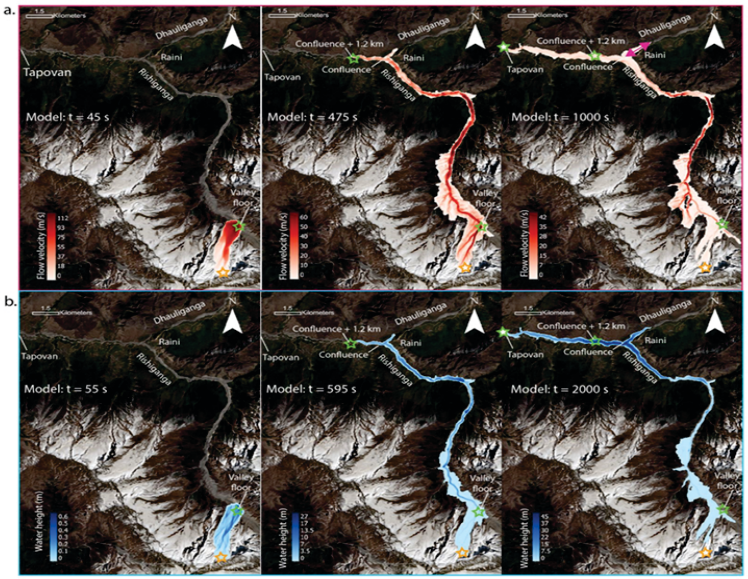


Failure of masonry infill

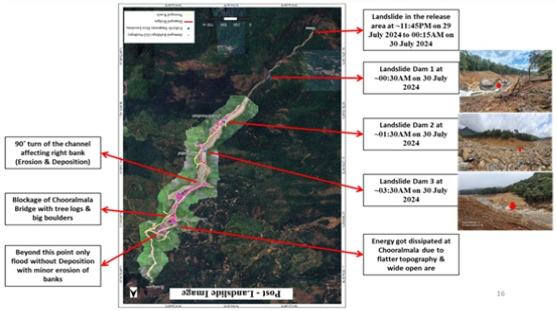
Risk Map

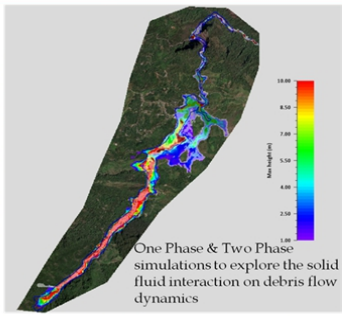


CHAMOLI ROCK ICE AVALANCHE (2021) EVENT SIMULATION



WAYANAD DEBRIS FLOW (2024)









DHARALI DEBRIS FLOW (2025)









(Photo Courtsey: Dr. Debi Prasanna Kanungo)



Dr. Debi Prasanna Kanungo
Chief Scientist,
CSIR-CBRI, Roorkee

Rainfall thresholding for landslide prediction demands a more nuanced approach than conventional intensity-duration (ID) curves, which often fail to accurately categorize susceptibility. A robust methodology begins with compiling a comprehensive landslide inventory, followed by classification of landslide types and failure mechanisms. Developing antecedent rainfall thresholds tailored to specific failure modes enhances predictive precision. Strengthening the underlying database infrastructure becomes essential for reliable analysis and long-term monitoring.

The recommended analytical workflow unfolds in four stages: quantify and forecast potential hazards, identify release and recession zones, measure and monitor using advanced instruments and technologies, and finally, mitigate and prepare through scenario-based modeling. For debris flow management, policy frameworks must establish buffer zones along drainage channels and implement a three-tiered barrier system to sequentially intercept boulders, cobbles and pebbles, and finer sediments like silt, clay, and sand.

A paradigm shift from post-disaster mitigation to proactive preparedness is critical. This involves quantifying debris release zones, conducting vulnerability modeling, and communicating findings in accessible language to local communities. Engaging residents with instrumentation and integrating scientific knowledge with indigenous understanding fosters inclusive resilience. Monitoring stations tailored to detect spatial and temporal shifts in rainfall patterns across hilly terrains are vital for early warning and adaptive planning. Scientific inquiry must remain grounded in thorough observation and analysis, avoiding premature conclusions and ensuring that interventions are both evidence-based and context-sensitive.











(Source: google images)



Prof. Vikram Gupta
Professor,
Sikkim University

Landslide susceptibility in the Himalayan region demands a multi-layered mapping approach—first-order, second-order, and third-order maps—each capturing different dimensions of vulnerability driven by climate change, land use transformation, and population dynamics. Climate change has significantly altered rainfall behavior, with extreme precipitation events now occurring over shorter durations and monsoon patterns expanding in intensity and spatial coverage across mountainous terrains. These shifts amplify the risk of slope failures and cascading hazards.

Prioritizing hazard mapping becomes essential for predicting landslide susceptibility with precision. Such maps must integrate spatial rainfall variability, topographic sensitivity, and anthropogenic pressures to identify high-risk zones. The increasing spatial shift of rainfall, coupled with the frequency of extreme events, necessitates a dynamic and data-rich mapping framework. This enables planners, scientists, and local authorities to anticipate risks, guide land use decisions, and implement targeted mitigation strategies that reflect the evolving climate realities of the Himalayan landscape.


Hazards in Vulnerable Terrains




02-day National Workshop
on
'ADAPTATION PLANNING FOR INDIA'S WATER SECTOR UNDER CLIMATE CHANGE'
21-22 AUGUST, 2025


GREEN CLIMATE FUND
Vulnerable Terrains


UNDP


SECTOR UNDER CLIMATE CHANGE
21-22 AUGUST, 2025






Mitigating Rainfall-Induced Landslide Hazards in Vulnerable Terrains
02-Day National Workshop
on
Adaptation Planning for India's Water Sector under Climate Change
(21-22 Aug 2025 – Hyatt Place, Haridwar, Uttarakhand)
Themes
Special Session
PROF SUMIT SEN
DR. SUDHIR KUMAR


Mitigating Rainfall-Induced Landslide Hazards in Vulnerable Terrains

DAY 01

Technical Session 1

- Integrated Strategies for Flood Risk Reduction and Adaptive Water Governance

Technical Session 2

- Drought Risk Management and Adaptation in a Changing Climate

Technical Session 3

- Adaptation to Glacial Lake Outburst Floods (GLOFs) in the Himalayan Region

Technical Session 4

- Mitigating Rainfall-Induced Landslide Hazards in Vulnerable Terrains

DAY 02

Technical Session 5

- Cyclone-Resilient Water Infrastructure and Risk Mitigation Approaches

Technical Session 6

- Adaptive Responses to Coastal Flooding and Sea Level Rise

Technical Session 7

- Mainstreaming Gender Equality, Disability, and Social Inclusion (GEDSI) in Water Sector Adaptation

ADAPTATION PLANNING FOR INDIA'S WATER SECTOR UNDER CLIMATE CHANGE

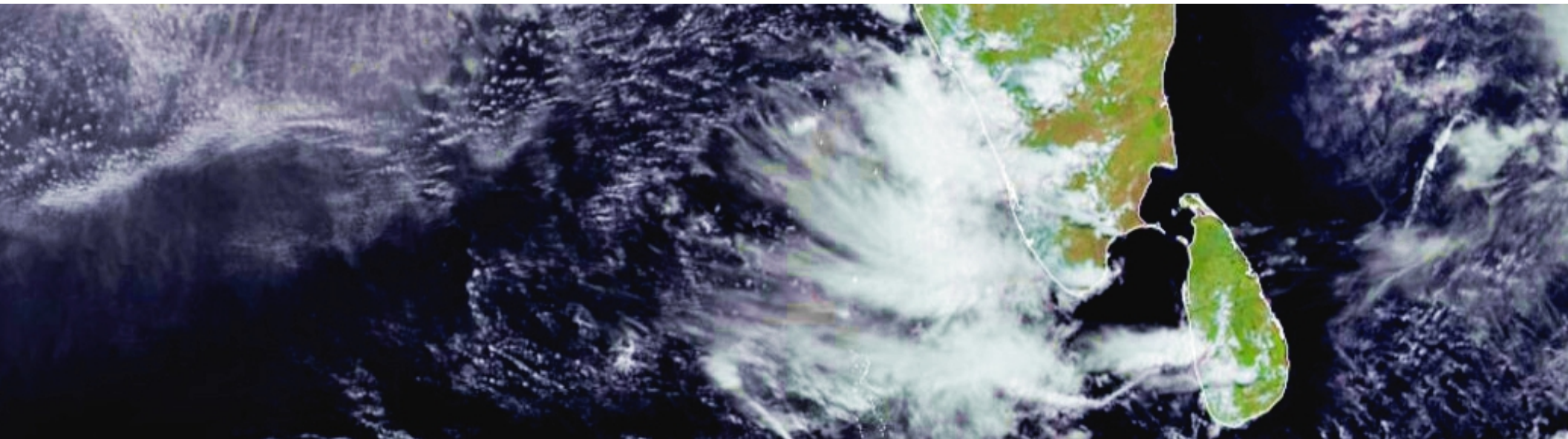
COMPENDIUM OF PROCEEDINGS OF THE TWO-DAY NATIONAL WORKSHOP

DAY 02

22 AUGUST, 2025

TECHNICAL SESSION 05

CYCLONE-RESILIENT WATER INFRASTRUCTURE AND RISK MITIGATION APPROACHES





PANELISTS

Dr. Kamal Lochan Mishra (IAS)
Executive Director, OSDMA

Dr. Ajit Tyagi
Former Director General, IMD
Air Vice Marshal (Retd.)

Prof. Sharad Kumar Jain
Former Director, NIH Roorkee
Visiting Professor, IIT Gandhinagar

Dr. Raghavendra Ashrit
Scientist 'G', National Centre for Medium Range Weather Forecasting,
Ministry of Earth Science, Noida

Prof. Krishna Kumar Singh
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Scientist 'E', IITM Pune

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Scientist 'D', Centre of Cryosphere and Climate Change, NIH Roorkee

Dr. Kuldeep Sharma
Scientist 'C', Centre of Cryosphere and Climate Change, NIH Roorkee









(Source: google images)



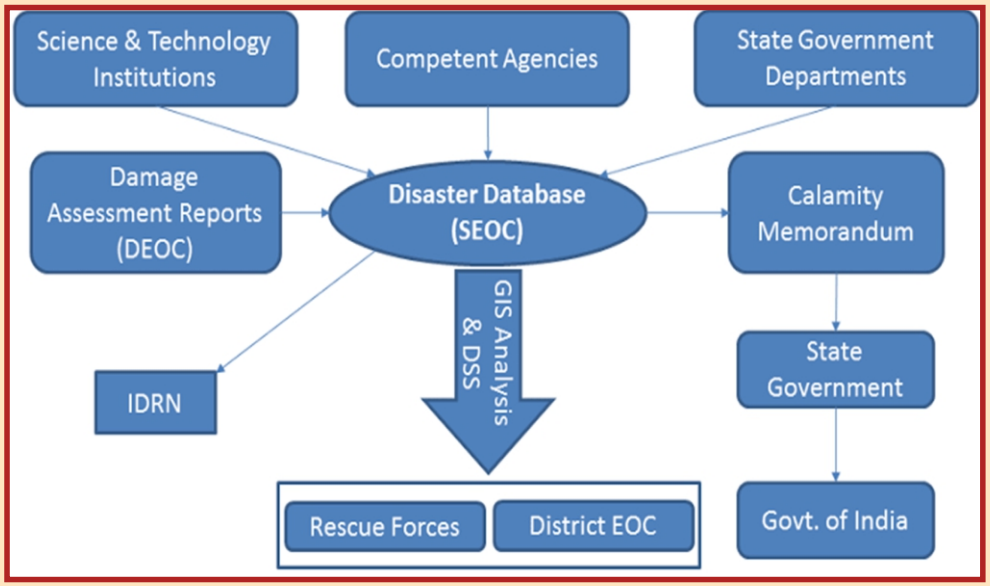


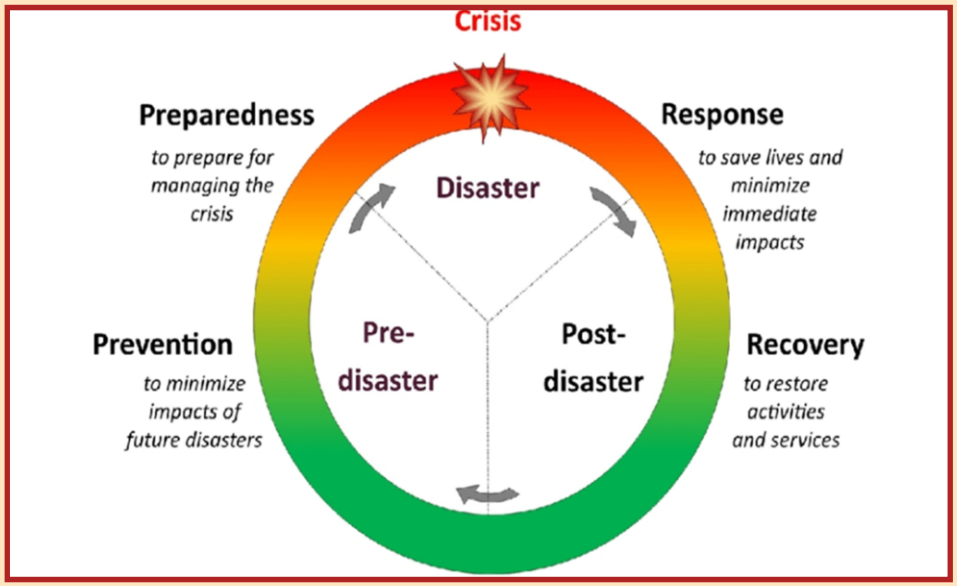
Dr. Medha S. Deshpande
Scientist 'E',
IITM Pune

Cyclones exert multifaceted impacts beyond wind and heavy rainfall, triggering secondary hazards such as storm surges, inland flooding, landslides, and even tornadoes. Addressing these cascading threats requires the development of cyclone-resilient water infrastructure across vulnerable coastal and inland regions. Key interventions include elevated water supply tanks and sealed boreholes to ensure uninterrupted access to clean water; flood-resilient sanitation systems such as raised latrines and sealed septic tanks to prevent contamination; and robust drainage solutions incorporating resilient drains, retention ponds, and wetlands to manage excess water and reduce urban flooding.

Coastal protection strategies must integrate engineered and ecological solutions—embankments, salinity barriers, and mangrove buffers—to shield communities from surge-related inundation and erosion. Risk mitigation demands a holistic framework encompassing detailed risk assessment planning, community-based preparedness measures, institutional and policy support, responsive emergency systems, and long-term climate adaptation. This integrated approach not only safeguards infrastructure but also strengthens the resilience of communities facing the intensifying impacts of cyclonic disturbances.







(Source: google images)



Dr. Kamal Lochan Mishra

IAS
Executive Director, OSDMA

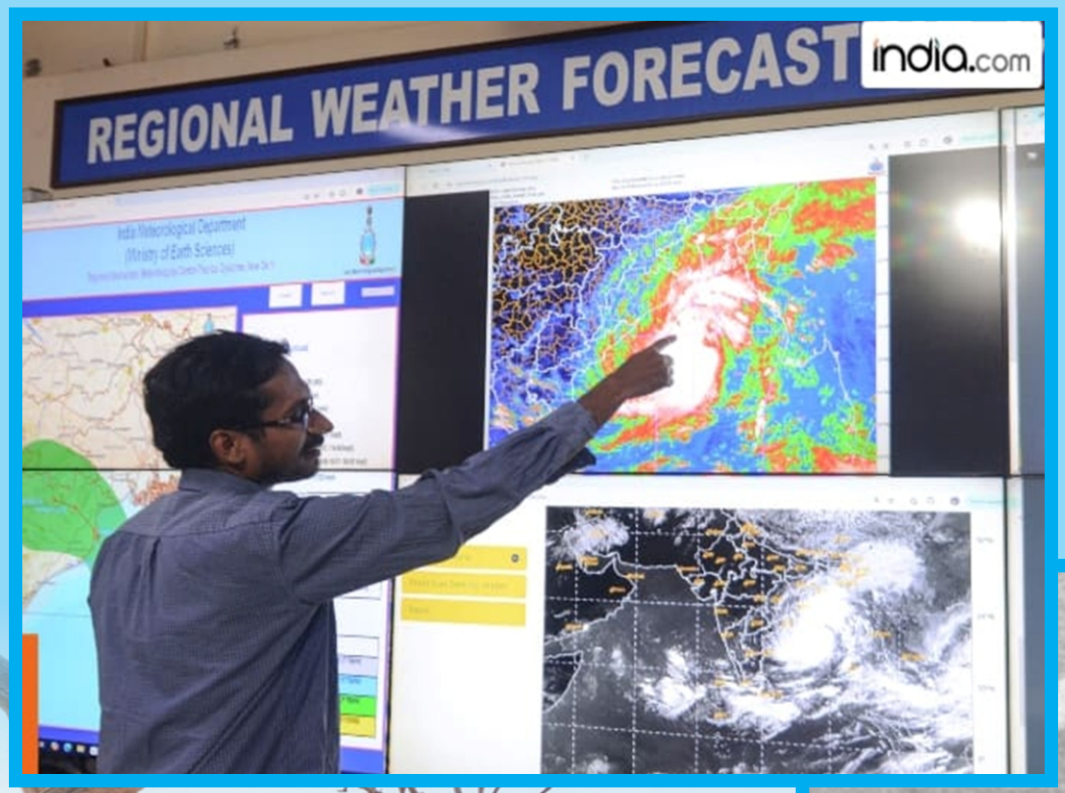
Disaster preparedness in cyclone-prone regions operates through a structured framework of Emergency Operation Centres (EOCs) at the state, district, and block levels. The district EOC serves as the critical node, receiving cyclone forecasts and alerts from the India Meteorological Department (IMD). Effective disaster response hinges on the principle of "unity of command," ensuring that all functionaries follow clear, actionable instructions to eliminate confusion and strive toward zero casualty outcomes.

A well-defined division of responsibilities between public and private entities enhances operational efficiency. While private agencies may generate data, government bodies must oversee its calibration and sanitization to maintain integrity and reliability. The water sector, in particular, offers vast potential for public-private collaboration, provided roles are clearly demarcated and responsibilities are transparently assigned.

Long-term resilience planning involves fortifying public infrastructure—energy systems, water supply, roads, and telecommunications—through technological upgrades, strategic investments, and protective measures. In one operational region, water supply systems are equipped with independent power sources and mandated to maintain a seven-day fuel reserve ahead of any cyclonic event. Communication interfaces are being developed to disseminate cyclone-related instructions effectively across diverse user groups and professional communities.

During crises, public trust in government system and factual communication becomes paramount. Two key strategies support this trust: appointing a media spokesperson (such as the Relief Commissioner) to deliver consistent, written updates, and ensuring uniformity in media messaging to prevent panic. Evacuation protocols are built on three pillars—awareness-level training, operational-level training, and mock drills—each reinforcing community readiness.

Citizens are urged to rely on IMD forecasts and adhere strictly to administrative directives, even when predictions deviate from actual outcomes. Trust in scientific institutions, meteorologists, and governance structures forms the backbone of effective disaster management, enabling informed decision-making and safeguarding lives in the face of uncertainty.





(Source: google images)



Dr Ajit Tyagi
Former Director General, IMD
Air Vice Marshal (Retd.)

The genesis of the India Meteorological Department (IMD) in 1875 traces back to the aftermath of two devastating cyclones and multiple droughts, marking the beginning of institutionalized weather forecasting in India. IMD pioneered the first global monsoon forecast and has since earned international recognition from bodies such as the United Nations and the World Meteorological Organization for its advancements in cyclone prediction. In recent years, IMD has received high commendation for its cyclone forecasting capabilities and now extends guidance Arabian Sea., reinforcing its role as a regional forecasting leader.

Climate resilience operates on a four-pronged framework: climate monitoring, climate predictions/projections, mitigation, and adaptation. Within this structure, hydrological parameter forecasting by the IMD plays a pivotal role, offering multi-component insights that support diverse sectors through robust datasets and predictive models. Effective disaster management hinges on inter-organizational collaboration, where shared data and coordinated strategies help overcome systemic limitations and enhance preparedness.

To strengthen community resilience, researchers and scientists must develop accurate and locally trusted warning systems. These systems should translate complex meteorological products into actionable alerts that resonate with local populations, bridging the gap between scientific precision and public trust. This approach ensures that forecasting not only informs policy but also empowers communities to respond proactively to climate-induced hazards.





(Source: google images)

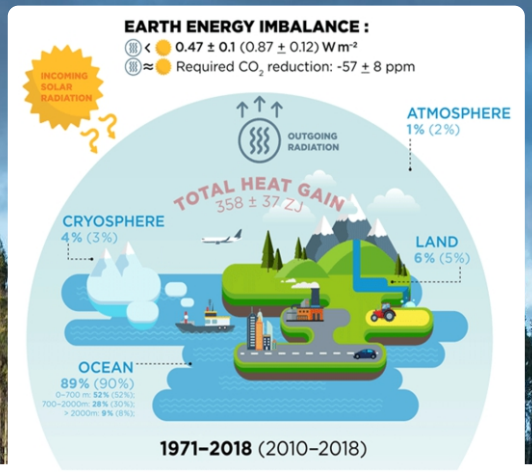


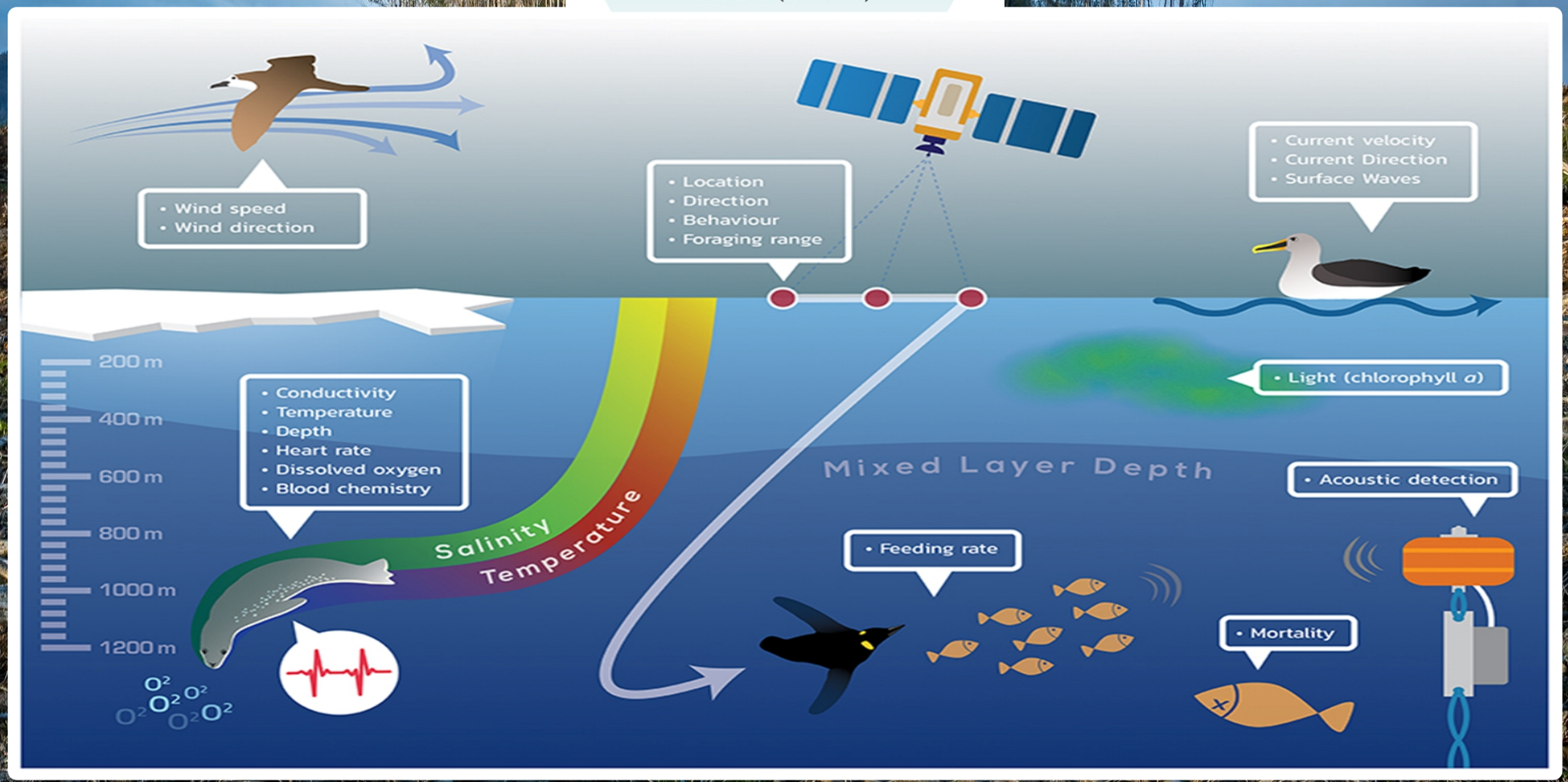
Prof. Sharad Kumar Jain
Ex-Director, NIH Roorkee,
Visiting Professor, IIT Gandhinagar

Urban vulnerability during cyclonic events stems primarily from high-intensity rainfall compounded by inadequate drainage infrastructure. Effective cyclone management begins with pre-event planning, including the design of resilient systems and the upgrading of drainage networks through routine maintenance. Incorporating permeable pavements and large-scale subsurface water storage—similar to Japan's urban flood mitigation models—offers a sustainable solution for managing excess rainfall dumped by a cyclone and repurposing it post-cyclone.

Water infrastructure can be grouped in three distinct categories. First, water storage systems, such as dams, face risks of overflow, bank erosion, and landslides during cyclones. Second, water conveyance systems—canals and pipelines—are vulnerable to flooding, breaches, and structural failure. Third, water treatment facilities, especially sewage treatment plants, experience overwhelming inflows mixed with sediment, often leading to complete operational shutdowns. Weather observation stations play a critical role in identifying these vulnerabilities by improving data acquisition during extreme events.

Reducing exposure requires ecological and structural interventions, including mangrove plantations and embankment reinforcement, which buffer cyclone impacts. Community safety hinges on clear, concise, and instructive communication. Rehearsals and evacuation maps should guide civilians to safe zones without causing unnecessary panic. This approach ensures that disaster preparedness is both technically sound and socially responsive, fostering resilience in densely populated urban landscapes.





(Source: google images)

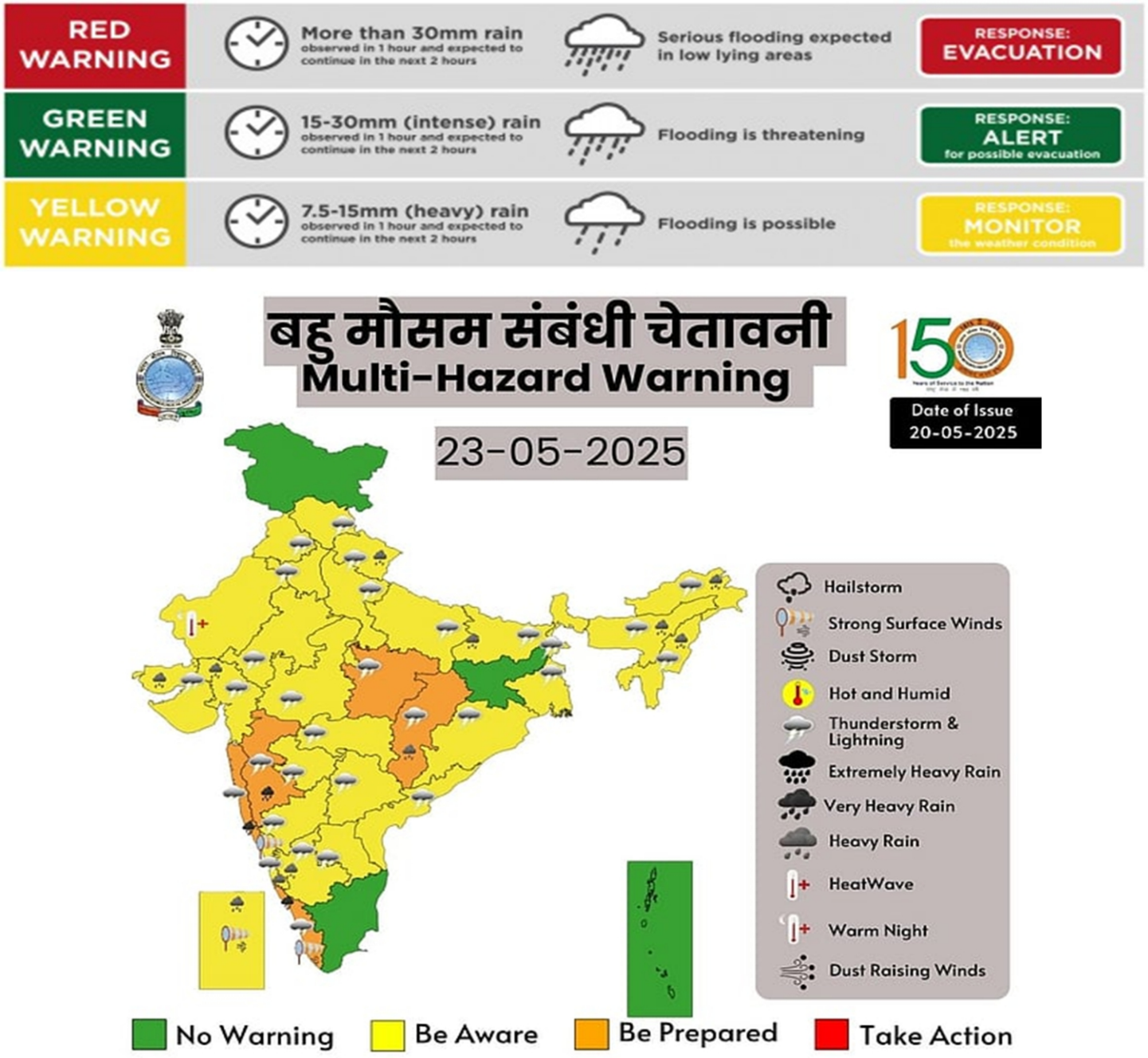


Dr. Raghavendra. Ashrit
Scientist 'G', National Centre for Medium Range Weather Forecasting, Ministry of Earth Science, Noida

Monitoring forms the foundation of cyclone forecasting, beginning with the early detection of cyclogenesis through oceanic observations and remote sensing technologies. Once identified, continuous tracking of cloud formations, ocean dynamics, and heat content enables organized prediction. Radar-based monitoring enhances accuracy, and integrated tracking systems—from cyclogenesis to landfall—significantly strengthen disaster management capabilities at the initial stages.

India's forecasting systems have seen notable advancements over the past two decades. Track forecasts now extend up to five days in advance, with a 15–20% improvement in accuracy for 3–5 day predictions. Intensity forecasts have improved by approximately 30%, reflecting the growing precision of meteorological models. Early evacuation planning, especially within the 3–5 day window, relies heavily on numerical modeling, which offers predictive depth and reliability.

High-performance computing and numerical simulations provide a futuristic edge to forecasting, leveraging high-resolution data and precise datasets for targeted warnings, mitigation strategies, and adaptive planning. The integration of artificial intelligence and modern technologies further enhances forecasting systems, enabling real-time responsiveness and scalable solutions. This evolution in cyclone prediction equips authorities and communities with the tools needed to anticipate, prepare for, and respond to extreme weather events with greater confidence and resilience.



(Source: google images)



Prof. Krishna Kumar Singh
Professor,
NIT Kurukshetra

Flood forecasting in India currently achieves an reliability level of approximately 60–70%, primarily due to the limited availability of high-resolution, real-time datasets—such as rainfall data, river discharge measurements, and soil moisture information, etc. During severe floods, critical water infrastructures predominantly pumping stations, water treatment plants, and distribution networks frequently experience operational interruptions.

Subsequently, water sources may become contaminated due to sewage overflow, runoff, and sediment intrusion. In such emergency situations, distilled water becomes essential to ensure safe drinking water and protect public health. The India Meteorological Department (IMD) color-coded alert system for flood warnings enables communities to quickly understand hazard severity based on simple visual cues. The color-coded alerts help bridging the gap between scientific forecasts and grassroots-level resilience. Extending this intuitive strategy to cyclone forecasting could further strengthen disaster preparedness and community engagement.


DR. AJIT TYAGI
DR. KAMAL LOCHAN MISHRA


DR. KRISHNA KUMAR SINGH










02-day National Workshop
on
ADAPTATION PLANNING FOR INDIA'S WATER
SECTOR UNDER CLIMATE CHANGE
21-22 AUGUST, 2025
Themes
Drought, Flood
GLOF, Landslide
Sea Level Rise








ADAPTATION PLANNING FOR INDIA'S WATER
SECTOR UNDER CLIMATE CHANGE
21-22 AUGUST, 2025



TECHNICAL SESSION 06

ADAPTIVE RESPONSES TO COASTAL FLOODING AND SEA LEVEL RISE







PANELISTS

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Director, NIH Roorkee

Dr. Anupma Sharma
Former Scientist 'G' & Head GWHD, NIH Roorkee

Dr. Pratap Singh
Vice President, RMSI, Noida

Dr. Abhisek Chatterjee
Scientist 'E', INCOIS, Hyderabad

Dr. Deepak Samuel
Scientist 'E', NCSCM, Chennai

MODERATOR

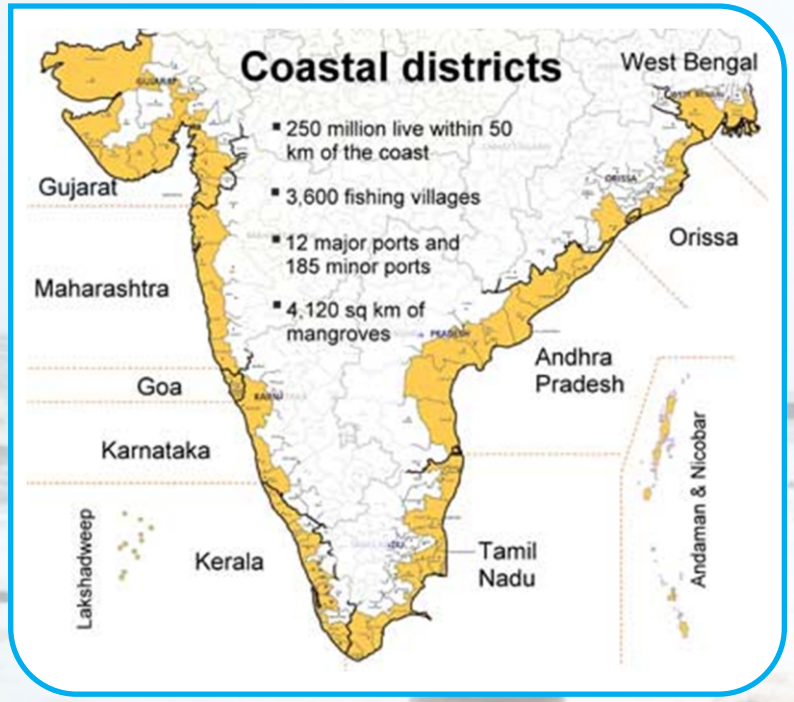
Dr. Gopal Krishan
Scientist 'E' ,
Hydrological Investigations Division, NIH Roorkee

RAPPORTEURS

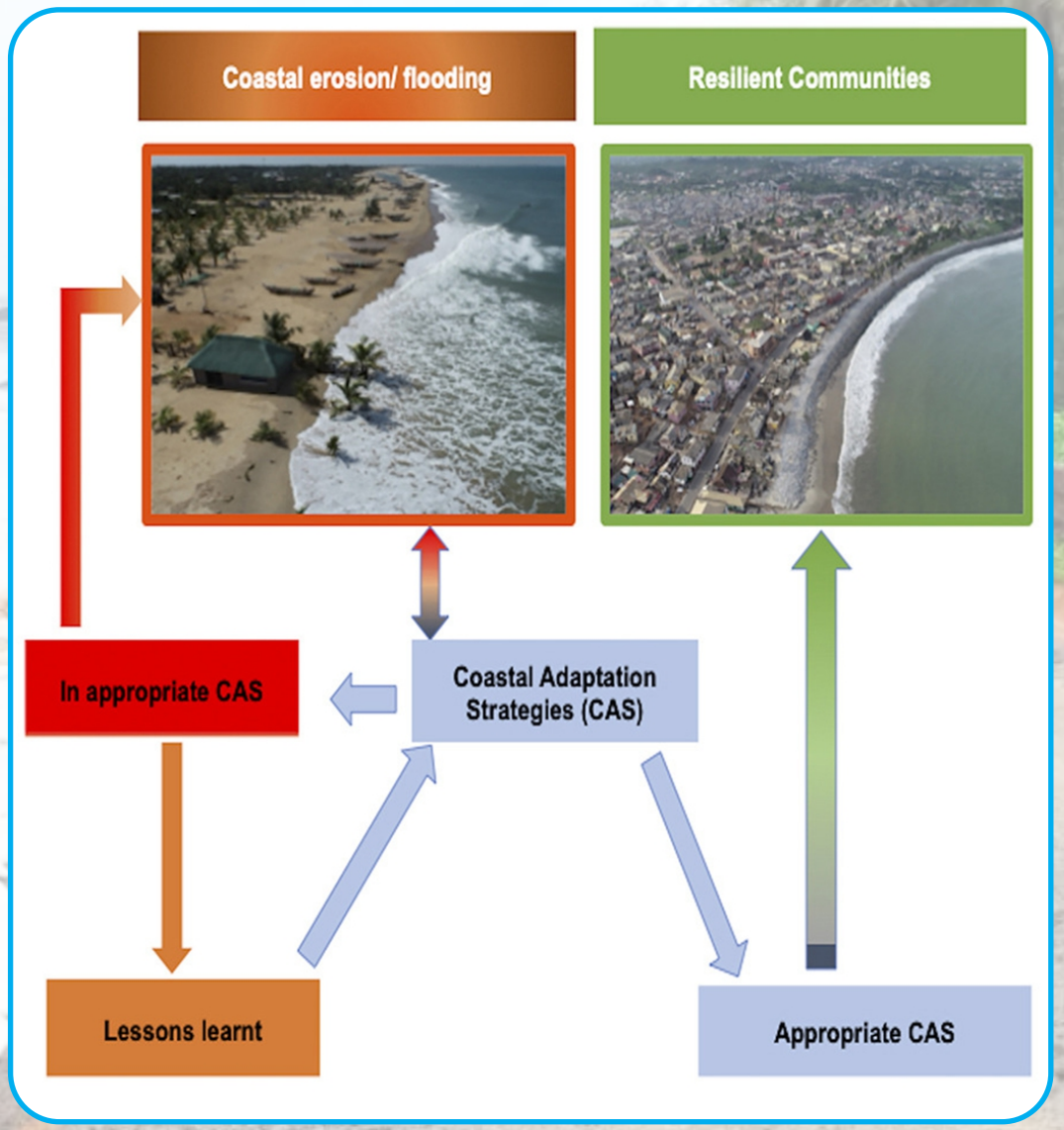
Dr. Lagudu Surinaidu
Scientist 'D', Groundwater Hydrology Division, NIH Roorkee

Dr. Amit Pandey
Scientist 'B', Hydrological Investigations Division, NIH Roorkee









(Source: google images)

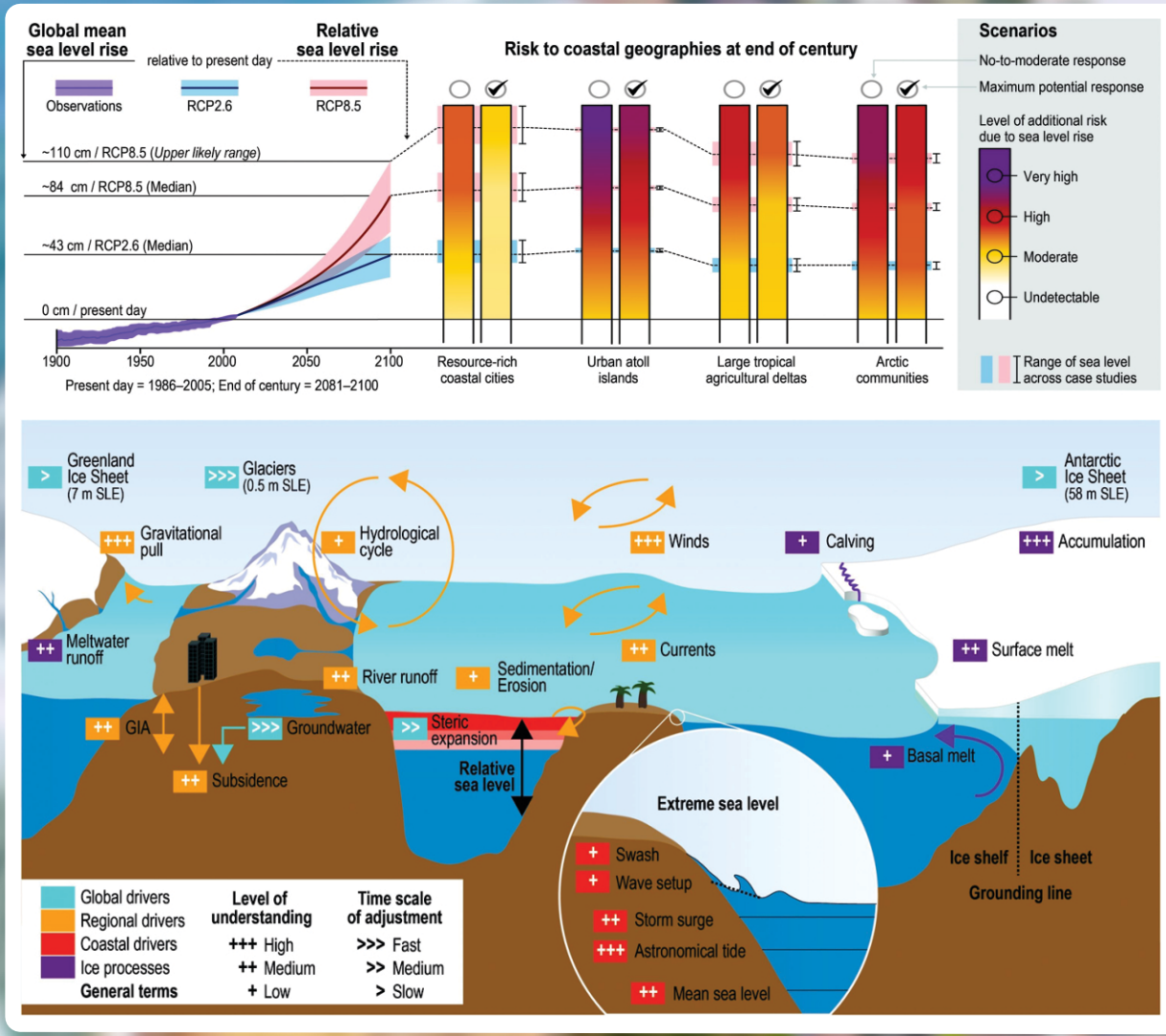


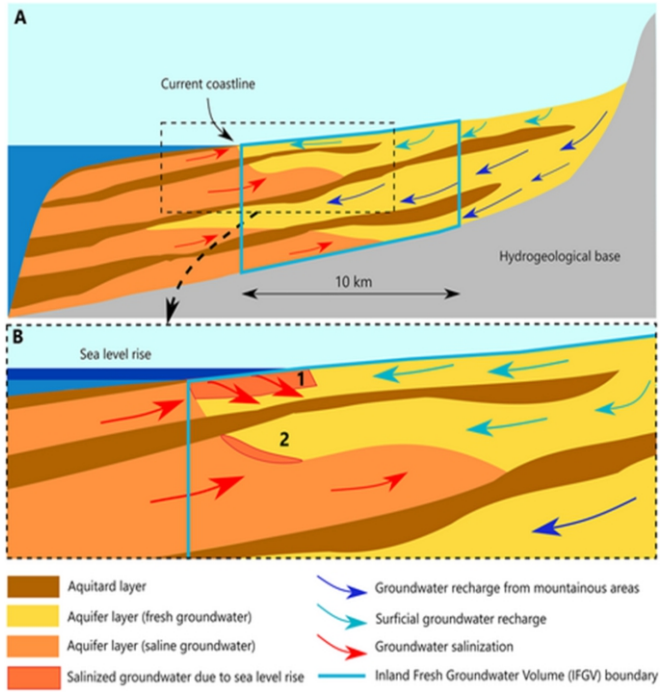
Dr. Gopal Krishan
Scientist 'E' ,
Hydrological Investigations Division, NIH Roorkee

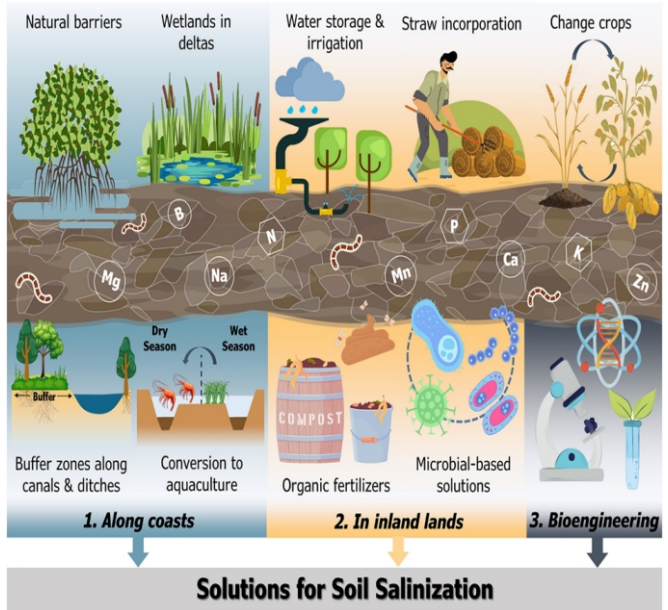
Nearly 30% of the global population resides near coastlines, including 14% of India's population, drawn by favorable living conditions. However, coastal regions face increasing risks due to sea level rise, which in 2023 reached 101.4 mm above the 1993 baseline. This rise contributes to the decline of liquid water availability on land—impacting aquifers, lakes, reservoirs, rivers, and soil moisture. A critical concern is the Ganga river system, where glacial melt threatens over 11,000 rivers with increased flood and erosion risks.

Even under the lowest greenhouse gas emission scenarios, sea level is projected to rise by at least 0.3 meters. In India, a 1-meter rise could inundate approximately 5,673 sq. km of land. Coastal erosion is already severe, with West Bengal experiencing the highest loss (70%), followed by Kerala (65%), Gujarat (60%), and Odisha (50%).

To address these challenges, four climate change adaptation guidelines have been outlined for coastal protection and management: regulatory, intervention-based, advisory, and island/environmental strategies. For coastal salinity ingress, a phased approach is recommended. Short-term strategies (5 years) include vulnerability assessments, pilot shoreline protection projects, and community capacity building. Mid-term strategies (7 years) focus on scaling up salinity mitigation and developing climate-resilient coastal livelihoods. Long-term strategies (10 years) aim to ensure sustainability and resilience of India's coastal zones in response to ongoing sea level rise.







(Source: google images)



Dr. Y.R. Satyaji Rao

Director,
NIH Roorkee

Access to coastal data remains a challenge, though advancements in high-resolution satellite imagery have eased analytical processes. The 2019 IPCC global assessment report highlights the severity of sea level rise—430 mm under the RCP 2.6 scenario and up to 840 mm under RCP 8.5. Communicating such findings to the public is essential for raising awareness about climate change impacts. A collaborative framework is needed to address coastal flooding, involving institutional mechanisms for data sharing, policy harmonization, legal implementation, stakeholder participation, financial coordination, and technological innovation. Adaptation strategies must be tailored to specific regions, zones, and locations, with vulnerability mapping and prioritization guiding implementation.

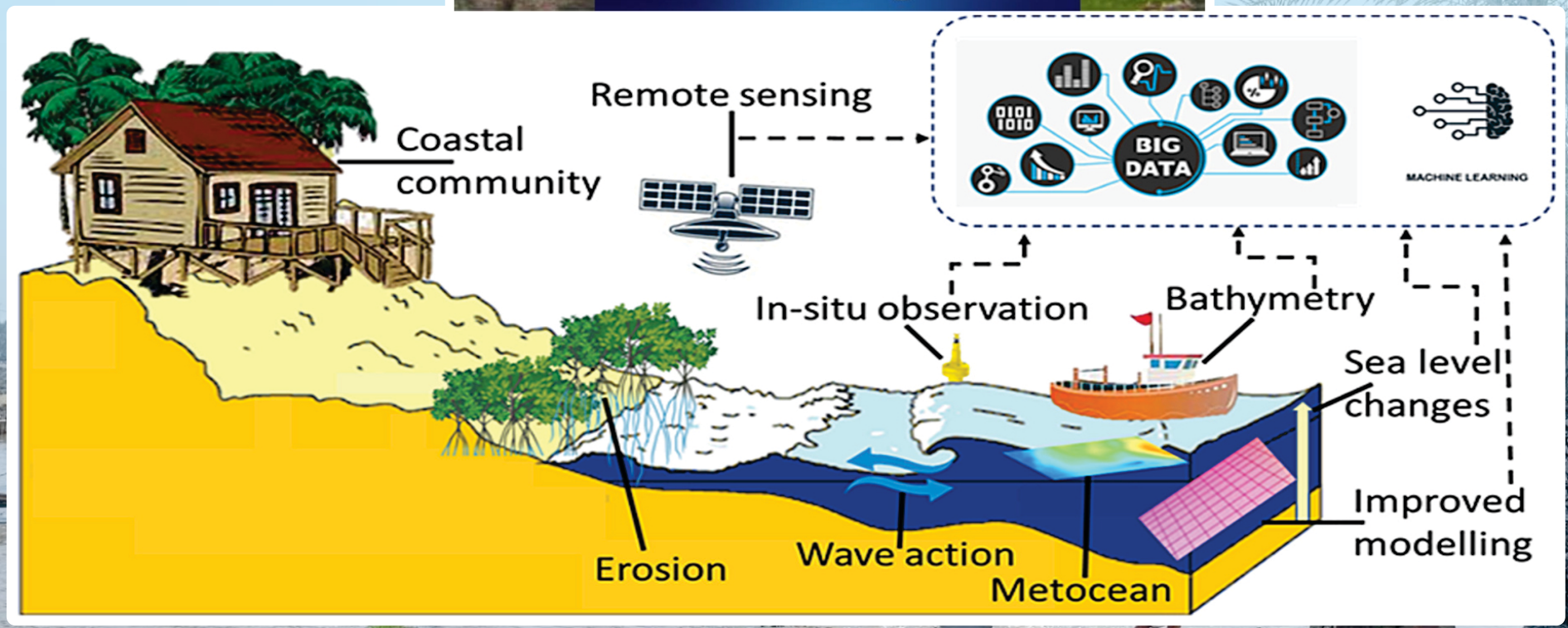
Global studies show that groundwater extraction between 1900 and 2008 contributed approximately 12.6 mm to sea level rise, with 4000 km^3 of water pumped. In the Nile Delta, a 500 mm sea level rise could lead to 9 km of seawater intrusion. Integrating hydrological assessments with sea level rise projections is critical for effective planning.

Observation wells should be installed in coastal regions to monitor ocean dynamics and aquifer vulnerability. Reliable data enables informed decisions and alternative measures based on groundwater pumping trends. In India, implementing adaptation strategies remains difficult due to gaps in zoning and enforcement. For example, aquaculture is practiced in non-designated zones in the Godavari basin, despite the existence of zoning maps.

Innovative tools like sensors capable of distinguishing freshwater and saline water (with a 6 ppt variation) can support detailed mapping and groundwater management. Land use changes—from paddy cultivation to aquaculture—further complicate salinity assessments. Comprehensive mapping must include aquaculture zonation, with emphasis on recirculation and equitable benefits for local communities. Strict laws, incentives, and interdepartmental collaboration are essential for sustainable coastal development.



Bandhara Irrigation



(Source: google images)



Dr. Anupma Sharma

Former Scientist 'G' & Head GWHD,
NIH Roorkee

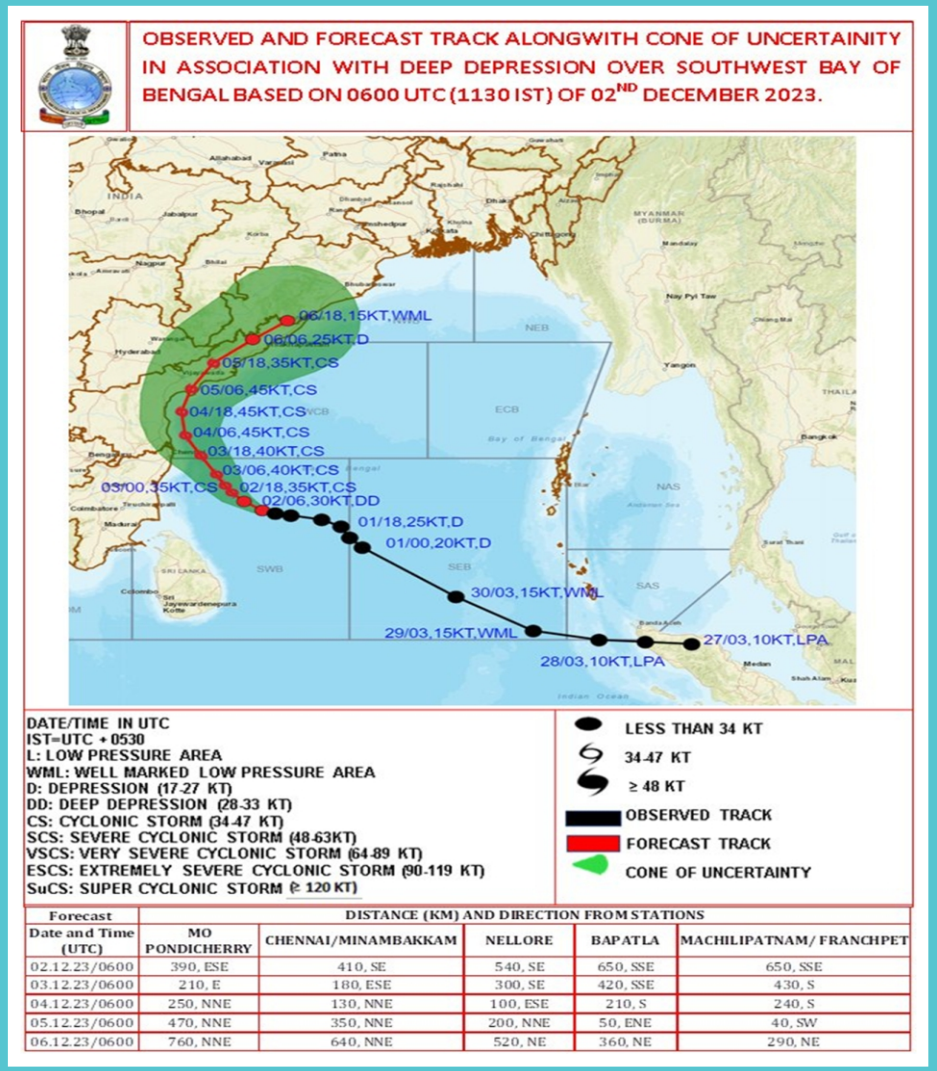
Mapping is essential in coastal regions due to the vast variability in geology and topography, compounded by data scarcity, rapid urbanization, and climate change impacts. Understanding salinity intrusion requires a structured approach—starting with satellite imagery to analyze coastal erosion, morphological changes, and land subsidence. A detailed workflow involves using GIS and remote sensing to integrate geospatial data, followed by field investigations with raw water sampling to assess parameters like EC and TDS, and conducting lab-based validation. Isotope analysis further supports the identification of seawater intrusion in coastal stretches.

Remote sensing and GIS tools are valuable for tracking sea level rise and the encroachment of seawater during high tides. Integrating these datasets into a unified platform using AI, machine learning, and numerical modeling—especially coupling artificial neural networks with simulation models—can enhance predictive mapping and future planning. Citizen-level data collection is vital for improving analysis and ensuring locally grounded adaptation strategies.

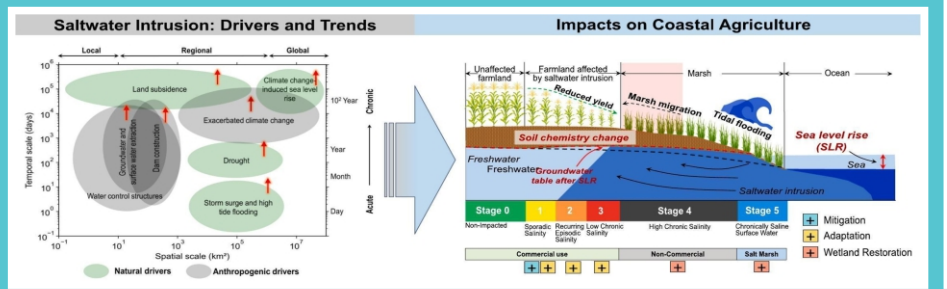
Drawing from field experience in Gujarat, climate-resilient livelihoods can be promoted through salt-tolerant crops, agroforestry, hydroponics, aquaponics, and integrated farming models like those in Sundarbans, where agriculture and pisciculture coexist. Restoration and protection of mangroves are critical, and hybrid approaches combining nature-based solutions with engineered interventions—such as sea walls reinforced with sea grass—can be effective.

The 'Bandhara' system in Gujarat demonstrates how monsoon runoff can be stored in low-lying areas, protected from tidal effects, and used for crop cultivation. Improving local livelihoods requires financial upliftment through self-help groups and digital tools like Android apps to raise awareness among youth about cyclone predictions and preparedness actions.

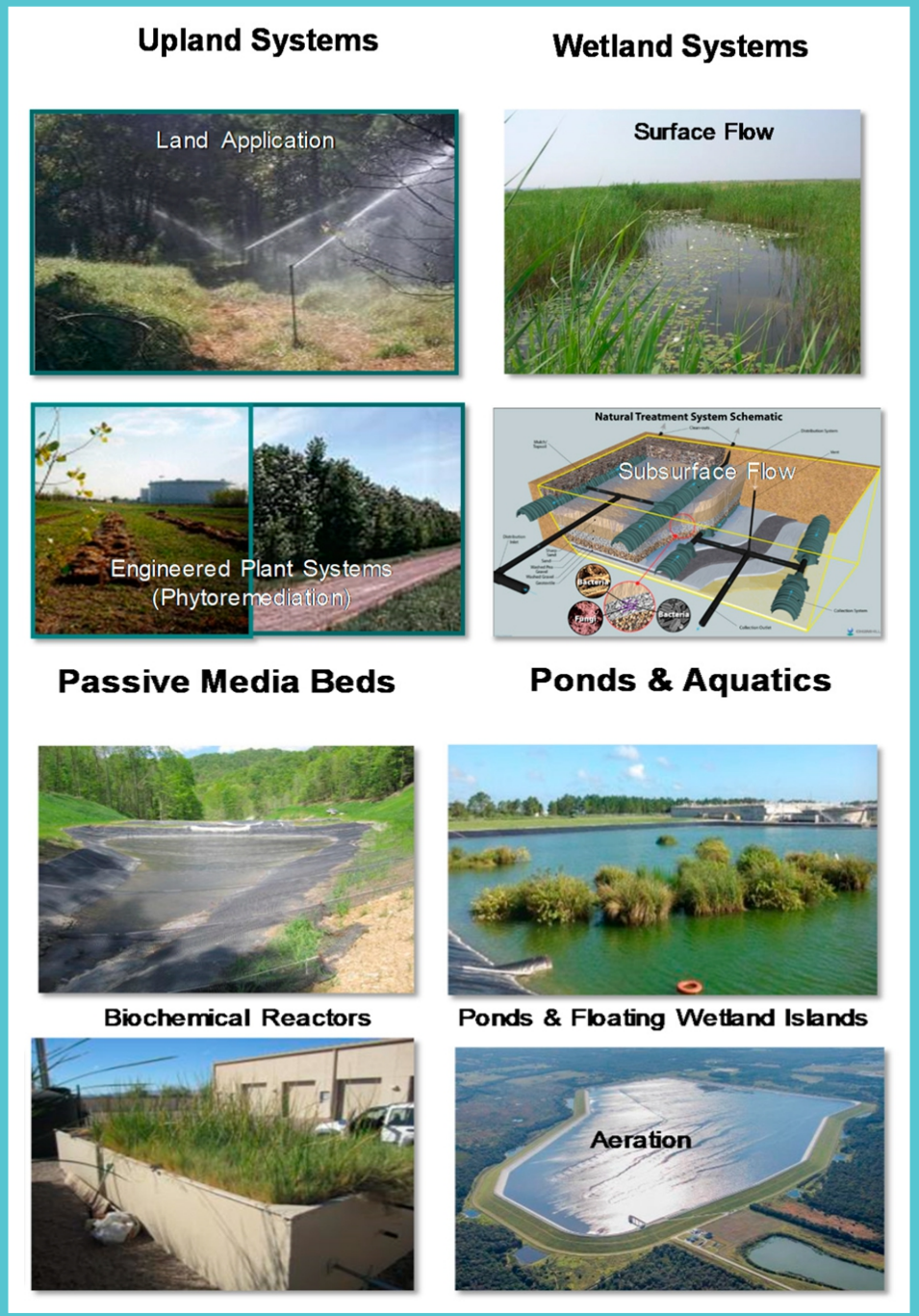
Sea level incline can lead to rising water tables, causing waterlogging and beach overflow. Addressing this requires urban drainage systems, bio-drainage, and upstream interventions like sprinkler and drip irrigation to manage soil salinity. Education on nature-based solutions must be paired with hybrid strategies where needed. Local communities should be engaged with the benefits of mangrove ecosystems, including mangrove-based livelihoods and eco-tourism. Initiatives by forestry departments to expand mangrove cover help mitigate storm surges and prevent saltwater intrusion. Innovative practices like bamboo-based floating farms and spreading channels parallel to coastlines can aid in rainwater recharge and irrigation, supporting sustainable agriculture in vulnerable coastal zones.



Forecast Date and Time (UTC)	DISTANCE (KM) AND DIRECTION FROM STATIONS				
	MO PONDICHERRY	CHENNAI/MINAMBAKKAM	NELLORE	BAPATLA	MACHILIPATNAM/ FRANCHPET
02.12.23/0600	390, ESE	410, SE	540, SE	650, SSE	650, SSE
03.12.23/0600	210, E	180, ESE	300, SE	420, SSE	430, S
04.12.23/0600	250, NNE	130, NNE	100, ESE	210, S	240, S
05.12.23/0600	470, NNE	350, NNE	200, NNE	50, ENE	40, SW
06.12.23/0600	760, NNE	640, NNE	520, NE	360, NE	290, NE



(Source: google images)





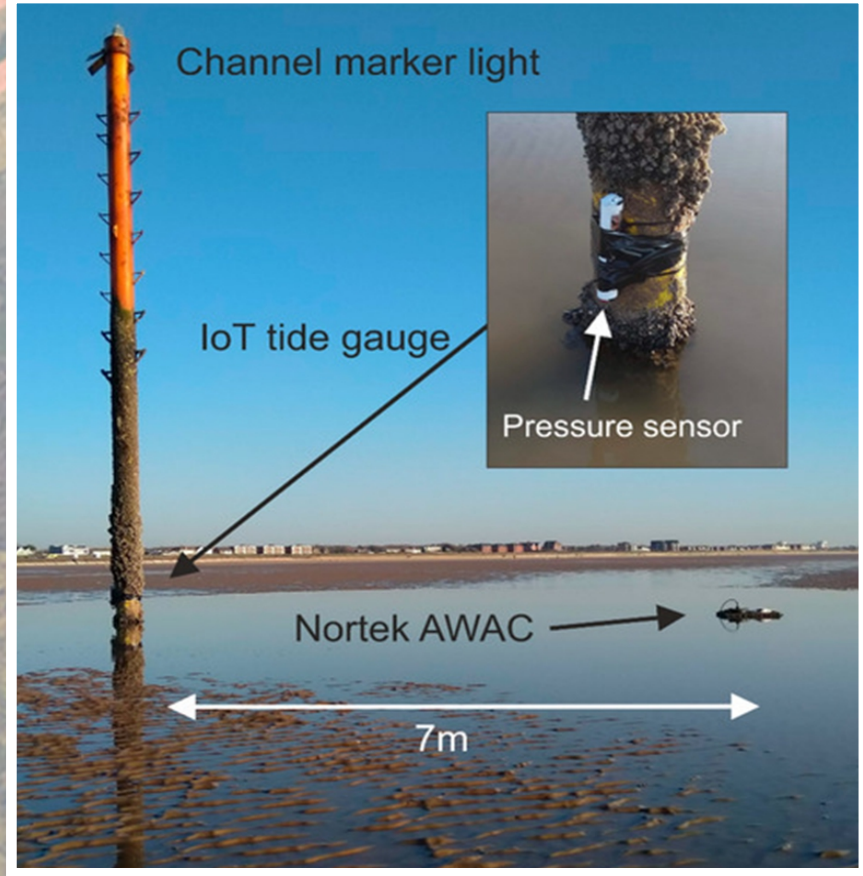
Dr. Pratap Singh
Vice President,
RMSI, Noida

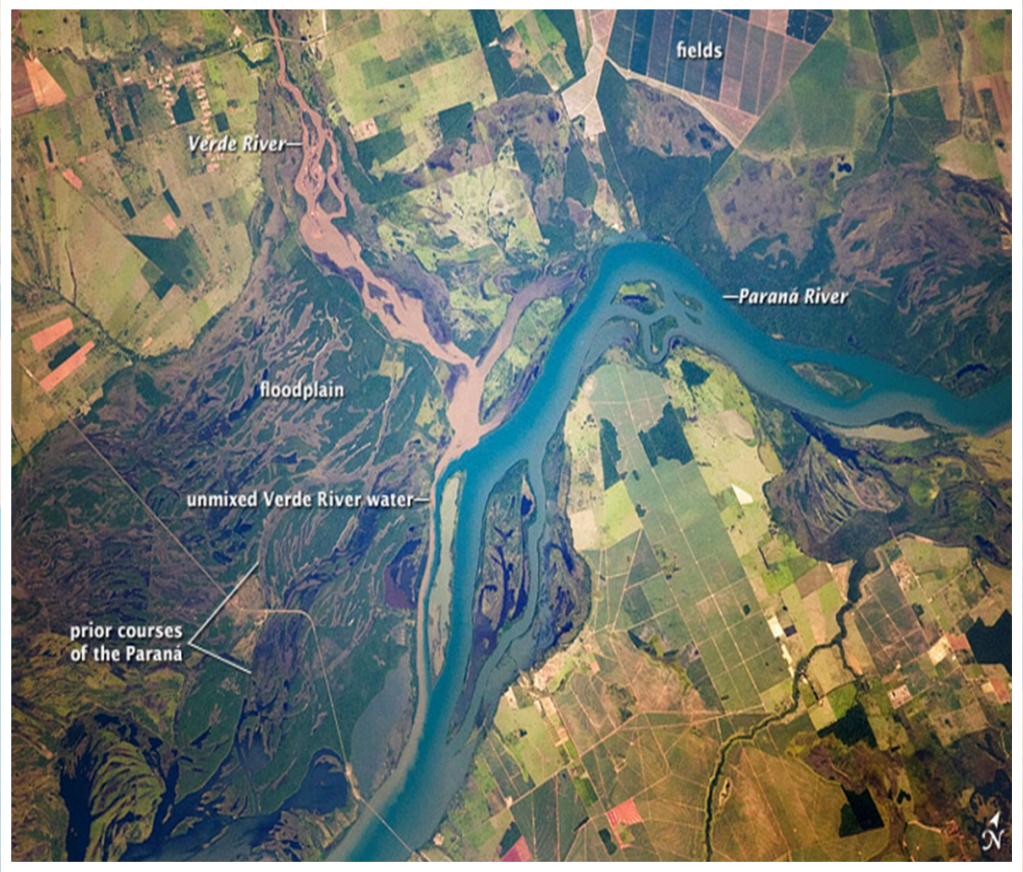
Collaboration between public institutions and private organizations plays a vital role in advancing cyclone forecasting and coastal resilience. RMSI's partnership with IMD, NDMA, and other government bodies exemplifies this synergy. Through this collaboration, RMSI developed a software tool that enabled Govt Departments to track cyclones with high precision and accuracy in forecasting of location and timings of landfall, and expected losses. The integration of IMD's advanced numerical models allowed for comprehensive forecasting of wind speed, direction, and rainfall intensity, demonstrating the power of coordinated efforts across sectors.

Cyclone forecasting has reached a stage where predictions can be made up to 7–10 days in advance. However, forecasting cloudbursts and flash floods remains a major challenge due to their unpredictable nature and rapid onset. Enhancing early warning capabilities for these extreme events requires further innovation in data modelling, real-time monitoring, and localized forecasting systems.

To support coastal restoration, strategies such as surface water preservation and desalination must be prioritized. These approaches not only address freshwater scarcity in coastal zones but also contribute to long-term resilience against salinity intrusion and ecosystem degradation. A holistic coastal management plan should integrate technological forecasting tools with water resource strategies to safeguard vulnerable communities and ecosystems.







(Source: google images)



Dr. Abhisek Chatterjee
Scientist 'E',
INCOIS, Hyderabad

Solutions to climate-induced coastal challenges must be region-specific, as the nature of vulnerability varies widely. For instance, Kerala's coastal erosion is largely shaped by shifting wave patterns and Kallakkadal flash floods, whereas in the Sundarbans, rising sea levels and land sinking—driven mainly by natural land subsidence rather than human-induced warming—are the dominant factors. Addressing these issues requires a structured approach: first, identify climate risks for each location; then conduct robust coastal assessments to reduce uncertainty and build confidence; and finally, tailor solutions to match the specific vulnerabilities.

The process begins with hotspot identification, followed by detailed climate risk analysis and implementation of targeted strategies. These efforts must be supported by continuous monitoring and integration across institutions. Expanding the tide gauge network is critical, with plans to include 15 mainland stations in the GNSS system to track subsidence and improve data accuracy.

Assessment of past interventions should incorporate all scientific components of sea level rise—oceanic dynamics, cryosphere changes, thermal expansion, glacier melt, and ice sheet loss. A more refined understanding of coastal vulnerability is needed, alongside improvements in socio-economic data, rural flood mapping, urban planning, and drainage infrastructure.

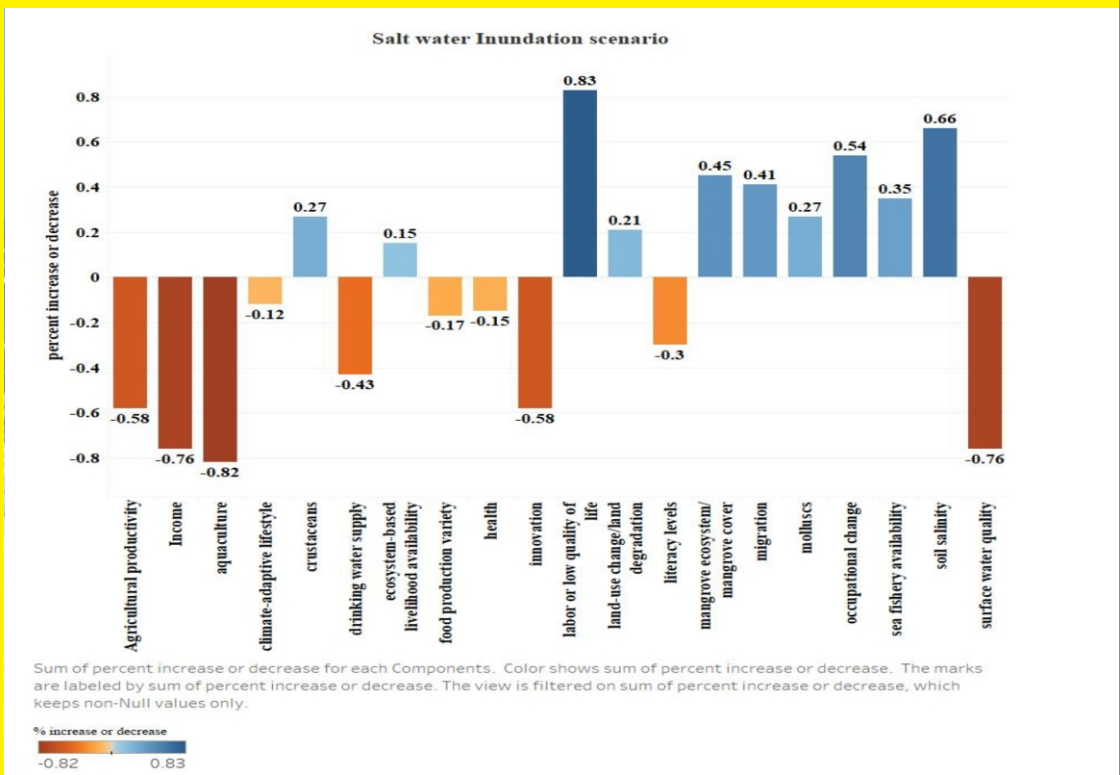
The National Adaptation Policy (NAP) offers a valuable platform for collaboration among experts and stakeholders. Future projects should adopt a centralized, top-down approach, integrating diverse components and expertise from multiple ministries across India to ensure cohesive and effective climate resilience planning.






MISHTI Scheme for Mangrove Plantations


(Source: google images)


Salt water Inundation scenario
percent increase or decrease
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.58
-0.76
-0.82
-0.12
0.27
-0.43
0.15
-0.17
-0.15
-0.58
0.83
0.21
-0.3
0.45
0.41
0.27
0.54
0.35
0.66
-0.76
Agricultural productivity
Income
aquaculture
climate-adaptive lifestyle
crustaceans
drinking water supply
ecosystem-based livelihood availability
food production variety
health
innovation
labor or low quality of life
land-use change/land degradation
literacy levels
mangrove ecosystem/ mangrove cover
migration
molluscs
occupational change
sea fishery availability
soil salinity
surface water quality
Sum of percent increase or decrease for each Components. Color shows sum of percent increase or decrease. The marks are labeled by sum of percent increase or decrease. The view is filtered on sum of percent increase or decrease, which keeps non-Null values only.
% increase or decrease
-0.82
0.83



Dr. Deepak Samuel
Scientist 'E';
NCSCM, Chennai

Hazard lines have been mapped across India, but they remain non-regulatory, with improved management introduced post the 2011 notification. To strengthen coastal resilience, MoEFCC is executing a GCF-UNDP project *Enhancing Coastal Community Resilience to Climate Change* across 24 target landscapes where NCSCM is undertaking the Coastal Vulnerability Index (CVI). This initiative aims to develop a Coastal Vulnerability Index by assessing physical, ecological, and social vulnerabilities. However, gaps persist in accessing detailed data on vulnerable communities and age groups, which limits targeted planning.

High-resolution, technology-driven analyses using GIS and remote sensing are being employed to map coastal vulnerability. The warning is clear: coastal zones are advancing toward heightened climate risks and require urgent attention. Adaptation planning must consider the economic realities of coastal populations, especially low-income fishermen, whose deep connection to their occupation makes livelihood transitions difficult.

National missions such as *Mission MISHTI* are underway to restore mangrove ecosystems, aiming to expand mangrove cover by 540 km² over five years while supporting local livelihoods. Community awareness remains limited, underscoring the need for an integrated approach involving experts, stakeholders, ministries, and local actors to design and implement effective adaptation strategies.

Soft engineering solutions—such as vegetative buffers and dune restoration—are primarily recommended by the Supreme Court and widely used for coastal protection. However, in certain contexts, hard structures like seawalls and embankments, when designed with sound engineering and environmental safeguards, may be necessary. A balanced, inclusive, and region-specific approach is essential to safeguard India's coastal communities against the growing threats of climate change.




Adaptive Responses to Coastal Flooding and Sea Level Rise
DR. DEEPAK SAMUEL
DR. PRATAP SINGH
DR. YRS RAO


DR. YRS RAO


02-day National Workshop
on
21-22 AUGUST, 2025


Adaptive Responses to Coastal Flooding and Sea Level Rise


DR. ANUPMA SHARMA


Adaptive Responses to Coastal Flooding and Sea Level Rise
DR. DEEPAK SAMUEL
DR. PRATAP SINGH


Sea Level Rise











TECHNICAL SESSION 07



MAINSTREAMING GENDER EQUALITY, DISABILITY AND SOCIAL INCLUSION (GEDSI) IN WATER SECTOR ADAPTATION





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(Photo Courtsey: Dr. Pradeep Mehta, UNDP)



Dr. Pradeep Mehta
State Program Lead UNDP,
Dehradun

India's diverse ecosystems are increasingly impacted by climate change, with the Himalayan region facing the most severe consequences. Adaptation strategies must be tailored to specific regions, as vulnerability and response capacity vary widely across locations. Historical shifts in agriculture underscore this reality—apple cultivation, once thriving in Ramgarh Valley and Nainital, has now vanished due to changing climatic conditions. Even lower regions like Bhuntar in Kullu can no longer support apple farming. Simultaneously, natural water sources such as springs, Naula/s, and ponds are in decline, exacerbating water stress in mountainous areas.

Gender disparities in water access remain stark, particularly in rural Himalayan communities. Women and children often walk 400–500 meters or more to fetch water, constrained by inadequate supply systems and a reluctance to use unfamiliar potable sources. Climate-induced migration further compounds this vulnerability. Male migration to cities leaves women behind in rural areas, increasing their exposure to climate extremes. Conversely, disasters like the Dharali incident have shown that male workers in mountainous zones are also at high risk. Moreover, the construction of permanent 'pakka' houses in fragile Himalayan terrain increases susceptibility to climate impacts due to poor alignment with local environmental conditions.

Rural communities, despite having the lowest carbon footprint, bear the brunt of climate impacts. They must be empowered as custodians of natural resources, especially water, while urban and commercial sectors often resort to borrowing water during crises. Poor water governance—marked by groundwater over-extraction and encroachment of lakes in cities—has worsened the situation.

Traditional and indigenous practices offer valuable solutions. Concepts like "Jaldevi" and "Dev Van" (Sacred Grove)reflect how faith-based conservation can succeed where formal regulations falter. These cultural frameworks should be integrated into the National Adaptation Plan (NAP) to enhance local engagement and sustainability. Finally, inclusive governance is essential. Gender-sensitive approaches must be embedded in capacity development, policymaking, and implementation. Both men and women should be actively involved in shaping climate resilience strategies to ensure equitable and effective outcomes.





(Source: google images)



Dr. Vinod Kothari

Executive Director,
Himmothan Society (Tata Trust), Dehradun

Women are the primary custodians of household water across India, especially in the Himalayan region. Despite widespread "tapification" initiatives, many households continue to face water scarcity during lean seasons, as tap infrastructure often lacks reliable and sustained supply. In mountainous states like Uttarakhand, nearly 96% of water sources are spring-fed, making the protection and sustainable management of springs a critical priority.

To strengthen water systems in these ecologically sensitive regions, Public-Private Partnership (PPP) models must be evaluated through an incentive-based lens—focusing on capacity building, operational sustainability, and long-term maintenance. While policy provisions exist, implementation challenges persist, particularly in distribution mechanisms and structural resilience. Communities living near waterbodies should be entrusted with their stewardship, and government programs must include financial and institutional incentives to support these local custodians.

Guidelines mandating 50% inclusion of women and persons with disabilities in water governance structures are already in place. However, operational and maintenance gaps—especially in rural areas—limit their effectiveness. Panchayats must take proactive steps to enforce these guidelines and ensure meaningful participation in planning and implementation.

All interventions must be framed through a climate lens, with region-specific strategies tailored to local vulnerabilities, hydrological conditions, and resource dynamics. Knowledge-sharing, incentivization, and integrated monitoring mechanisms are essential to build resilient water governance frameworks. These efforts should be embedded across a phased strategy:-

Short-term: Focus on seasonal planning, immediate infrastructure support, and awareness-building.

Mid-term: Invest in capacity building, community-led monitoring, and institutional strengthening.

Long-term: Pursue structural reforms, climate adaptation, and ecosystem restoration.

By aligning these actions with climate-sensitive and inclusive approaches, sustainable water security in mountainous regions can be achieved.



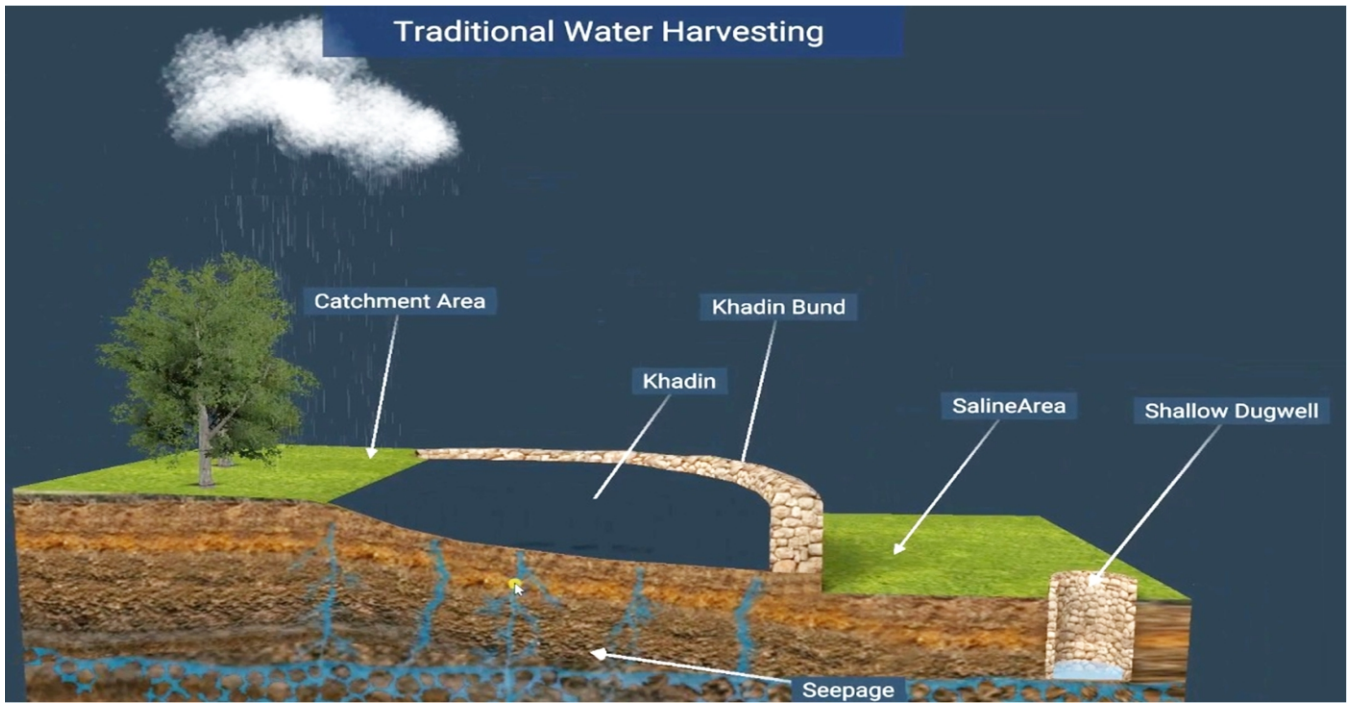














(Source: google images)



Dr. Archana Sarkar

Scientist 'F',
NIH Roorkee

Adaptation support must be tailored to the unique needs of climate-resilient programs, especially in vulnerable regions. Natural infrastructures—such as water harvesting systems and soil conservation structures—play a critical role in enhancing land capacity to absorb climate shocks. In 2019, the Government of India launched Jal Shakti Abhiyan to raise groundwater levels in over-exploited and stressed districts, marking a significant step toward water security.

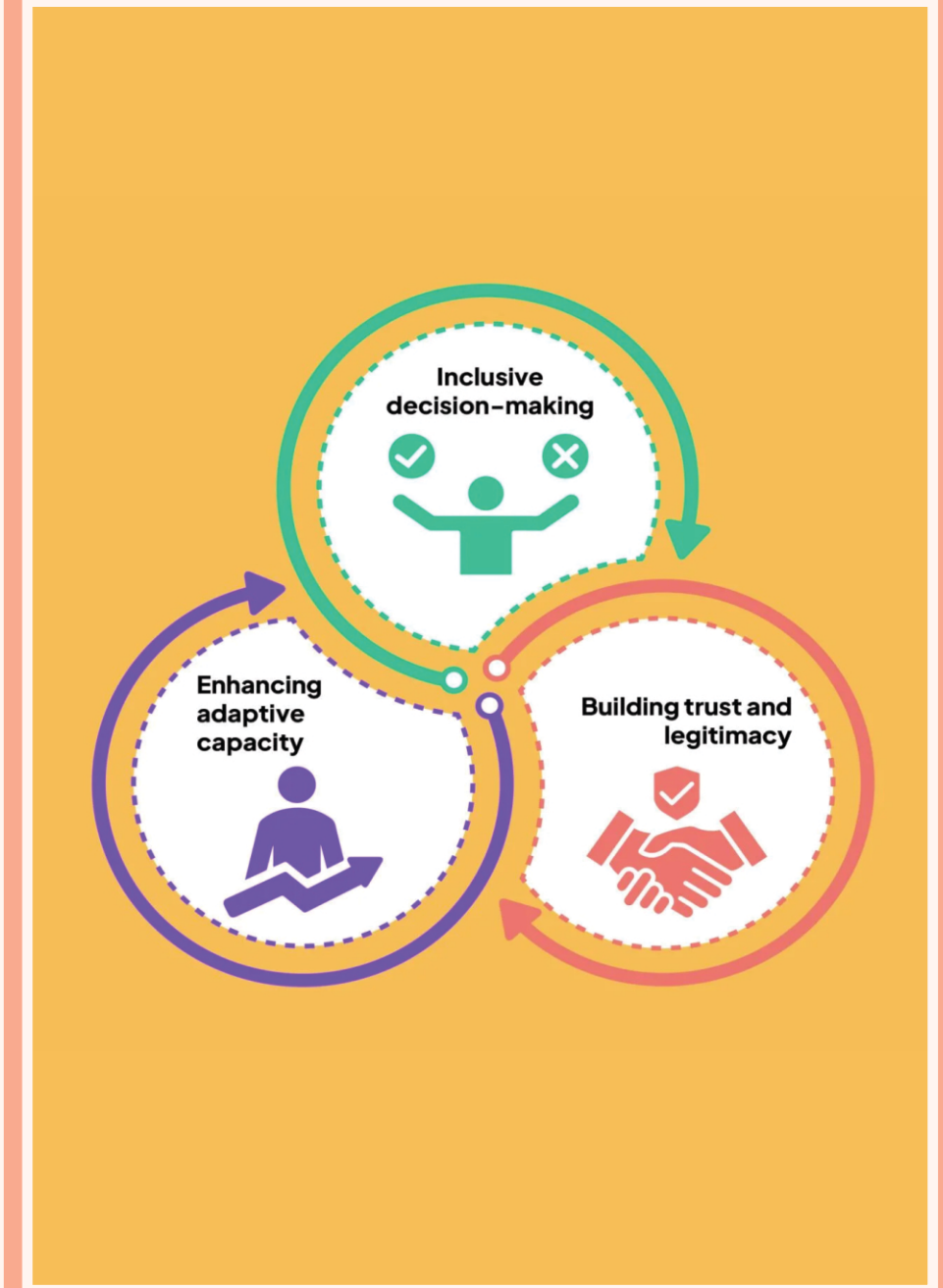
Technological integration is also advancing climate adaptation. The International Institute for Environment & Development supported the use of climate-based rules and weather-responsive tools for MGNREGA via web and mobile platforms, enabling scientific data to guide rural employment schemes. Livelihood missions further strengthen resilience by promoting self-employment and skill development through Self-Help Groups (SHGs). Notable examples include SWAYAM SHIKSHA PROYOG, a women-led initiative for clean energy and climate-resilient farming recognized at COP Egypt, and SEWA, a pioneering SHG empowering poor women across India.

While flagship schemes like Jal Jeevan Mission (JJM) and Swachh Bharat Mission (SBM) address water and sanitation, gaps remain in integrating GEDSI (Gender Equality, Disability, and Social Inclusion) principles. Inclusive indicators must be embedded in these programs—such as reducing the burden of water connections, improving toilet safety and hygiene in schools, and preventing dropout among adolescent girls. Infrastructure standards should reflect universal design principles, as disability-inclusive WASH facilities are still lacking globally.

Monitoring GEDSI participation in planning and decision-making is essential. Indicators must be added to the evaluation frameworks of JJM and SBM to track inclusivity. Establishing grievance redressal systems for women, persons with disabilities, and socially marginalized groups is vital, with the number of complaints itself serving as a valuable indicator of systemic gaps.

Community empowerment through inclusive technologies must be prioritized. The example of a disabled individual who, after completing his duties, educated the community underscores the transformative potential of inclusive participation. Promoting such leadership and integrating modern tools to support physically-abled individuals can strengthen climate resilience and foster social equity.





(Source: google images)



Dr. Debashish Sen

Director,
People's Science Institute, Dehradun

Climate change affects individuals differently across age and gender. Children, women, disabled and the elderly often facing the greatest risks. Adaptation strategies must therefore be age and gender sensitive and inclusive, ensuring that no demographic is left behind in resilience planning. Central to this approach is the empowerment of vulnerable communities through ownership and leadership. This begins with participatory processes that allow communities to define their own sustainability criteria, engage in dialogue about how climate change impacts their resources and livelihoods, and co-develop locally grounded adaptation strategies.

Capacity building is a critical next step, enabling these communities to actively participate in decision-making processes and ensuring that dedicated funding supports their initiatives. Effective capacity development must consider the needs of three key stakeholder groups: policy/decision makers, extension workers (from both government and non-government sectors), and the communities themselves. Planning should reflect the priorities of all stakeholders, with a strong emphasis on GEDSI (Gender Equality, Disability, and Social Inclusion). Participatory methods are essential to uncover gender disparities, collect disaggregated data, and design inclusive adaptation mechanisms. Addressing social biases and resolving community-level conflicts are integral to this process.

Community-based monitoring strengthens self-evaluation and accountability, transforming communities into active agents of resilience. This localized approach enhances governance and ensures that adaptation efforts remain responsive, inclusive, and sustainable.

From a strategic perspective, a phased approach is recommended. In the short term, efforts should focus on building a low-carbon, adaptable society that is sensitive to GEDSI components, supported by early warning systems and disaster preparedness. Medium-term priorities include developing climate-resilient infrastructure and ecosystems, promoting sustainable lifestyles, and creating green jobs. Long-term strategies must institutionalize inclusive governance through robust capacity-building frameworks, availability of disaggregated GEDSI data, inclusive representation in decision-making bodies, dedicated funding streams, and comprehensive monitoring and evaluation systems. These interconnected actions form the foundation for equitable, climate-resilient development.









(Source: google images)



Dr. Diptimayee Nayak
Associate Professor,
IIT Roorkee

Water insecurity must be addressed through a multidimensional lens that reflects the lived realities of vulnerable populations. It manifests in three interconnected forms: first, water insecurity related to WASH (Water, Sanitation, and Hygiene), which disproportionately affects women and girls—particularly adolescent girls who face heightened vulnerability during puberty and often drop out of school due to inadequate sanitation facilities. Despite women being the primary providers of water in households, their needs are frequently overlooked. Second, water insecurity arises in broader domestic and community settings, where access, quality, and reliability of water remain inconsistent. Third, it extends to social situations such as displacement, migration, and marginalization, where water access becomes even more precarious.

To respond effectively, micro-level disaggregated data—capturing gender, disability, and social inclusion dimensions—must be systematically aligned with policy frameworks. Bridging the gap between granular field realities and macro-level decision-making is essential for inclusive water governance. A robust data strategy should integrate qualitative insights with quantitative metrics, using participatory methods such as community engagement and stakeholder consultations to gather fine-scale, ground-level data. Age-specific data collection adds further precision, ensuring that interventions are tailored to the needs of different demographic groups.

Machine learning and big data analytics offer powerful tools to enhance the granularity, accessibility, and responsiveness of disaggregated datasets. These technologies enable real-time decision-making and targeted responses during crises, forming the backbone of evidence-based, inclusive water security planning.

To operationalize these insights, a phased strategy is recommended. In the short term, institutions and mechanisms must be revisited, rethought, and re-established—addressing local barriers through education and awareness, and challenging entrenched social norms. In the mid-term, monitoring systems should be strengthened to ensure accountability and adaptive learning. Long-term strategies must focus on financial and institutional sustainability, integrated monitoring frameworks, and inclusive budgeting practices. The Gender Budget introduced by the Uttarakhand Government serves as a promising example of embedding equity into water sector planning. Together, these measures lay the foundation for a resilient, inclusive, and just water future.





(Source: google images)



Dr. Suparana Katyaini
Programme Lead,
CEEW, New Delhi

Identifying the most vulnerable communities—particularly women with disabilities and socially disadvantaged groups such as SC and ST populations—is essential for inclusive climate adaptation and water governance. Many systemic gaps stem from an incomplete understanding of GEDSI (Gender Equality, Disability, and Social Inclusion), often shaped by unconscious biases and language choices. For instance, while "disabled" is an accepted term in UN frameworks, "differently-abled" is discouraged, as it implies that everyone is differently abled, diluting the specific challenges faced by persons with disabilities.

Representation must go beyond tokenism. A five-level framework was outlined to ensure meaningful GEDSI participation: active involvement in committees and planning processes; enabling participation within feasible timeframes and environments; recognizing diverse capacities across individuals and communities; amplifying voices; and fostering inclusive decision-making. These sensitive and complex challenges must be acknowledged and addressed through deliberate, empathetic strategies.

Climate change and gender are cross-cutting issues that cannot be siloed within a single department. Inter-departmental coordination is crucial for effective governance. Building trust and accountability in GEDSI processes requires long-term vision, adaptability, and inclusive structures. Examples from Rajasthan's water sector illustrate successful integration—linking water, agriculture, and women & child development to mainstream gender in irrigation and climate-resilient livelihoods. Initiatives like Dampati training in micro-irrigation promote gender equality through joint participation.

GEDSI must be embedded across all stages of program design and implementation—Vision, Mission, Review, and Reporting. Legislative reforms have already enabled greater inclusion of women in Water Users Associations. Further, local governance bodies such as panchayats and district offices should adopt automated tools and apparatus to support physically challenged individuals in their operations, ensuring accessibility and dignity in public service delivery.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21-22 AUGUST, 2025


Thank you
India's Water Sector
Under Climate Change


Integrated Strategies for Flood Risk Reduction and Adaptive Water Governance
Adaptation Planning for India's Water Sector Under Climate Change




Thank you

















KEY RECOMMENDATIONS

KEY RECOMMENDATIONS

- It is recommended that flood risk management shift from fragmented, event-based responses to integrated, basin-scale and floodplain-based planning frameworks.
- Evidence indicates that flood adaptation must combine structural measures, nature-based solutions, traditional knowledge, and modern engineering rather than relying on stand-alone interventions.
- Floodplain zoning should be institutionalized through enforceable legal frameworks, supported by community participation, transparent risk classification, and penalty-based compliance mechanisms.
- Urban flood resilience must prioritize hierarchical drainage design, protection of natural drainage pathways, and re-evaluation of building codes to reflect hydrologic realities and climate change scenarios.
- It is essential to establish interoperable, cloud-based data systems and high-resolution topographic datasets to enable evidence-driven flood risk assessment and implementation.
- Public–private–community partnerships should be promoted to finance, operate, and maintain flood protection infrastructure, with incentives for private engagement in high-risk areas.
- Flood forecasting and early warning systems should be strengthened using advanced modelling, AI/ML tools, and last-mile communication mechanisms.
- Government schemes should be systematically aligned to support flood adaptation, insurance mechanisms, livelihood protection, and ecosystem-based interventions.

KEY RECOMMENDATIONS

- Drought management must transition from crisis response to proactive, long-term risk management anchored in monitoring, planning, and behavioral change.
- Village-scale, multi-year adaptation pilots should be prioritized to demonstrate the effectiveness of water-efficient technologies and climate-resilient agricultural practices.
- Automated weather and hydrological monitoring, coupled with micro-irrigation, conjunctive water use, and groundwater recharge strategies, should be scaled up nationwide.
- Economic instruments, including flow metering and rational water pricing, are necessary to incentivize efficient water use.
- PPP models should be developed to support innovation, long-term maintenance, and deployment of drought-resilient technologies, including water reuse and water farming approaches.
- Centralized drought data platforms and unified early warning systems are required to support coordinated decision-making.
- Adaptation efforts must be aligned with agricultural, livelihood, and post-harvest infrastructure schemes to enhance drought resilience beyond crop production.
- Short-, medium-, and long-term roadmaps should guide early warning deployment, infrastructure development, groundwater governance, and future drought risk projection.

KEY RECOMMENDATIONS

- Continuous monitoring of glaciers and glacial lakes using integrated ground-based, airborne, and satellite technologies is a critical adaptation priority.
- Vulnerable glacial lakes should be systematically identified and prioritized based on hazard potential, exposure, and downstream socio-economic vulnerability.
- Community-based preparedness, integrating indigenous knowledge with scientific risk assessment, must be strengthened through training, mock drills, and awareness programs.
- Engineering interventions such as controlled spillways, moraine stabilization, and downstream protection measures should be implemented for high-risk lakes.
- Multi-hazard early warning systems integrating meteorological, hydrological, and seismological inputs must be operationalized with robust communication protocols.
- Dedicated governance mechanisms are required to coordinate cryosphere monitoring, data sharing, and cross-border collaboration regarding cryosphere-related hazards.
- PPP frameworks should support sensor development, infrastructure maintenance, research innovation, and risk transfer mechanisms.
- A phased roadmap is required to establish monitoring networks, scale interventions, and institutionalize long-term Himalayan cryosphere governance.

KEY RECOMMENDATIONS

- Strengthening rainfall, soil moisture, and slope monitoring networks is essential for effective landslide early warning.
- Community-based monitoring and reporting systems should complement technical surveillance to enhance local preparedness.
- State-level rapid response teams must be institutionalized, trained, and equipped to operate in difficult and high-altitude terrains.
- Land-use regulations should be strictly enforced based on geotechnical assessments and periodically updated to reflect evolving climate and demographic pressures.
- Advanced modelling approaches integrating remote sensing, hydrological processes, and AI/ML techniques should be adopted to improve hazard prediction.
- High-resolution weather forecasting must be systematically integrated with hydrological and slope stability models.
- Disaster management strategies should prioritize preparedness, public education, and community capacity building over post-event relief.

KEY RECOMMENDATIONS

- Cyclone risk management must be anchored in impact-based forecasting that integrates advanced numerical models, AI/ML tools, and sector-specific advisories.
- Climate projections, including sea-level rise and rainfall intensification, should be embedded within infrastructure design standards.
- Cyclone-resilient water supply, sanitation, drainage, and power systems must be prioritized to ensure continuity of critical services.
- Nature-based solutions, such as mangrove restoration, should be integrated with engineered structures to enhance coastal resilience.
- Smart sensors, IoT systems, and modular emergency water supply solutions should be deployed to support real-time monitoring and post-cyclone recovery.
- Clearly defined PPP roles are essential to leverage private sector capacity while ensuring public oversight, validation, and emergency response.
- Unified communication frameworks and integrated command centres should be institutionalized to ensure consistent, reliable, and panic-free information dissemination.
- Phased roadmaps should guide forecasting upgrades, infrastructure strengthening, and long-term ecosystem restoration.

TECHNICAL SESSION 06

Adaptive Responses to Coastal Flooding and Sea-Level Rise

KEY RECOMMENDATIONS

- Coastal adaptation strategies are urgently required to address population exposure, salinity intrusion, erosion, and health risks associated with sea-level rise.
- Integrated monitoring systems combining satellite data and field observations should inform region-specific risk and vulnerability assessments.
- Hybrid adaptation approaches combining nature-based and engineered measures should be adopted to manage coastal flooding and salinity.
- Community participation and citizen science must be embedded in implementation strategies to ensure local ownership and sustainability.
- PPP models should support desalination, wastewater reuse, eco-tourism, and technology deployment for coastal resilience.
- Governance frameworks must integrate coastal projects across administrative scales and strengthen coordination between water, health, and disaster agencies.
- Adaptation initiatives should align with national coastal risk mitigation programs and climate action plans.
- Time-bound roadmaps should guide resilient agriculture, livelihood diversification, ecosystem restoration, and long-term coastal protection.

KEY RECOMMENDATIONS

- Climate adaptation planning must systematically integrate GEDSI considerations to address differentiated vulnerabilities, workloads, and access inequities.
- Disaggregated, micro-level data on gender, disability, age, and socio-economic status are essential for evidence-based policy formulation.
- Community-led identification of vulnerabilities should guide adaptation design, implementation, and monitoring.
- Capacity-building initiatives must empower vulnerable groups to participate meaningfully in governance, decision-making, and leadership roles, also in the formulation of policies.
- Dedicated financial allocations and monitoring mechanisms are required to ensure GEDSI outcomes in water adaptation projects.
- Public–private–community participation models should replace narrow PPP frameworks to enhance accountability, inclusivity, and sustainability.
- GEDSI indicators must be embedded within flagship water, sanitation, livelihood, and social welfare schemes.
- A phased roadmap should guide awareness building, institutional reform, inclusive infrastructure design, and long-term integration of GEDSI in science–policy–practice frameworks.

ADAPTATION PLANNING FOR INDIA'S WATER SECTOR UNDER CLIMATE CHANGE

COMPENDIUM OF PROCEEDINGS OF THE TWO-DAY NATIONAL WORKSHOP




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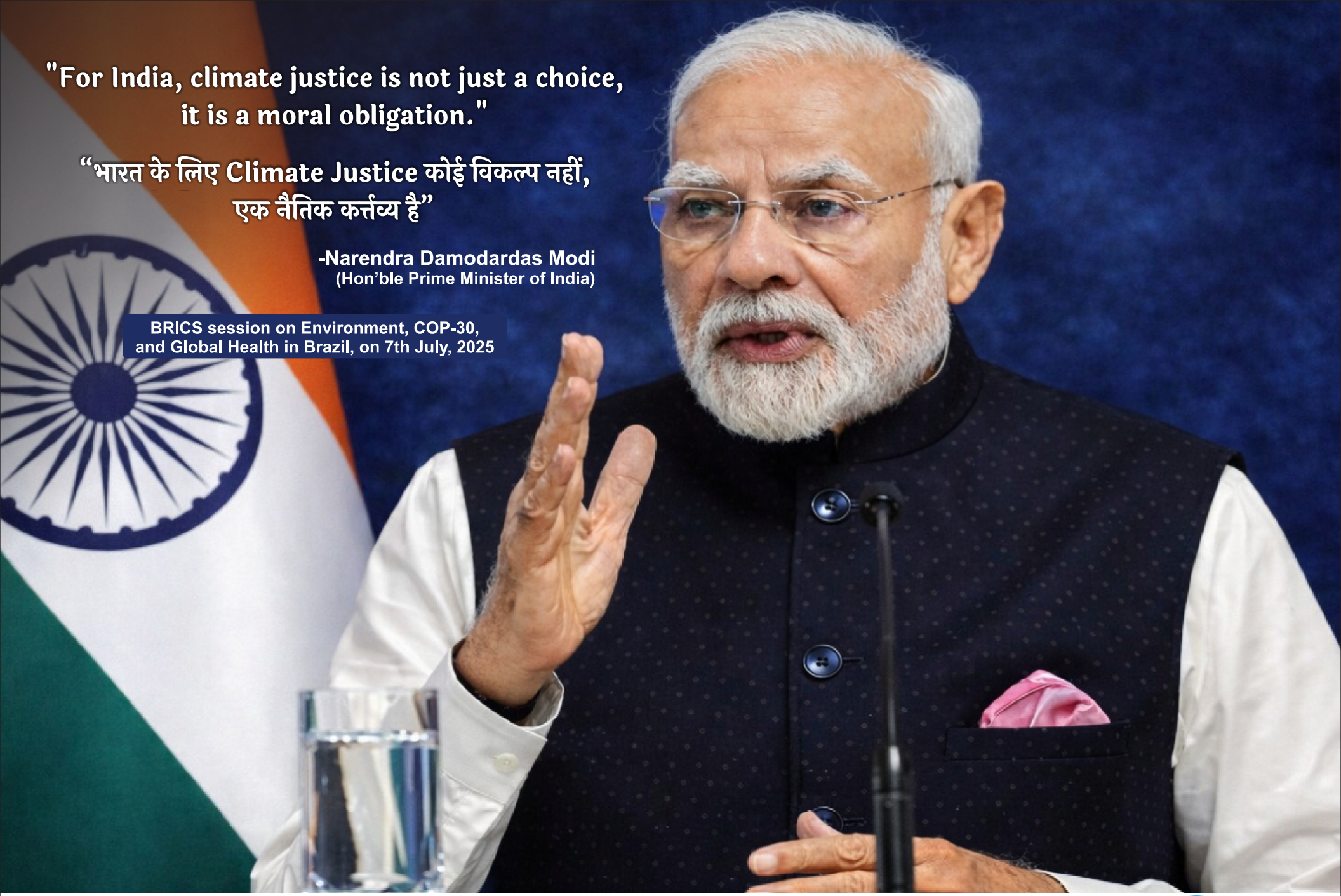

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