



Status of Science and Technology in Disaster Risk Reduction in Asia Pacific

UNDRR AND AP-STAG
2024



UNDRR

UN Office for Disaster Risk Reduction

KEY CONTRIBUTORS

Kumar Abhinay, Indian Institute of Technology, Roorkee (India)
Ranit Chatterjee, Resilience Innovation Knowledge Academy (RIKA) (India)
Qunli Han, Integrated Research on Disaster Risk (IRDR) (China)
Takako Izumi, Tohoku University (Japan)
Pavni Jaitly, Indian Institute of Technology, Roorkee (India)
Anubhuti Lakhera, Indian Institute of Technology, Roorkee (India)
Urvi Mishra, Indian Institute of Technology, Roorkee (India)
Mahua Mukherjee, Indian Institute of Technology, Roorkee (India)
Diana Patricia Mosquera Calle, United Nations Office for Disaster Risk Reduction (UNDRR)
Aslam Perwaiz, Asian Disaster Preparedness Center (ADPC) (Thailand)
Aishwarya Pillai, Coalition for Disaster Resilient Infrastructure (CDRI) (India)
Subir Sen, Indian Institute of Technology, Roorkee (India)
Sumit Sen, Indian Institute of Technology, Roorkee (India)
Rahul Sengupta, United Nations Office for Disaster Risk Reduction (UNDRR)
Rajib Shaw, Keio University (Japan)
Roopam Shukla, Indian Institute of Technology, Roorkee (India)
Harshit Sosan Lakra, Indian Institute of Technology, Roorkee (India)
Marco Toscano-Rivalta, United Nations Office for Disaster Risk Reduction (UNDRR)
Saini Yang, Beijing Normal University (China)

Cite the report as:

UNDRR and AP-STAG (2024). Status of Science and Technology in Disaster Risk Reduction in Asia Pacific. Bangkok: UNDRR, 86 pages.

The findings, interpretations, and conclusions expressed in this document do not necessarily reflect the views of UNDRR or of the United Nations Secretariat, partners and governments, and are based on the inputs received from the science and technology community.

© 2024 UNITED NATIONS OFFICE FOR DISASTER RISK REDUCTION

For additional information, please contact:

United Nations Office for Disaster Risk Reduction (UNDRR)

7bis Avenue de la Paix Geneva 1211, Switzerland

E-mail: undrr@un.org

Website: www.undrr.org

About the Report

This report was developed by the UNDRR's Asia Pacific Scientific and Technology Advisory Group (AP-STAG), with contributions from the session co-chairs of the Asia Pacific Science Technology Conference on Disaster Risk Reduction (APSTCDRR) 2024, and scientists and researchers in the Asia Pacific region. It is based on a comprehensive review and qualitative survey, which examine the application of science and technology to disaster risk reduction, specifically to the four Priorities for Action of the Sendai Framework for Disaster Risk Reduction.

The report is comprised of two parts:

Part 1 presents a regional, survey-based analysis of the progress made with regard to the Science and Technology Roadmap for Disaster Risk Reduction.

Part 2 includes a regional status review of six selected themes, including:

- (1) Early Warnings for All
- (2) Localization, inclusion and governance: role of Science, Technology and Innovation
- (3) Linking EWS and localization
- (4) Cities and resilient infrastructure in changing climate
- (5) Innovation and entrepreneurship for disaster risk and climate resilience
- (6) Advancing innovation in disaster risk reduction
- (7) Role of youth and innovation as means to advance science and technology in disaster risk reduction

These seven sections correspond to six sessions of the 5th Asia Pacific Science Technology Conference on Disaster Risk Reduction (APSTCDRR), which was held in Indian Institute of Technology (IIT) Roorkee in July 2024. The third section is the cross-cutting theme linking EWS (early warning system) and localization.

The preparation of the report was coordinated by Rajib Shaw, Marco Toscano-Rivalta and Rahul Sengupta, with contributions from AP-STAG members, APSTCDRR 2024 session co-chairs and support from Professor Subir Sen and his team at IIT Roorkee. The publication was commissioned by the United Nations Office for Disaster Risk Reduction.

Foreword

In the face of escalating natural hazards, the Asia Pacific region stands at a critical juncture where science, technology, and innovation are pivotal in disaster risk reduction (DRR). This report explores the transformative potential of these fields in mitigating the impacts of natural hazards and building resilient communities across this diverse and vulnerable region.

Asia Pacific, characterized by its dynamic climates and complex geographies, is uniquely susceptible to a wide range of disasters, both natural, and human induced. The increasing frequency and intensity of these events due to climate change necessitate a proactive and technologically advanced approach to disaster risk reduction. This report delves into the innovative strategies and technological advancements that are revolutionizing DRR practices across the region.

Governments, research institutions, and private sector stakeholders are leveraging cutting-edge technologies to enhance disaster preparedness, response, and recovery. The report highlights the crucial role of early warning system for all, importance of science technology and innovation (STI) in localization, inclusion and local governance, as well as of citizen science and Indigenous, local, and traditional knowledge (ILTK). The report highlights the importance of urban risk reduction as well as critical infrastructure resilience. The report also takes stock of new innovation, youth leadership as well as entrepreneurship development to foster disaster resilience.

This report emphasizes the importance of collaborative efforts and knowledge sharing among Asia Pacific nations. By fostering regional cooperation and leveraging each country's strengths in science and technology, the region can develop robust, scalable solutions to common challenges.

As we confront an era of unprecedented environmental volatility, this report serves as a testament to the ingenuity and resilience of the Asia Pacific region. It provides a comprehensive overview of how science, technology, and innovation are not only safeguarding lives and livelihoods but also paving the way for a more resilient future.



Rajib Shaw
Co-Chair, AP-STAG
Professor, Graduate School of Media
and Governance, Keio University



Marco Toscano-Rivalta
Co-Chair, AP-STAG
Chief, UNDRR Regional Office for Asia
and the Pacific

Table of Contents

ABOUT THE REPORT	3
FOREWORD	4
TABLE OF CONTENTS	5
LIST OF TABLES AND FIGURES	6
EXECUTIVE SUMMARY	7
PART 1: REGIONAL ANALYSIS OF STI STATUS	11
PART 2: THEMATIC REGIONAL STATUS	
1. Early Warnings for All	28
2. Localization, inclusion and governance: role of STI	41
3. Linking EWS and localization	47
4. Cities and resilient infrastructure in changing climate	53
5. Innovation and entrepreneurship for disaster risk and climate resilience	60
6. Advancing innovation in DRR	65
7. Role of youth and innovation as means to advance ST in DRR	75
REFERENCES	81

List of Tables and Figures

TABLES

Table 1 Regional Implementation of Priority for Action 1	14
Table 2 Regional Implementation of Priority for Action 2	16
Table 3 Regional Implementation of Priority for Action 3	17
Table 4 Regional Implementation of Priority for Action 4	18
Table 5 Overall Regional Implementation of Priority for Action	22
Table 6 Implementation Status Matric of Outcomes per Priority for Action	23

FIGURES

Figure 1 Categories of survey respondents	12
Figure 2 Interest in the Priorities for Action of the Sendai Framework	13
Figure 3 Outcome-wise Progress in Implementation in 2024	23
Figure 4 Components of EWS	28
Figure 5 Examples of CDRI fellows' innovation	71
Figure 6 Global inputs on youth and young professionals	78



©UNDRR/Sanjay Pariyar

Executive Summary

THE 2024 STATUS REPORT PROVIDES A COMPREHENSIVE ANALYSIS OF PROGRESS AND CHALLENGES IN DISASTER RISK REDUCTION (DRR) AS GUIDED BY THE SENDAI FRAMEWORK FOR DISASTER RISK REDUCTION (SFDRR) 2015-2030. THE REPORT HIGHLIGHTS KEY AREAS OF ADVANCEMENT, STAKEHOLDER ENGAGEMENT, AND ACTIONABLE INSIGHTS FOR FUTURE IMPROVEMENTS.

Key Findings

1. Regional Status Survey and Methodology

- An online survey conducted by the Asia Pacific Science and Technology Advisory Group (AP-STAG) received 151 responses from diverse stakeholders across 35 countries, including civil society organizations, private sector, academia, governments, and inter-governmental organizations.
- The survey focused on four main priorities of the SFDRR: Understanding Disaster Risk, Strengthening Disaster Risk Governance, Investing in DRR for Resilience, and Enhancing Disaster Preparedness for Effective Response.

2. Regional Implementation and Progress

- The report reveals significant progress in Priority for Action 4 (Enhancing Disaster Preparedness for Effective Response) with the highest stakeholder interest.
- There is a marked improvement in multi-hazard early warning systems (MHEWS) coverage, with 26 countries in the region reporting their implementation, representing a 116% increase from 2015.

3. Technological and Innovative Strategies

- The integration of advanced technologies such as Artificial Intelligence (AI), Geographic Information Systems (GIS), and Internet of Things (IoT) for early warning systems and disaster management has shown promising results.
- Examples include the use of Python-based scripts for weather forecasting in Himachal Pradesh, ultrasonic level sensors for glacial lake outburst flood management in Sikkim, and wireless sensor networks for flood prediction in West Bengal.

4. Inclusive and Collaborative Efforts

- The importance of inclusive approaches in DRR, such as ensuring early warning messages are accessible to all, including persons with disabilities and those with lower literacy levels, is emphasized.
- Initiatives like the Women's Weather Watch in Fiji demonstrate effective community engagement and dissemination of critical information through networks of rural women leaders.

5. Challenges and Areas for Improvement:

- Despite progress, challenges remain in enhancing risk knowledge and ensuring comprehensive coverage of MHEWS across all countries in the region.
- The need for continuous capacity building, regional cooperation, and knowledge sharing is crucial for addressing these gaps.

Recommendations for a better application of S&T

A number of recommendations have been made which are aligned under the following key areas

1. Strengthening Risk Knowledge
2. Enhancing Early Warning Systems
3. Fostering Inclusive Governance and Community Engagement
4. Promoting Regional Cooperation
5. Data governance
6. Research and Development
7. Multi-stakeholder Cooperation

This report underscores the transformative potential of science, technology, and innovation in building disaster-resilient communities across the Asia Pacific region. It calls for sustained collaborative efforts and innovative solutions to safeguard lives and livelihoods against increasing disaster risks.



PART 1:

Regional Analysis of STI Status

STATE OF IMPLEMENTATION OF SCIENCE AND TECHNOLOGY ROADMAP IN THE ASIA PACIFIC REGION

The Science and Technology Conference held in Geneva in January 2016 under the stewardship of the United Nations Office for Disaster Risk Reduction (UNDRR) led to production of the Science and Technology Roadmap to support the SFDRR 2015-2030. Thereafter, once in every two years, the Asia Pacific Science and Technology Group (AP-STAG) is curating responses from key stakeholders in the domain of disaster risk reduction in general and disaster management in particular to assess the progress with the implementation of the SFDRR. The past four publications, together referred to as the Status Report, has explored various aspects as highlighted in the SFDRR implementation footprints across countries to make the focus region, Asia Pacific, disaster resilient. In line with previous editions, the current edition too focuses on four expected outcomes and 58 actions, structured around the four Priorities for Action of the Sendai Framework.

An online survey was conducted by the Asia Pacific Science and Technology Advisory Group (AP-STAG) in May - June 2024 to assess the implementation of the S&T Roadmap in the Asia Pacific region. It was disseminated widely in various countries within the region, throughout governments, academic and research organizations, civil society networks and private sector. The survey aimed at measuring the progress in the outcomes outlined under the four Priority areas under the SFDRR namely (1) Understanding Disaster Risk, (2) Strengthening Disaster Risk Governance to Manage Disaster Risk, (3) Investing in Disaster Risk Reduction for Resilience and (4) Enhancing Disaster Preparedness for Effective Response, and to “Build Back better” in Recovery, Rehabilitation and Reconstruction. To assess the progress, respondents were asked questions under four broad sub-heading and these are termed as “Outcome” in this

S&T Report. The Outcomes are Assess and update data and knowledge, Dissemination, Monitoring and Review and Capacity Building for every Priority Action. The response to each question can be ranked between 1 to 5 with 1, 2, 3, 4 and 5 representing “poor”, “fair”, “good”, “very good” and “great”, respectively. To understand the implications of the scores received for this report, we may either consider the median or simply calculate the average values. The latter is opted and initially we have rounded off the average values to the nearest integer. For example, if the average is between 1 and ≤ 2 , we use 2 as the final score. These form the basis for the discussion in this section (and for the Tables 1, 2, 3, 4 and 5 as well as Figure 3).

A total of 151 responses were received from different stakeholders consisting of civil society organizations, private sector, academia and research, governments at both national and sub-national levels, inter-governmental organizations and the United Nations. Of the 151 respondents, 57 identified themselves as female and 92 as male. The responses came from 35 countries including small island countries in Asia Pacific, Latin America and Africa. In Figure 1, we have presented the different categories of survey respondents. The survey, almost in line with what we observed in the previous year, show an increased interest in Priority for Action 4 and the least interest in Priority for Action 3.

Figure 1: Categories of survey respondents

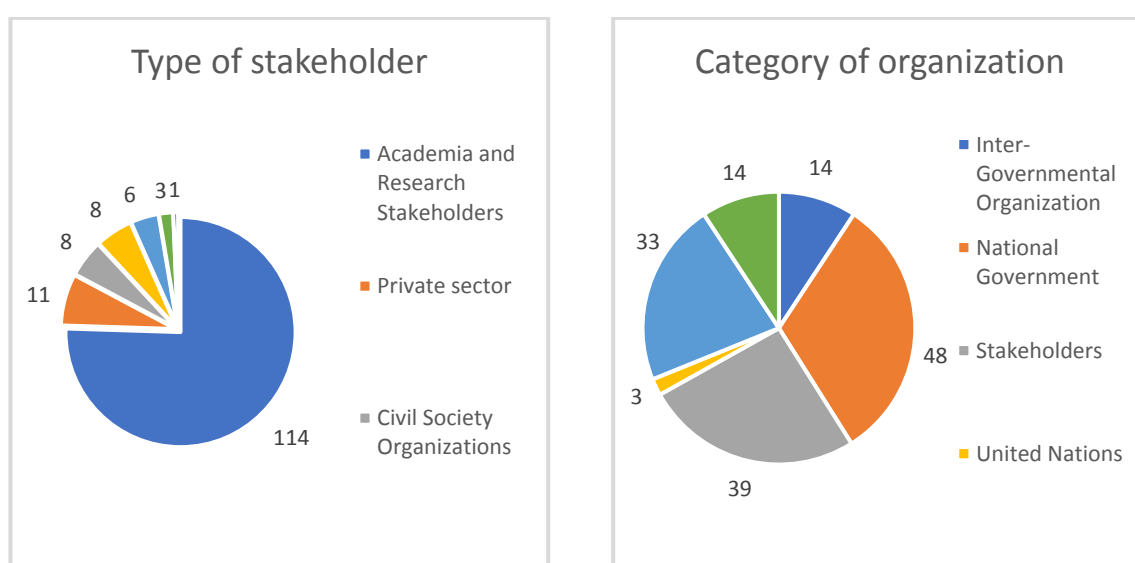
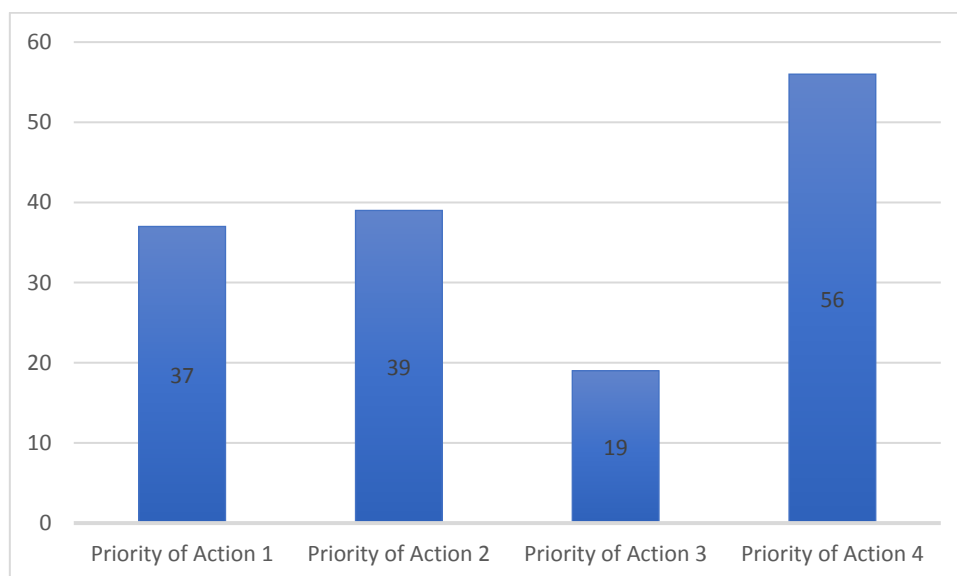


Figure 2: Interest in the Priorities for Action of the Sendai Framework

Key findings

The results from the recently conducted survey is encouraging and indicates that there has been overall progress in many actions of the S&T Roadmap. However, there are cases where more could have been achieved or at least expected, given the constant inputs from the advisory stakeholders and the uninterrupted efforts of those responsible for implementation of the policies to ensure a disaster safe society and fulfillment of the priorities under SFDRR. There are only a few outcomes where respondents have given “Fair” and mostly suggest that the progress has been “Good” thus far. However, we need to understand why, we fail to observe enough consensus on “Very good” or “Great”, although there are an insignificant few who are of the opinion that few Priorities for Actions have improved.

For Priority for Action 1, the action requiring more focus is only “analyse ethics of scientific input” (Table 1). There are no actions identified under Priority for Action 2 that requires immediate attention and unlike the previous assessment, all sub-outcomes are opined to be “good” (Table 2). However, under priority for Action 3, we observe that four components have been highlighted by the respondents namely, (1) Provide funding for science & technology in DRR to enhance knowledge, research,

technology transfer, (2) Assess the impact of investment of S&T in DRR, (3) Monitor science & technology investment in DRR as an integral part of national plan & policies and (4) Collect information on voluntary evaluation of S&T investment achievements periodically in collaboration with S&T partners (Table 3). This is less than the number identified in the previous assessment report (6 were identified). So, we may consider that there is an improvement in progress under Priority for Action 3 but still, this is identified as the least priority by the respondents. Finally, under the Priority for Action 4, only one is identified for urgent attention and that is “Incorporate build back better in insurance policies” (Table 4). There is a significant improvement noticed here from what was observed in the previous report. The respondents commented and identified need for improvements in 6 sub-outcomes and they were critical about both “Monitoring and Review” and “Capacity Building” under Priority for Action 4.

The respondents also shared their opinion on how efficient application of S&T may foster achieving the actions under the Sendai Framework. These opinions, in the form of recommendations have been collated under Table 5. We have further grouped these recommendations under 8 areas of concern.

Regional Implementation of Priority for Action 1: Understanding Disaster Risk

Table 1: Regional Implementation of Priority for Action 1 (1-Poor, 2-Fair, 3-Good, 4-Very good, 5-Great)

OUTCOMES AND ACTIONS UNDER THE ROADMAP		1	2	3	4	5
1.1	ASSESS AND UPDATE DATA AND KNOWLEDGE					
1.1.1	Promote integrated and multi-disciplinary research					■
1.1.2	Conduct solution-driven research at all levels that involves the users in the earliest stages					■
1.1.3	Establish/link existing and update/maintain global databases					■
1.1.4	Develop methods, models, scenarios and tools					■
1.1.5	Integrate risk assessments across sectors					■

1.1.6	Promote scientific focus on disaster risk root causes, emerging risks and public health threats, insurance and social protection and safety nets	■
1.1.7	Analyse ethics of scientific input	■
1.1.8	Adopt a multi-hazard approach that integrates lessons learned, including trans-boundary, biological and technological and Natech hazards	■
1.2	DISSEMINATION	
1.2.1	Develop evidence-based research on effective dissemination strategies for informed decision and policy-making.	■
1.2.2	Promote access to data, information and technology	■
1.2.3	Integrate traditional, indigenous and local knowledge and practices	■
1.2.4	Develop partnerships between all S&T and DRR stakeholders, and integrate gender equality	■
1.3	MONITORING AND REVIEW	
1.3.1	Link Science and Technology progress to Sendai Monitoring indicators, and report using online voluntary commitment system	■
1.3.2	Promote coherence in data collection and M&E indicators with SDGs and Paris Agreement	■
1.3.3	Develop a liaison group between the DRR community and the major global assessments, such as IPCC 6th Assessment Report and other related assessment.	■
1.4	CAPACITY BUILDING	
1.4.1	Build national and local capacities for the design, implementation and improvement of DRR plans	■
1.4.2	Promote inclusiveness, interdisciplinary, and inter-generational participatory approaches	■
1.4.3	Develop expertise and personnel to use data, information and technology	■

1.4.4	Promote the development and use of standards and protocols, including certifications	■
1.4.5	Utilize knowledge resources of S&T community for effective education programs on disaster risk reduction for scientists, practitioners and communities	■
1.4.6	Promote systems approaches in understanding disaster for better informed decision	■

Regional Implementation of Priority for Action 2: Strengthening Disaster Risk Governance to Manage Disaster Risk

Table 2: Regional Implementation of Priority for Action 2 (1-Poor, 2-Fair, 3-Good, 4-Very good, 5-Great)

OUTCOMES AND ACTIONS UNDER THE ROADMAP		1	2	3	4	5
2.1	ASSESS AND UPDATE DATA AND KNOWLEDGE					
2.1.1	Consider root causes of risk and inputs from traditional knowledge for decision-making			■		
2.1.2	Promote disaster risk assessment in spatial planning and development both in public and private sectors and increase participation of civil society for this process			■		
2.1.3	Integrate climate change adaptation & DRR and other relevant sectors (such as well-being, environment, health, economy, etc.) in governance mechanism			■		
2.1.4	Develop flexible governance system to adapt to emerging risks and climate change			■		
2.1.5	Promote the assessment of ecosystem-based development options			■		
2.2	DISSEMINATION					
2.2.1	Promote dialogue and networking on DRR between scientists, academia, policy- makers, civil society, media, business and private sectors at regional, national and sub-national level			■		
2.2.2	Raise scientific awareness and improve understanding			■		

2.2.3 Establish an understandable, practical, evidence based scientific knowledge needed for all actors ■

2.2.4 Improve access to data on DRR generated by international organizations, S&T communities, governments at different levels and stakeholders ■

2.3 MONITORING AND REVIEW

2.3.1 Strengthen the engagement of S&T in national coordination and promote sub-national implementation. ■

2.3.2 Promote disaster risk assessment in planning and development ■

2.3.3 Promote participatory monitoring mechanism involving civil society organizations and local communities ■

2.4 CAPACITY BUILDING

2.4.1 Promote dialogue and networking on DRR between scientists and policy-makers, civil society and business ■

2.4.2 Raise scientific awareness and improve understanding, considering future risk ■

Regional Implementation of Priority for Action 3: Investing in Disaster Risk Reduction for Resilience

Table 3: Regional Implementation of Priority for Action 3 (1-Poor, 2-Fair, 3-Good, 4-Very good, 5-Great)

OUTCOMES AND ACTIONS UNDER THE ROADMAP		1	2	3	4	5
3.1	ASSESS AND UPDATE DATA AND KNOWLEDGE					
3.1.1	Assess & update the status of mainstreaming science & technology in DRR			■		
3.1.2	Provide funding for science & technology in DRR to enhance knowledge, research, technology transfer		■			
3.1.3	Assess the impact of investment of S&T in DRR		■			
3.1.4	Include scientists of all disciplines in analyzing investment in DRR as well as climate change adaptation, including loss and damages			■		

3.1.5	Conduct research, develop tools, explore challenges in S&T in DRR	■
3.2	DISSEMINATION	
3.2.1	Promote various means of science communication for decision-making & policy makers	■
3.2.2	Promote changing roles of science and reflective practices of implementation that will contribute to the effectiveness of disaster risk reduction	■
3.3	MONITORING AND REVIEW	
3.3.1	Monitor science & technology investment in DRR as an integral part of national plan & policies	■
3.3.2	Collect information on voluntary evaluation of S&T investment achievements periodically in collaboration with S&T partners	■
3.3.3	Support innovations in earth observation and geospatial data for risk profiling and decision making	■
3.4	CAPACITY BUILDING	
3.4.1	Encourage & enhance capacity of stakeholders in DRR to increase investment in science & technology	■

Regional Implementation of Priority for Action 4: Enhancing Disaster Preparedness for Effective Response, and to “Build Back Better” in Recovery, Rehabilitation and Reconstruction

Table 4: Regional Implementation of Priority for Action 4. (1-Poor, 2-Fair, 3-Good, 4-Very good, 5-Great)

OUTCOMES AND ACTIONS UNDER THE ROADMAP		1	2	3	4	5
4.1	ASSESS AND UPDATE DATA AND KNOWLEDGE					
4.1.1	Promote multi hazards early warning systems with improved climate information, aerial and spatial data,					■

emergency response services and communication to end users

4.1.2 Develop and share best practices in new threats and risks (including infectious diseases) to inform preparedness planning

4.1.3 Identify, collect and analyze case studies and assess options to strengthen recovery and rebuilding efforts

4.1.4 Collaborate with the humanitarian community in exploring best practices for survivor led response and reconstruction

4.2 DISSEMINATION

4.2.1 Develop, disseminate information and practices on contingency planning and protection of critical infrastructure including the promotion of build back better approach in recovery, rehabilitation and reconstruction

4.2.2 Inform national disaster risk reduction plans and strategies that focus on community preparedness and awareness, considering relative needs of different groups including women, people of diverse Sexual Orientation, Gender Identity and Expression and Sex Characteristic (SOGIESC) and men, elderly and youth, persons with disabilities, etc.

4.2.3 Review and share build back better indicators among the relevant stakeholders

4.3 MONITORING AND REVIEW

4.3.1 Identify and address the need for, and gaps in, early warning systems in the least developed countries and the small island developing states

4.3.2 Incorporate build back better in insurance policies

4.4 CAPACITY BUILDING

4.4.1 Institutionalize effective recovery and reconstruction as strategies to reduce risk and promote resilient developments

4.4.2 Promote science-based decision making for resettlement processes

4.4.3 Generate and utilize scientific information to gain prior public consensus on post- disaster actions and to enable their smooth implementation after a disaster

Recommendations for a better Application of S&T

1. Strengthening Risk Knowledge:

- Focus on improving the risk knowledge, by investing in data collection, analysis, and dissemination including citizen science and Indigenous, local, and traditional knowledge (ILTK).
- Encourage collaborative research and development to advance understanding of disaster risks and effective risk reduction strategies.
- Build stronger knowledge of economic and social vulnerabilities.
- Give due consideration to the question of intersectionality in the understanding of risk.
- Address cascading and compounding risks in building comprehensive risk reduction measures.

2. Enhancing Early Warning Systems:

- Expand the coverage and effectiveness of MHEWS by leveraging new technologies and ensuring their accessibility to all communities.
- Promote the use of AI and other predictive tools to enhance early warning capabilities and response strategies.

3. Fostering Inclusive Governance and Community Engagement:

- Ensure that DRR strategies are inclusive, considering the needs of women, people of diverse SOGIESC and men, elderly and youth, persons with disabilities, etc. and supporting community-based approaches.

- Strengthen local governance and capacity building to empower communities in DRR, disaster preparedness and response.

4. Promoting Regional Cooperation:

- Foster regional cooperation through joint emergency planning, data sharing, and mutual aid agreements to address disaster risk reduction.
- Leverage each country's strengths in science and technology to develop scalable solutions for common DRR challenges.
- Explore opportunities for an Asia Pacific regional funding mechanism to promote S&T for DRR.

5. Data governance:

- Promote use of Artificial Intelligence, big data and Machine Learning to enhance the precision of risk assessments and optimizing resource allocation.
- Strengthen application of S&T in data management, including data collection, data quality control, and data sharing, for use in DRR and related robust monitoring and evaluation frameworks.
- Establish regional open data platforms and utilize Geospatial Information Systems (GIS) for comprehensive disaster risk management especially in urban planning.

6. Research and Development:

- Promote investment in research and development in the Asia Pacific region and foster public-private partnerships to enhance resilience.
- Build resilient infrastructure through the application of scientific advancements including Citizen Science and Indigenous, local, and traditional knowledge (ILTK).
- Facilitate exchange programs for scientists, technologists, and practitioners, especially giving opportunities to young researchers to share best practices and innovations in DRR.

7. Multi-stakeholder Cooperation:

- Strengthen inter-disciplinary participation in addressing disaster risk and in building resilience through sharing platforms and upscaling good practices and similar methodologies.
- Understand the diverse sociocultural nature of our communities to leverage technology effectively like the use of social media and mobile apps for stronger community-based DRR, disaster preparedness and response.
- Develop S&T tools that are easy to access by all stakeholders with strong applications like in aligning DRR with climate change adaptation.

Table 5: Overall Regional Implementation of Priorities for Action (1-Poor, 2-Fair, 3-Good, 4-Very good, 5-Great)

PRIORITIES FOR ACTION	2020					2022					2024				
						Outcomes									
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1. Understanding Disaster Risk		■						■					■		
2. Strengthening Disaster Risk Governance to Manage Disaster Risk			■					■					■		
3. Investing in Disaster Risk Reduction for Resilience		■					■						■		
4. Enhancing Disaster Preparedness for Effective Response, and to "Build Back Better" in Recovery, Rehabilitation and Reconstruction		■					■						■		

Table 6: Implementation Status Matric of Outcomes per Priority for Action

	2020					2022					2024				
OUTCOME	1	2	3	4	Average	1	2	3	4	Average	1	2	3	4	Average
OUTCOME 1: DATA AND KNOWLEDGE	2.84	2.97	2.85	3.00	2.90	3.08	3.06	2.95	3.14	3.06	3.20	3.10	3.00	3.21	3.13
OUTCOME 2: DISSEMINATION	2.96	3.12	3.00	2.82	2.98	3.10	3.15	3.04	3.04	3.08	3.25	3.23	3.05	3.13	3.17
OUTCOME 3: MONITORING AND REVIEW	2.68	3.15	2.97	2.48	2.81	3.03	3.09	2.93	2.83	2.97	3.14	3.19	2.98	2.98	3.07
OUTCOME 4: CAPACITY BUILDING	3.18	2.95	3.14	2.63	3.00	3.16	3.13	2.93	2.89	3.03	3.26	3.26	3.09	3.05	3.17
AVERAGE	2.94	3.05	2.93	2.77	2.92	3.09	3.11	2.96	2.98	3.03	3.21	3.20	3.03	3.10	3.13

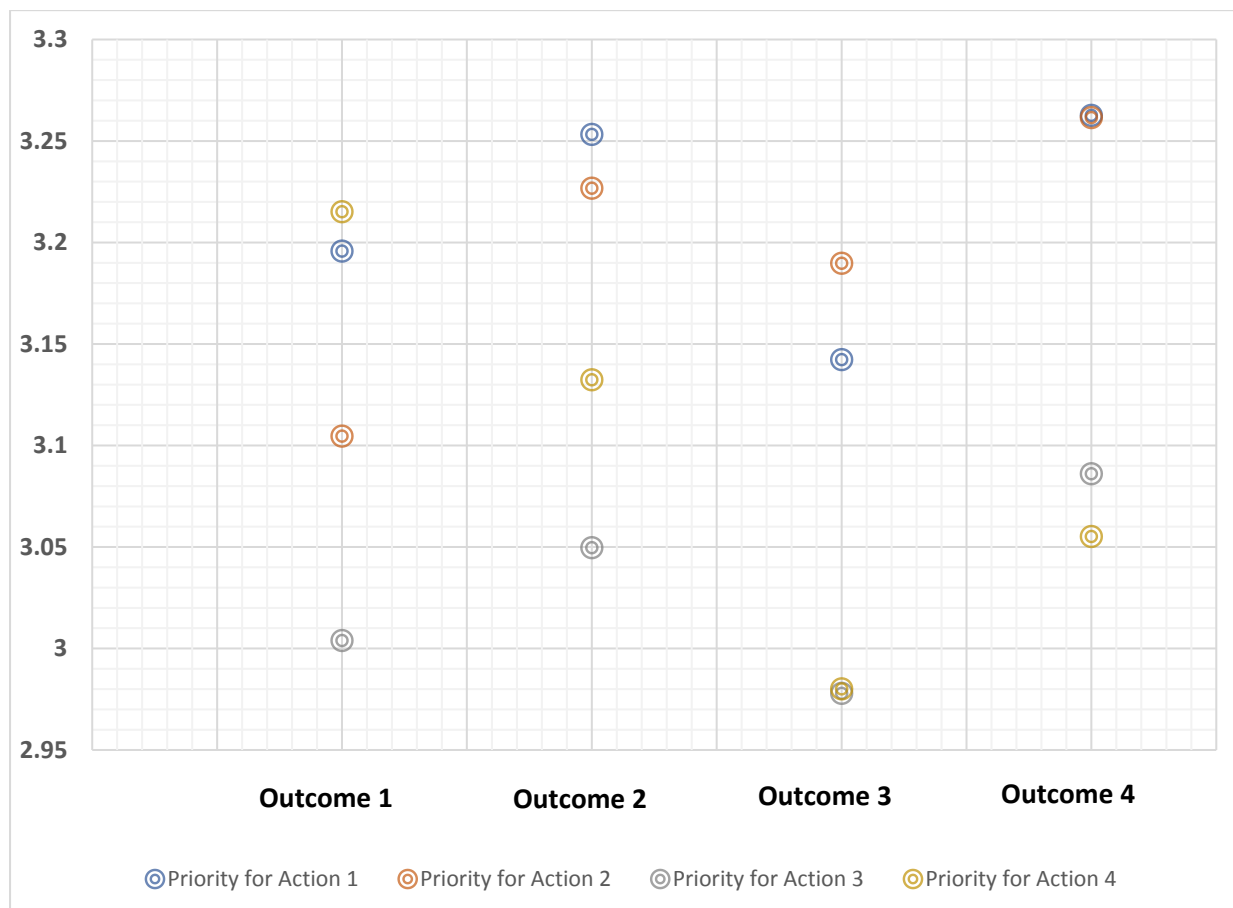
Figure 3: Outcome-wise Progress in Implementation in 2024

Table 5 and Table 6 present a comparison of progress made in overall regional implementation of Priority for Action (the two time periods considered are 2022 and 2024). We observe that there is significant improvement under Priority for Action 3 and Priority for Action 4 (Table 5). While analyzing the improvement in the outcomes, we observe that Monitoring and Review, Capacity Building have made significant progress (Table 7). There is partial improvement in Dissemination as well. However, Monitoring and Review and Capacity Building under Priority for Action 2 has declined. Most of the outcomes here show a steady progress but we need to deep-dive on the reasons as to why Dissemination and Monitoring and Review under Priority for Action 3 remains unchanged.

Different ideas on improving Disaster Risk Reduction (DRR) through Science and Technology in the Asia Pacific Region have talked about involving communities, utilizing local knowledge, and establishing policy frameworks to improve DRR in the region with partnerships, funding, and investments in education and infrastructure for a more resilient future.

Community involvement is essential for successful DRR efforts because it guarantees that the plans are customized to the unique needs and circumstances of the individuals most impacted. This includes integrating traditional knowledge and practices with modern technological advancements. Empowering communities through education and capacity-building initiatives by considering relative needs of different groups including women, people of diverse SOGIESC and men, elderly and youth, persons with disabilities, etc. is crucial for enhancing resilience. Enhancing community capacity building can be further improved by using civil defence apparatus and local self-governments.

Promoting collaborative Research and Development in S&T is of vital importance by facilitating regional collaboration through exchange programs for scientists, technologists, and practitioners to share best practices and innovations. Investing in research focused on new technologies, materials, and forecasting models can significantly improve disaster preparedness and response.

Financial support for DRR initiatives particularly for youth capacity building and community preparedness is essential. There is need for the governments to prioritize DRR in their policies while ensuring institutionalization across sectors such as environment, energy, and education. It is important to establish clear DRR policies, utilize international aid, and promote disaster insurance mechanisms to improve preparedness and recovery capabilities.

The risk assessment's accuracy might be enhanced while the allocation of resources can be improved through the use of Artificial Intelligence (AI) and big data analytics. To reduce the effect of disasters, creating localized early warning systems in real-time and using Geospatial Information Systems (GIS) for thorough risk assessment and city planning are essential. Additionally, it is essential to enhance data management, which involves collection, quality control, and sharing, for successful DRR.

Scientific advancements and fostering public-private partnerships will enhance investing in resilient infrastructure. Incorporating climate change adaptation into DRR efforts and implementing strong monitoring and evaluation systems lead to ongoing enhancement and successful execution of DRR projects. Promoting transparency in information sharing and creating organizational structures to promote accountability and collaboration among stakeholders is equally essential.

Education and training play an important role for the future application of S&T in DRR which includes integrating DRR into university curricula and providing opportunities for young researchers to receive mentorship from experts.

Developing human resources through education and training is vital for the future application of S&T in DRR. This includes integrating DRR into university curricula and providing opportunities for young researchers to receive mentorship from experts. Accessibility and understanding of scientific knowledge for local communities which enables them to effectively utilize S&T tools in disaster management needs to be prioritized for capacity building.

To conclude, various responses highlight the important role played by technological innovation with local knowledge, community engagement and policy frameworks for enhancing DRR in AP region. Through promoting teamwork, obtaining funding, and

enhancing education and infrastructure, the area can develop a strong future to combat the growing danger of disasters from multiple hazards.





PART 2:

THEMATIC REGIONAL STATUS

1. EARLY WARNINGS FOR ALL (EW4ALL)

Early warning systems are a proven, effective and feasible disaster risk reduction, climate change adaptation and sustainable development measure that save lives, reduce poverty and economic losses from disasters. Yet, according to UNDRR and WMO report on the Global Status of early warning systems published in 2022, half of the countries globally are not protected by multi-hazard early warning systems. To address these gaps and challenges, the UN Secretary-General launched the Early Warnings for All initiative (EW4All) in 2022 with the ambitious aim to create a world where every person, everywhere in the world has access to a life-saving early warning system by 2027. At COP27 an Executive Action Plan (EAP) was presented that guides the implementation of the initiative. The EAP underlines the importance of partnerships and inclusive multi-stakeholder engagement as critical cross cutting enablers for successful implementation of the initiative. The initiative is co-lead by the UN Office for Disaster Risk Reduction (UNDRR) and the World Meteorological Organization (WMO) and mirrors the four pillars of early warning systems (EWS), as follows (Figure 4):



Figure 4: Components of EWS

The Initiative is also supported by “pillar leads” leading the work on the four early warning system pillars:

1. Disaster risk knowledge [UNDRR],
2. Observation and forecasting [WMO],
3. Dissemination and communication [ITU] and
4. Preparedness and response [IFRC].

Economic and Social Commission for Asia and the Pacific ESCAP (2023) estimates that under the scenario of 1.5°C warming, 85 per cent of the population in Asia Pacific would be exposed to multi-hazard risk and sectors such as food and energy are exposed to increasingly intense and frequent shocks. ESCAP (2023) estimates that multi-hazard early warning systems could reduce disaster losses by up to 60 per cent. The importance of multi-hazard early warning systems (MHEWS) is broadly acknowledged in the Asia Pacific region. Closely related to MHEWS is early action, also known as anticipatory action or forecast-based action. Early action defines actions and financing based on forecasts and predefined triggers. Advances in science have led to the possibility of more precise forecasts that facilitate anticipatory action

In Asia Pacific, 26 countries have reported the existence of MHEWS, representing two thirds of the countries in the region. This represents a 116% increase in the number of countries reporting as compared to 2015, when only 12 countries reported having MHEWS. Among these, 15 countries have self-assessed to have limited to moderate MHEWS coverage, and 11 countries with substantial to comprehensive coverage. There are still 13 countries not reporting on MHEWS.

In terms of reporting by MHEWS indicators (EW4All key pillars), 56% of the Asia Pacific countries reported on the “observation and forecasting” (SFM G-2), 62% on “warning dissemination and communication” (G-3), 46% on the “prepared to response” (G-4) and 38% on “risk knowledge” (G-5).

According to UNDRR and WMO (2023), in the region, the pillar which is the strongest is **warning and dissemination** and the pillar which needs most strengthening in the

region is **risk knowledge**. Based on the reporting, there is much room for improvement to advance end-to-end early warning systems.

In terms of risk knowledge, only about half of the countries reporting on implementation of the Sendai Framework report having multi-hazard EWS, and indicate they have disaster risk information and assessments available in an appropriate manner. UNDRR and WMO (2023) point out that the scores are especially low in the south-east and south-south-west regions of Asia and among the LDCs, SIDS and LLDCs, suggesting that more needs to be done to translate risk analysis to national and subnational levels.

WMO (2023) suggests that Asia is “facing an alarming gap in climate projections and tailored products that are needed to inform long-term interventions such as adaptation to and mitigation of climate change and its impacts” p.21. WMO (2023) suggests that currently, less than 50% of members are providing tailored products.

WMO (2023) further suggests that most of the engagement of the National Meteorological and Hydrological Services (NMHSs) is in “initial stages”, which means, in identifying needs rather than providing tailored products and services to address sectorial needs. In spite of these challenges, overall, the regional analysis of the data for observations and forecasting clearly shows that the Asia and Pacific region is the most advanced compared to global data. However, more detailed examination of the data for this region reveals a large discrepancy between countries with comprehensive systems and countries with limited systems, with LDCs and LLDCs faring the worst (UNDRR and WMO, 2023). In-situ observations fall far short of meeting the requirements of the Global Basic Observation Network. In the forecasting area, many countries lack the capacity to incorporate an impact-based approach to forecasting and still have challenges in accessing, analysing and translating prediction model outputs into actionable warning messages.

Regarding warning and dissemination (pillar 3), here too, a more thorough examination of the data shows gaps in dissemination capacities, particularly in the LDCs and Pacific SIDS, likely due to the limitations of the communication networks in those locations (ESCAP, 2023; UNDRR and WMO, 2023). Technology and innovation

offer important opportunities to advance warning communication and dissemination, especially in terms of mobile networks and internet connectivity.

The third pillar of EWS also faces challenges in ensuring that public warnings from official sources are easily recognized, that redistribution including through relays of information at the community levels is inclusive enough to reach all people at risk, especially the most vulnerable. Last but most importantly, implementation at each stage needs to be planned accordingly with co-ordination of all stakeholders in all regions in a synchronized manner before or after a disaster for better effective responsive planning.

For pillar 4 on preparedness to respond, it is necessary for plans and procedures to be in place at the local, subnational and national levels, so that people know how to respond when warnings are received, especially communities, local government actors and national agencies as well as the NGOs and community-based organizations supporting them. Ideally, these plans should be co-produced and practiced through exercises and drills, supported by training for key actors and access to the necessary resources to act. As per a report on anticipatory action in 2022 (Anticipation Hub, 2023), 70 anticipatory action frameworks were in place globally, developed by IFRC, United Nations organizations and NGOs. The recent years have also seen a steady increase in the number of people pre-emptively evacuated. The pre-emptive evacuation is highly disproportional in terms of regional distribution and matches the comprehensiveness of the MHEWS captured in the data for Indicator G4 of the Sendai Framework monitor. Asia and the Pacific accounted for 64 per cent of all people evacuated – a total of 1.1 billion people.

For all the key pillars, coverage of Asia Pacific is higher than global average. In Asia Pacific countries, 13 countries reported that 1.3 billion people pre-emptively evacuated from 2015 to 2023, the highest of any region, and this accounts for 64% of the global total. However, as mentioned earlier, discrepancies are observed in the data from LDCs and SIDS.

In terms of governance, very few countries in the region have MHEWS that are based in national legislation and regulatory frameworks for emergency response, which are

essential to ensure their effectiveness. Beyond the technical issues related to data collection and interoperability, a lack of understanding of the socioeconomic benefits of EWS, a lack of legislation and governance among national institutions are key drivers to be addressed to remediate the situation.

To address these gaps and reinforce end-to-end MHEWS, several initiatives are ongoing in the Asia Pacific region with the collaboration of a diversity of partners. It is not the objective of this chapter to list those initiatives exhaustively, but to illustrate emerging good practices to showcase progress and way forward.

In Asia, regional frameworks and working groups have been established to further advance the operationalization of early warnings and early action. For example, the Association of Southeast Asian Nations (ASEAN) Framework on Anticipatory Action in Disaster Management provides guidance for defining and contextualising anticipatory action at the regional level with some considerations for its implementation by members of ASEAN. The Regional Technical Working Group on Anticipatory Action Asia Pacific supports the development of guidance and frameworks on early warning early action in the region. CREWS, Risk-informed Early Action Partnership (REAP) and Regional Integrated Multi-Hazard Early Warning System (RIMES) support governments and communities in strengthening early warning and early action.

In the Pacific, the Framework for Resilient Development in the Pacific (FRDP, 2016) identified strengthening multi-hazard early warning systems as a key priority action for national and sub-national governments, regional organizations and the private sector. More recently, the Nadi Declaration endorsed by the Pacific Disaster Management Ministers at the Inaugural Pacific Disaster Risk Management Ministers Meeting in 2022 highlighted early warning systems as a key adaptation measure. The project Weather Ready Pacific, implemented by the Pacific Meteorological Council, aims to reduce the human and economic cost of severe weather events across the region and it is the vehicle for the implementation of the EW4All Initiative in the Pacific.

The Climate Risk and Early Warning Systems (CREWS) initiatives in Asia Pacific aim to address gaps in timeliness and last mile connectivity in the dissemination of warnings from issuers to end-users and to ensure that early warnings take into

account the relative needs of different groups including women, people of diverse SOGIESC and men, elderly and youth, persons with disabilities, etc.

Upgrading early warning systems and observation networks, enhancing data management, and strengthening capacities of staff, are the main priorities for the National Meteorological Services in the Asia Pacific region. While there is common understanding of the importance of working together with other government departments and sectors, few of the strategic national plans related to early warning explicitly mention the need to work with communities. There is also limited evidence on how early warning plans in the region include relative needs of different groups including women, people of diverse SOGIESC and men, elderly and youth, persons with disabilities, etc. in designing, managing and implementing community-based early warning systems.

Overall, for a number of hazards, mostly related to hydrometeorological events, including glacial lake outburst floods, there are numerous initiatives and technological solutions that reach all populations in a timely manner and through various channels. Significant progress in improving multi-hazard forecasting, monitoring and dissemination has been reported by Member States. A specific aspect is the upgrading of cell broadcast emergency alert systems to enable sending alerts to connected mobile phones, including voice recordings, which also involves dedicated mobile phone applications. Also, toll-free numbers to receive weather forecast and warning messages have been reported. To reach foreigners, e.g., migrant workers or tourists, messages are translated in relevant languages. Other means to notify provincial authorities and the public are social media, websites, TV, radio, loudspeakers and even handmade instruments; the latter four to cater for people without mobile phone or Internet. In some places, the private and citizens also share relevant early warning information via social media to complement information provided by governmental sources.

Inhibiting factors for early warning systems are lack of funding and capacity, as well as limited access to satellite communication. Countries also stressed that effective early action, which includes safe evacuation of potentially affected people based on easy-to-understand instructions, needs to be tailored. Special attention and

engagement need to be ensured for older persons and those with disabilities. The relative needs of different groups including women, people of diverse SOGIESC and men, elderly and youth, persons with disabilities, etc. need to be taken into account in the measures to be undertaken. It is also critical that the public is informed in advance about the importance and meaning of warning signals and the measures to be taken, including through evacuation drills. Community-level structures that involve volunteers to improve risk knowledge are good practice in this regard.

In spite of this progress and initiatives, the strengthening of early warning systems remains a key priority. Significant work remains to be done to ensure that they are multi-hazard, end to end and people-centred. Countries, including many small islands, especially those with the highest risks and the least resources, remain highly challenged in building and sustaining integrated, people-centred, end-to-end early warning systems that are fully functional across the four interrelated components of early warning systems.

What used to be called “the last mile” of early warning systems is now increasingly understood as “the first mile”, i.e., the point of departure to understand how a community, all its members with their specific needs and without leaving anyone behind, is ready to act on warnings and relevant infrastructures are in place. Despite significant progress, gaps remain for instance in timeliness and last mile connectivity in warning dissemination from warning issuers to end-user communities and to ensure early warnings consider the different risks and needs of the population, including women, people of diverse SOGIESC and men, older persons and youth, persons with disabilities, etc. and are also disseminated in local languages. Financial mechanisms to support early action are the focus of continued strengthening and further enhancements are necessary.

It is expected that the Early Warnings for All initiative of the UN Secretary General to be achieved by 2027 will provide the necessary focused stakeholders’ collaboration and investment. In fact, investing in multi-hazard, people-centred, early warning systems results in multiple benefits at the national and local levels and contributes positively to the advancement of several key global and regional agendas, and the promotion and protection of human rights.

Conclusion and way forward

The understanding and analysis of early warning systems through four pillars has demonstrated to be a useful approach to promote early warning systems as a holistic system including technical and social aspects. While the four-pillar approach is advantageous, it is important to ensure that siloes are not reinforced and that early warning systems are supported in a coherent manner. For this, science and technology is a suitable connector ensuring that diverse kinds of knowledge, including local, traditional and indigenous knowledge, contribute to the improvement of early warning systems and universal coverage. While significant progress has been achieved in the establishment of EWS in the region, as demonstrated by their impact in mortality reduction, some challenges still remain.

Under the umbrella of the EW4All Initiative, national governments with the support of partners, including the UN system, are taking stock of the status of their early warning systems and identifying critical gaps for potential investments. This is being done through comprehensive gap analyses, stakeholder engagement, and the development of national roadmaps for EWS improvement. This process offers a good opportunity to reinforce the use of science and technology to strengthen all the pillars of early warning systems in a coordinated manner.

EMERGING GOOD PRACTICES

Pillar 1: Disaster Risk Knowledge

ESCAP's Risk and Resilience Portal, for example, has emerged as a useful tool to address critical gaps, particularly in disaster risk knowledge (Pillar 1) and the observation, monitoring, analysis, and forecasting of hazards (Pillar 2) of early warning system components. Equipped with the latest CMIP6 data, the Portal offers a unique capability in disaster risk knowledge to visualize current and future climate scenarios at baseline, 1.5, and 2 degrees. It identifies risk hotspots, providing a multi-hazard risk profile for the region. This foresight is crucial for understanding the evolving risks of floods, droughts, heatwaves, and tropical cyclones, allowing for anticipatory actions for early warnings for the changing hazard landscape.

Pillar 2: Observations and Forecasting

Digital technologies and data science provide transformational opportunities to leveraging innovations towards achieving people-centered, last mile, multi-hazard early-warning systems that can help minimize the harm to people, assets, and livelihoods key enables advances in data driven modelling, spectrum of emerging technologies, cloud computing and big data analytical techniques.

Additionally, towards Pillar 2, the Portal supports the forecasting component of EWS through its Impact-Based Forecasting (IBF) methodology. IBF provides a deeper understanding of forecast impacts on socioeconomic variables and specific sectors, enhancing the effectiveness of early warnings. These analytics have supported countries

like Maldives in implementation of the components of early warning. Smaller countries like Maldives face challenges in disaster risk knowledge and visualizing hazard and climate risks due to the coarseness of global data sets. Working with partners such as the Asia Pacific Climate Change Adaptation Information Platform to downscale climate projection data to a 5- kilometre grid, the Portal's analytical and visualization framework was able to provide impact analysis, including for early warning, tailored to local conditions.

The tool developed under the Portal 6 identified climate risk hotspots, assessed vulnerability of climate sensitive sectors, and provide adaptation solutions for multiple climate scenarios.

For various disaster events across different regions of the Indian Himalayan states, there are numerous types of EWS, categorized by disaster type and use of technology.

Earthquake Early Warning Systems (EEWS)

An EEWS which utilizes a network of 84 sensors including 3-axis MEMS accelerometers connected via Statewide Area Network (SWAN) and Multi-Protocol Label Switching (MPLS) of Virtual Private Network over broadband (VPNoBB), connecting with SWAN room and BSNL's BTS to the central server at IIT Roorkee, with real-time data processing on the Earthworm platform for timely earthquake warnings, has been implemented in Uttarakhand. This system issues warnings for earthquakes with epicentres in this region and magnitudes greater than 6 to adjoining cities and towns of Uttarakhand, Western Uttar Pradesh, and Delhi.

Landslide Early Warning Systems (LEWS)

In Himachal Pradesh, the LEWS features monitoring instruments like rain gauges, tiltmeters, and various sensors for real-time data collection, transmitted wirelessly to a remote location and analysis in intervals of 30 minutes (24/7), with alerts triggered via SMS, email, and visual/auditory signs when thresholds are reached. Similarly, in the Tehri region of Uttarakhand, a seismological network comprising 18 stations has been established by Tehri Hydro Development Corporation (THDC) Limited in collaboration

with the Department of Earthquake Engineering at the Indian Institute of Technology, Roorkee. It employs a seismological network for detecting seismic activity and rainfall-induced debris flows, using methods like the Short Time Average/Long Time Average (STA/LTA) and the Wavelet Synchro squeezed Transform (WSST) for precise early warnings in local and regional seismic activity of the northwest Himalayas. In Sikkim, analyses of daily rainfall observations from IMD stations and local rainfall observations from Chandmari for the period 1990–2017 and 2015–2018 and uses regional Intensity-Duration (ID) thresholds for predicting landslides, with systems in place to monitor and evaluate the accuracy of predictions. In West Bengal, the MEMS technology is utilized with high resolution solar powered tilt sensor with temperature sensor which enables the detection of slope movements as small as 0.02. to monitor surface tilt and volumetric water content in slopes, with empirical thresholds for issuing landslide warnings. This sensor is suitable for detecting shallow landslides but may not be effective for deep-seated failures. Another more advanced method is the combined SIGMA + Tilt approach which integrates statistical rainfall data from the SIGMA model with tilt sensor readings. This approach aims to reduce false alarms by verifying yellow alerts predicted by the SIGMA model against tilt sensor data.

Flood Early Warning Systems (FEWS)

Himachal Pradesh (Sone River Basin): Uses a three-stage process involving weather forecasting using Python-based scripts, hydrological modelling utilizing NCEP GFS 0.25-degree data, IMD grid data, INSAT 3D IMR data, and CPC daily rainfall inputs with the HEC-HMS model, and flood simulation with MIKE 11-based HD modelling for flood risk prediction.

Sikkim (Glacial Lake Outburst Floods): Incorporates ultrasonic level sensors, a GIS-based Spatial Decision Support System, and real-time data transmission via satellite for managing glacial lake outburst floods. This system empowers disaster managers to query data and visualize results spatially and in tabular form, enhancing their capacity for informed decision-making.

West Bengal (Damodar River): Deploys Wireless Sensor Networks (WSNs) and Artificial Neural Networks (ANNs) for flood prediction, utilizing a multilayer perceptron model for classifying hydrological data and predicting flood conditions.

Assam: Uses a three-tier architecture with Wi-Fi and stressed sensors, comprising sensors, processing units via edge computing (NodeMCU ESP8266), and user-level communication devices to monitor and alert for flood conditions, integrated with the Thing Speak IoT platform for real-time data visualization and alerts. It offers advantages in terms of reduced latency and increased privacy compared to cloud-based solutions.

These systems are designed with a focus on leveraging advanced technologies and real-time data processing to enhance disaster preparedness and response capabilities across the Himalayan region, tailored to the specific environmental and geological characteristics of each area.

Pillar 3: Dissemination and Communication

Data ecosystem and technology need to be accessible on for scaling-up of digitalization of early warning products and services to ensure its inclusivity and effectiveness in reaching out to the communities in need, in multi-hazard risk hotspots.

In the Pacific, efforts have been made to improve dissemination by incorporating CAP (Common Alerting Protocol) into standard operating procedures, as seen in Tonga and the Solomon Islands. This includes combining visual and impact descriptions for clearer communication.

Effective early warning systems utilize multiple channels to ensure that warnings reach everyone, considering factors such as age, gender, health, disability, and education level. where traditional communication infrastructures might be limited alternative methods like community loudspeakers and word-of-mouth through local networks are sometimes used in some African areas. The importance of making warnings accessible to all, including persons with disabilities and those with lower literacy levels, is recognized. This involves using diverse formats like sign language, braille, and visual aids. The Women's Weather Watch in Fiji exemplifies an inclusive approach by providing updates through a network of rural women leaders, ensuring that the needs and priorities of different groups including women and people of diverse SOGIESC are considered.

New technologies, such as drones and mobile satellite communication systems, are being explored to overcome communication blackspots and enhance the reach and resilience of early warning systems. The affordability and accessibility of such technologies are expected to improve, supporting broader and more equitable access.

The AI sub-group applies AI to support the attainment of the EW4All Initiative objectives. The recommendations of this sub-group are inclined with the EW4All Executive Action Plan. Another initiative of ITU, deploys satellite telephones and terminals as well as other emergency telecommunications equipment to affected countries within the first 24 to 48 hours of a disaster event. This equipment helps restore vital communication links and is critical for coordination of disaster response activities within the government and humanitarian agencies involved in rescue and relief operations. ITU deployed satellite telecommunications equipment with coordinate evacuation activities to support Papua New Guinea in the aftermath of the volcanic eruption of Mount Bagana in Bougainville. The satellite equipment deployed is composed of 10 Iridium satellite phones and 5 Inmarsat BGAN terminals.

Pillar 4: Preparedness to Respond

Preparedness for disasters and emergencies is a key focus in humanitarian assistance, it enhances resilience and response effectiveness through innovative solutions. The initiatives include using AI tools for predictive analytics. They also aim to improve disaster forecasting and resource allocation. Additionally, they focus on implementing climate-smart disaster risk reduction through nature-based solutions. Another aspect is the

development of projects such as the IFRC Limitless Youth Innovation Academy Water Prize, which concentrates on effective water, sanitation, and hygiene (WASH) solutions.

The Humanitarian Data Detective Game trains volunteers in data collection and analysis, it helps them to manage data in emergencies. The Future Fellows Programme develops future leaders within the Red Cross and Red Crescent Movement. It fosters innovative thinking and solutions to humanitarian challenges. Strategy 2030 is the IFRC's roadmap for its global network. It focuses on adapting to change and building resilience to new global challenges. The rapid deployment of emergency teams and efficient information management enabled by SIMS during the response to the Nepal Karnali earthquake illustrate the crucial role of data-informed decision-making and coordination platforms such as Slack and Trello. These efforts show a complete approach to being prepared. This includes using new technology, careful planning, and community-based solutions to improve the effectiveness and resilience of humanitarian responses.

Regional transboundary perspective

There is a focus on regional cooperation for disaster risk management, particularly in areas prone to transboundary hazards. This includes sharing data, joint emergency planning, and mutual aid agreements between neighbouring countries. Initiatives that involve collaborative research and development efforts to advance knowledge in disaster risk management. This includes joint studies and sharing of best practices across regions.

Implementing the EW4All in the Pacific, a distinct approach complementing regionally led initiatives: The EW4All roll-out in the Pacific will be taken forward differently from other regions, as there are already regionally led early warning systems programmes, initiatives, and frameworks in place or under development. The Weather Ready Pacific (WRP) 3 Programme was endorsed by Pacific Leaders in 2021 and its implementation plan was presented for adoption at the Pacific Island Forum (PIF). In addition, Pacific ministers responsible for Meteorological Services, at the 6th Pacific Meteorological Council (PMC) meeting in August 2023, concluded in the Namaka Declaration 4 that & quotes: WRP will be the key vehicle for EW4All delivery in the Pacific.

Pacific Pillar leads are now defining how EW4All can complement and supplement, what is being taken forward under WRP. Projects under the Climate Risk and Early Warning Systems (CREWS) initiative focus on increasing the capacity for early warnings in Small Island Developing States (SIDS) and least developed countries, involving multiple international organizations such as the World Meteorological Organization (WMO), the United Nations Office for Disaster Risk Reduction (UNDRR), and the World Bank. Initiatives like the Inaugural Pacific Disaster Management

Ministers meeting and outcomes from the Asia Pacific Ministerial Conference on Disaster Risk Reduction highlight regional cooperation to enhance EWS and integrate traditional knowledge into resilience building. The G20 provides an opportunity to support and supplement ongoing initiatives aimed at enhancing early warning systems across the globe. This includes fostering regional plans of action and financing models that build on regional cooperation mechanisms.

The Asia Pacific Disaster Resilience Network (APDRN) plays a crucial role in fostering transboundary advocacy and action to build resilience against climate-related hazards. National climate outlook forums, such as monsoon forums, are pivotal in this effort, bringing together multi-sectoral stakeholders to review seasonal forecasts and prepare for incoming weather systems. These forums, conducted in collaboration with National Hydro Met Services, enhance preparedness across various sectors, including water management, energy, agriculture, disaster management, and urban planning, thereby significantly reducing disaster risks and losses.

The APDRN supports these national and sub-regional forums by integrating regional products and services that combine risk information across different timescales. This integration strengthens the forecasting of cascading risk scenarios each season and validates sub-regional and national climate outlooks, while also providing technical resources and capacity-building to national hydrometeorological services and forecast user sectors in low-capacity, high-risk countries.

For instance, during the COVID-19 pandemic, the APDRN presented predictive analytics to capture cascading risk scenarios at the regional level, particularly focusing on the intersection of the pandemic with extreme climate events in South Asia. This analysis highlighted the expected convergence of water-related hazards with the pandemic, enabling national services to better prepare for such complex, intersecting risks. Through these efforts, the APDRN fosters a culture of risk-informed seasonal preparedness, crucial for tackling multi-hazards across sectors and enhancing regional resilience to transboundary climate threats.



2. LOCALIZATION, INCLUSION AND GOVERNANCE: ROLE OF STI

Context of the theme

According to the 2022 Status of Science and Technology in Disaster Risk Reduction in Asia Pacific report, significant progress has been made in adopting S&T. One of the areas of concern was “Governance” such as periodic review and assessment, strengthened use of S&T, coherence among national and local plans, consistency and sustainability of actions, increased funding for R&D in S&T, and continuous advocacy of the science-policy nexus. Conducting a thorough assessment has been especially required after the COVID-19 experience. It is relatively common to focus on natural hazards when a risk assessment is conducted, while biological hazards and diseases such as COVID-19 and other types of hazards such as technological, chemical, and environmental hazards were not considered under a risk assessment. The need to focus on all types of risks is emphasized in GA A/77/293 issued in August 2020 and The Sendai Framework also advocates an all-hazards approach, to which an understanding of the full scope of hazards faced by communities is essential.

The issues related to “Localization” were also identified under the priority focuses in the 2022 report, such as enhancing local resilience and focusing on local governance. Inclusivity will not be materialized without localization. Localization, Governance, and Inclusivity are closely linked and depend on each other. However, many countries face various challenges due to a lack of resources, technical support, and knowledge. The collection and access to data necessary for risk identification and sharing these data with communities needs to be strengthened. It is possible to understand disaster risks through the lens of science and technology, such as the application of remotely sensed data, real-time digital data, etc.

Just as science, technology, and innovation are considered critical elements of sustainable development, they are vital to the advancement of disaster risk reduction and resilience building efforts. DRR is possible without the use of technology, but the potential to greatly enhance positive outcomes through their incorporation is

undeniable. The technology role is as diverse as the technologies themselves, existing in all aspects of DRM from hazard identification for prevention and mitigation, to during response, and throughout long-term recovery. There has been a remarkable increase in the scope of technology options available to stakeholders engaged in such pursuits, whether the national disaster management organization or the individual citizen. This progress is in line with trending increases in the importance and attention afforded to DRR and the components of economic and social (United Nations 2021).

Key regional issues and challenges

The following issues and challenges are identified and often hamper the implementation of localization, inclusivity, and governance:

1. The mindset that disaster risk reduction or management is the responsibility of the government: Governments have a responsibility to take the initiative of reducing and managing disaster risks – allocating the budget for such activities, training human resources, adopting science and technology for improvement, establishing networks and coordination mechanisms among various stakeholders, applying early warning systems, implementing disaster educational and awareness raising programs, etc. However, it is not possible to carry out all these activities only by governments. They have resources and knowledge, but there are many areas in which the communities can take initiative as they are the ones who know the local situation the most, and that means they are in the best position to propose solutions. For the implementation of localization, the active involvement and initiatives of both the communities and local governments are indispensable.
2. Difficulty in access to early warning and unclear risk communication: Early warning is a major element of disaster risk reduction. With early warnings, people can make the decision to evacuate and take action to protect their lives. Early warning systems are integrated systems of hazard monitoring, forecasting and prediction, disaster risk assessment, communication, and preparedness activities and processes. Therefore, collaboration among

ministers and government agencies is essential to issue timely and accurate warning signs. However, the warning signs often do not reach the entire communities that may face the dangers due to some technical problems and lack of ideas and knowledge on what these signs mean. For example, persons with disabilities need support to receive such warning and take an evacuation action. Early warning systems are completed with effective risk communication with multiple communication channels.

3. Low interest in pre-disaster (disaster risk reduction) and high interest in post-disaster (rescue, providing relief efforts, etc.) by government agencies: It is crucial for governments to take immediate and effective response actions after an emergency occurs. They need to strengthen such capacity to save people's lives and provide urgent support. At the same time, it must be understood that it is effective to invest in and conduct disaster risk reduction efforts before an emergency happens to reduce the impact using science and technology. It is crucial that governments collaborate with local universities and research institutes to learn latest science and technology in DRR and discuss how they can be adopted in their context.

MAJOR REGIONAL AND GLOBAL INITIATIVES

Global Assessment Report on DRR (2019) includes several initiatives at local level:

Localization initiatives

Successful initiatives at the local level can influence regional and even national level actions. Evaluators of the United States Agency for International Development (USAID) Neighborhood Approach project across urban informal settlements in Latin America observed that some of the local projects funded by USAID generated multiplier effects at different levels. Local-level DRR actions can be triggered by a disaster event that provides “a window of opportunity” for resilience building.

Governance initiatives

Risk governance at the urban scale brings forth DRR stakeholder participation at all levels, from decision-making to design and implementation, and incorporates formal and informal urban contexts. While capacities are often very limited at local

government levels, they can be enhanced by tapping into resources of the private sector, academic and research organizations, and civil society, provided their data are evidence based and streamlined in a format for easy use by local governments.

Inclusivity initiatives

In Australia, the Disability Inclusive Disaster Risk Reduction (DIDRR) Framework and Toolkit for Collaborative Action for all Australians – individuals, communities, organizations, sectors, and governments – was established to improve how we learn and work together to identify and remove barriers for persons with disability before, during, and after disasters. Ensuring the safety and well-being of persons with disability during disasters demands their active inclusion in local emergency management practices, planning, and decision-making. Research consistently highlights the disproportionate risks faced by persons with disability during disasters. They face increased mortality rates, higher risks of injury and property loss, evacuation difficulties, and greater dependence on health and social services during and after disaster events (University of Sydney 2006).

‘STRENGTHENING DISASTER RISK REDUCTION CAPACITY TO IMPROVE THE SAFETY AND SECURITY OF COMMUNITIES BY UNDERSTANDING DISEASE RISKS (SeDAR)’ IN MALAYSIA

Malaysia experienced a tragic flood in 2021 and more than 50 people lost their lives and left 70,000 people displaced and affected over 125,000 persons. Global challenges such as climate change and the increase in developing activities can make the situation worse in the future. A project ‘Strengthening disaster risk reduction capacity to improve the safety and security of communities by understanding disease risks (SeDAR)’ was initiated in 2018 in cooperation with the Selangor State, Tohoku University, University of Technology Malaysia, and Civil Defence (APM) in Malaysia with the funding support by the Japan International Cooperation Agency (JICA). This project aims to equip local governments, community leaders, and community members with the skills and know-how to build a disaster risk reduction (DRR) program at the grassroots level, from the bottom up. It also emphasizes the need to adopt science and technology to identify the risks and respond to and prepare for future disasters. The key concept of the program

includes 1) Understanding of disaster risks by local governments and communities, 2) Leadership and ownership by the communities to lead DRR projects, and 3) Continuity and sustainability of the program by local governments and communities. To achieve these concepts, the program adopts the following phases:

- a) Understanding risk with scientific evidence/analysis,
- b) Training the local leaders,
- c) Increase knowledge of communities on disaster risk and preparedness,
- d) Plan and implement DRR activities by communities,
- e) Localize and sustain program.

Eventually, this project made significant impacts on DRR in Malaysia as follows:

- Established a mechanism for enabling local governments and communities to plan and implement CBDRR.
- Change in mind-set with DRR becoming a part of everyday life. The changes made included (1) increased knowledge about DRR, (2) understanding the causes of the disasters in their communities, (3) importance of inclusive, communal effort, (4) strengthening the collaboration between residents and community leaders and between the authorities and the communities, (5) increasing awareness on environmental changes and issues, and (6) understanding the effectiveness and benefit of the use of the scientific data in explaining disaster risks.
- Created a Network of DRR Collaborators at the Government and Community Level. Inclusivity was one of the key points that they have realized. And under SeDAR, these two groups—government agencies and communities—have worked together to forge a deepened community-government working relationship.

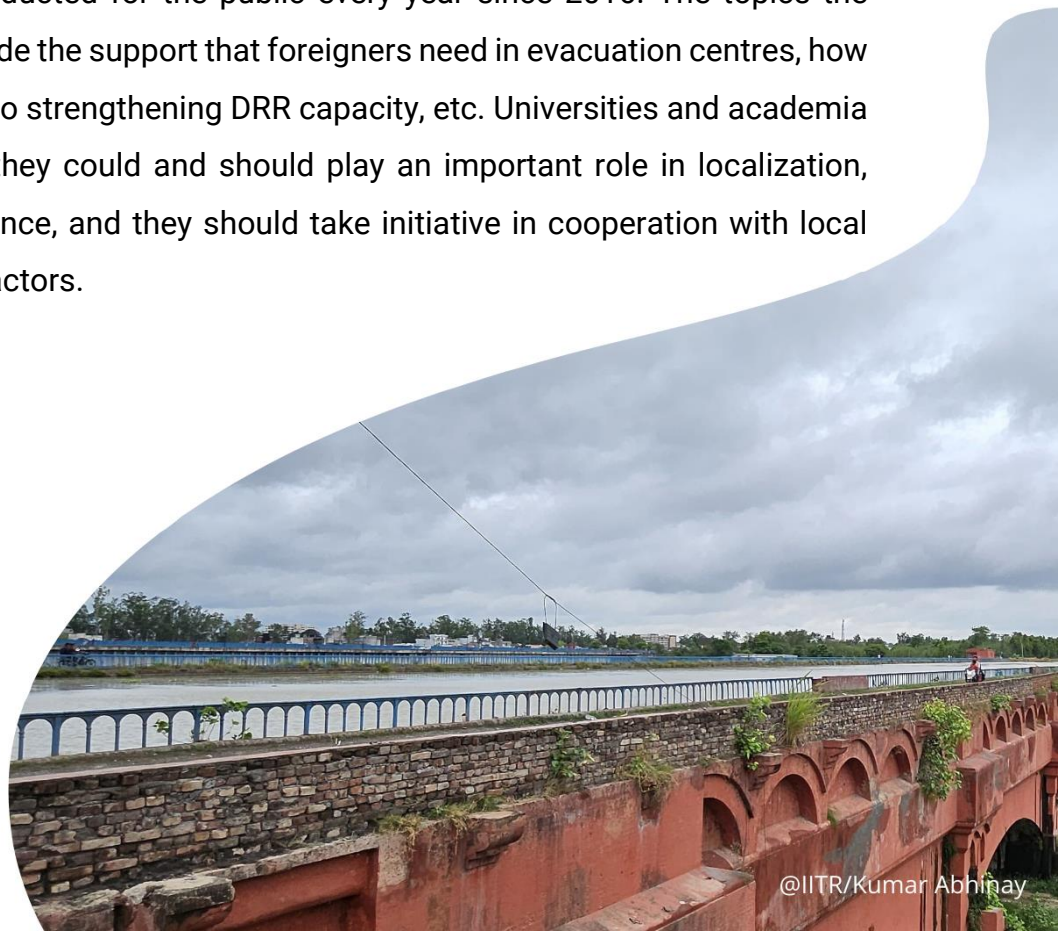
In the Asia Pacific area, the most effective methods for reducing disaster risks with an emphasis on early warning systems involve a thorough, community-involved strategy that incorporates advanced technology. Bangladesh and the Philippines blend conventional wisdom with sophisticated technology to provide culturally fitting and easily accessible alerts. The Cyclone Preparedness Programme (CPP) in Bangladesh effectively reduces fatalities by utilizing local volunteers to spread warnings and organize evacuations (UNDRR, 2019). Mobile technology improves the speed and range of notifications, allowing for quick community response.

Regional collaboration, such as Regional Integrated Multi-Hazard Early Warning System (RIMES), allows countries to share information and resources, enhancing hazard predictions. Both Japan and Indonesia demonstrate comprehensive early

warning systems for multiple hazards, with Japan relying on seismic sensors and immediate data analysis, while Indonesia combines community-based risk assessments and technological tools for monitoring volcanic eruptions (UNESCO, 2018). The ASEAN Coordinating Centre for Humanitarian Assistance (AHA Centre), assists in sharing information and coordinating joint responses in the ASEAN region. Efforts to build capacity, like training and simulation activities, improve local technical abilities, as the Sendai Framework for Disaster Risk Reduction proposes integrating EWS into national plans (UNDRR, 2015). By promoting collaborations and utilizing technology, the Asia Pacific region can improve EWS, lessening disaster effects and increasing community resiliency.

Conclusion

Localization, inclusivity, and governance are increasingly important in situations where more disasters will occur and be more severe. It has been a challenge to adopt science and technology at local level though progress has been made. To further progress, the role of academia and universities are critical in sharing the research results and findings and the products with the public using numbers and figures that enable to understand the situation quickly. In Sendai city, where the SFDRR was adopted in 2015, in collaboration with Sendai city and a local university, the “SFDRR seminar” has been conducted for the public every year since 2016. The topics the seminar picked up include the support that foreigners need in evacuation centres, how women can contribute to strengthening DRR capacity, etc. Universities and academia should recognize that they could and should play an important role in localization, inclusivity, and governance, and they should take initiative in cooperation with local government and other actors.



3. LINKING EWS AND LOCALIZATION

This section provides an overview on the issue that in the context of early warning systems (EWS), what are the extent of reforms required at the local and regional levels so that the interventions taken by the agencies responsible for DRR are actually able to create resilient societies. Enhancing the effectiveness of early warning systems (EWS) and to build resilient societies various reforms at local and regional levels need to be undertaken. Effective EWS requires ongoing monitoring, evaluation, and adaptation. These reforms need to focus on community engagement, governance, infrastructure and technological advancements.

1. Community Engagement

Awareness campaigns to educate the public on disaster risks, early warning signals and appropriate response actions need to be undertaken while providing training programs for local communities, build preparedness and response capacities. This would enable understanding of local vulnerabilities, culturally appropriate warnings, and increased community ownership. It should be ensured that different groups including women and people of diverse SOGIESC, elderly and youth, persons with disabilities, etc. are actively involved in the planning and decision-making process.

2. Governance

To ensure coordination among various agencies such as metrological departments, emergency services, health departments among others, there is need to establish disaster risk reduction (DRR) frameworks. Empowering local governments with the authority, resources, and training to implement and manage EWS effectively along with updating and enforcing legal frameworks that mandate the development and maintenance of EWS and DRR strategies is needed.

3. Infrastructure Development

Development of resilient and effective communication systems is needed to ensure uninterrupted flow of information before, during and after disasters. The capacity to enhance real-time monitoring of hazards through advanced technologies like remote sensing, GIS and automated weather stations along with constructing and maintaining safe shelters and clearly marked evacuation routes to protect communities during disasters would ensure resilient societies.

4. Technological advancements

Creating open data platforms where relevant hazard data and risk assessments are accessible to all stakeholders and public can enhance predictive capacities and warnings to specific regions and communities.

Localization and EWS: Safety First

The key question here is: “How localization of EWS may foster changes in disaster risk perception and inculcate a safety-first behavior that would strengthen the local systems and reduce vulnerability of the hazard exposed communities?” Localization of Early Warning Systems (EWS) can significantly foster changes in disaster risk perception and safety-first behavior, ultimately strengthening local systems and reducing vulnerability in hazard-prone communities. It can be done by the following:

1. Increasing risk awareness and ownership

Local communities directly involved in data collection, risk identification, and system design develop a deeper understanding of their specific vulnerabilities thereby fostering a sense of ownership and responsibility for preparedness. This can lead to proactive mitigation measures.

2. Culturally Appropriate Warnings and Communication

Localized EWS which include communication channels familiar to the community (local languages, SMS, community radio) and traditional knowledge

systems can ensure warnings are clear, timely, and culturally relevant, reducing confusion and panic during emergencies.

3. Empowerment and Action

Localized training programs equip community members with knowledge of response protocols, evacuation plans, and first aid. This empowers them to take immediate action based on localized warnings, potentially saving lives and reducing property damage.

4. Strengthened Local Systems

Localization fosters collaboration between communities, local authorities, and DRR agencies. This helps strengthening communication channels, facilitates resource mobilization, and also lead to more effective risk reduction strategies.

5. Reduced Vulnerability

By fostering risk awareness, safety-first behavior, and empowered communities, localized EWS directly contributes to a reduction in vulnerability. Communities become better prepared to respond to disasters thereby reducing casualties and accelerating post-disaster recovery.

Implementing risk-informed land-use planning and building codes reduces exposure and vulnerability to hazards thereby encouraging sustainable agriculture and environmental practices mitigating risks and building long-term resilience. Also strengthening social networks ensure vulnerable individuals receive timely assistance during disasters. EWS planning should include marginalized and vulnerable groups to ensure addressing their specific need and reduce vulnerability.

Overall, localized EWS plays a crucial role in shifting mindsets from reactive to proactive disaster management. By empowering communities and fostering a culture of safety, it strengthens local systems and significantly reduces the vulnerability of hazard-exposed communities.

Best practices

In the Asia Pacific area, the most effective methods for reducing disaster risks with an emphasis on early warning systems involve a thorough, community-involved strategy that incorporates advanced technology. Bangladesh and the Philippines blend conventional wisdom with sophisticated technology to provide culturally fitting and easily accessible alerts. The Cyclone Preparedness Programme (CPP) in Bangladesh effectively reduces fatalities by utilizing local volunteers to spread warnings and organize evacuations (UNDRR, 2019). Mobile technology improves the speed and range of notifications, allowing for quick community response.

Regional collaboration, such as Regional Integrated Multi-Hazard Early Warning System (RIMES), allows countries to share information and resources, enhancing hazard predictions. Both Japan and Indonesia demonstrate comprehensive early warning systems for multiple hazards, with Japan relying on seismic sensors and immediate data analysis, while Indonesia combines community-based risk assessments and technological tools for monitoring volcanic eruptions (UNESCO, 2018). The ASEAN Coordinating Centre for Humanitarian Assistance (AHA Centre), assists in sharing information and coordinating joint responses in the ASEAN region. Efforts to build capacity, like training and simulation activities, improve local technical abilities, as the Sendai Framework for Disaster Risk Reduction proposes integrating EWS into national plans (UNDRR, 2015). By promoting collaborations and utilizing technology, the Asia Pacific region can improve EWS, lessening disaster effects and increasing community resiliency.

Inclusivity in EWS

Ensuring that marginalized and under-represented groups receive equal benefits from Early Warning Systems (EWS) involves implementing a variety of key strategies. First and foremost, it is essential to engage these communities in the planning and execution of the EWS. Involving local leaders, women and people of diverse SOGIESC, indigenous people, and marginalized groups in participatory risk assessments and decision-making processes guarantees their unique needs and expertise are taken

into account (IFRC, 2020). Customizing communication strategies for various languages and literacy levels, as well as utilizing various media platforms like community radio, social media, and local networks, guarantees that warnings are effectively transmitted to all individuals, even those in distant regions (UNDP, 2021).

Next, it is crucial to develop local skills and encourage community involvement in early warning systems (EWS). Training programs should be all-encompassing, providing chances for marginalized groups to gain skills in hazard monitoring, data analysis, and emergency response (UNESCO, 2018). Creating local community groups and volunteer networks can improve resilience within the community and ensure ongoing involvement. Policies should also focus on addressing socio-economic obstacles by offering resources and assistance to vulnerable groups, guaranteeing they can reach essential infrastructure like shelters and secure evacuation routes (UNDRR, 2019). By incorporating these techniques, EWS can enhance inclusivity, guaranteeing fair protection and advantages for every member of the community.

Framing of disaster management policies for local led development of EWS

In order to support the development of Early Warning Systems (EWS) led by local communities, it is essential to make key changes in the way disaster management policies are shaped at both sub-national and national levels. To begin with, it is important for policies to give more importance to decentralized decision-making and enable local communities to create, execute, and oversee EWS customized to their unique risks and weaknesses. This can be done by giving resources directly to local governments and community organizations, allowing them to invest in local infrastructure, training, and technology (World Bank, 2020). Next, policy frameworks should prioritize participatory methods that incorporate indigenous knowledge and customary practices into official EWS systems. Involving community leaders, indigenous groups, women's organizations, and other stakeholders in risk assessments, planning, and response strategies guarantees culturally suitable, inclusive, and efficient early warning systems (UNESCO, 2018). In addition, policies

must require frequent capacity-building programs at the community level, such as training in monitoring hazards, sharing early warnings, and implementing evacuation protocols (UNDP, 2021).

At the national level, policies should enable sub-national entities to work together and ensure that local early warning system initiatives have the necessary technical knowledge, funding sources, and access to timely and precise information. This involves creating norms, procedures, and recommendations for EWS deployment with room for adjustments at the local level. Finally, incorporating EWS into wider development plans, like sustainable urban planning and climate adaptation strategies, guarantees that disaster risk reduction becomes a key element of local development projects (UNDRR, 2019). Embracing these changes can help disaster management policies promote a proactive and resilient approach to early warning systems, effectively safeguarding communities at the local level.



4. CITIES AND RESILIENT INFRASTRUCTURE IN CHANGING CLIMATE

Climate Change Impacts in the Asia Pacific Region

The Asia Pacific region is one of the most populated region housing around 60% of the global population, reaching 4.7 billion as of 2022 (ESCAP 2023) and vulnerable areas in the world, heavily exposed to climate-related risks and is rapidly urbanizing. Urban resilience is critical as cities in the Asia Pacific region face increasing threats from climate change.

Significant effects of climate change are being felt throughout the Asia Pacific area, including rising sea levels, temperature increases, and an increase in the frequency and severity of extreme weather events, and altered patterns of precipitation. For instance, the Philippines and Indonesia frequently experience typhoons, while cities like Ho Chi Minh City and Bangkok are at risk of flooding due to rising sea levels and heavy rainfall, and cities in Northeastern China experienced severe urban flooding due to record-breaking precipitations. These hazards are made worse by the fast rate of urbanization, since infrastructure often fail to catch up to the rapid population growth and economic expansion.

According to IPCC projections for 2021, these trends will pick up speed, making pre-existing vulnerabilities worse. For example, frequency of typhoons in the Philippines is predicted to rise, posing serious dangers to livelihoods and infrastructure. Rising temperatures are a major concern, as they result in heatwaves which have devastating effect on agriculture, public health, and energy demand. Record-breaking temperatures have already been observed in cities like New Delhi and Melbourne, which have resulted in a rise in fatality rates from heat-related ailments in 2024. Higher temperatures can also worsen urban heat island effects, which are places where infrastructure and human activity cause built-up areas to become noticeably warmer than their rural surroundings. Another major concern is sea level rise, which is especially problematic for island nations and low-lying coastal communities. In the Maldives, rising sea levels threaten to submerge entire islands, displacing communities and disrupting local economies. Extreme weather events, such as typhoons, cyclones, and heavy rainfall, are becoming more frequent and intense in the

Asia Pacific region. Changing precipitation patterns are also affecting the Asia Pacific region, leading to more intense and unpredictable rainfall. This can result in severe flooding, as seen in cities like Jakarta and Bangkok, where drainage systems are often overwhelmed by heavy downpours. Conversely, some areas are experiencing prolonged droughts, which can strain water resources and agriculture. For instance, Australia has faced severe droughts that have impacted its agricultural output and water supply.

Climate Resilient Infrastructure

Climate-resilient infrastructure is characterized by its planning, design, construction, and operation with the intention of anticipating, preparing for, and adapting to changing climatic circumstances. It is also capable of withstanding interruptions brought on by these climatic conditions, responding to them, and recovering quickly. During the asset's life, climate resilience must be continuously ensured. Efforts to achieve climate resilience can be mutually reinforcing with efforts to increase resilience to natural hazards (OCED 2018). Blue-Green infrastructure, which makes use of natural systems to offer social and environmental advantages, has become a significant part of resilient infrastructure. Urban forests, green roofs, permeable pavements, and wetlands are examples of BGI. These systems contribute to better air quality, biodiversity enhancement, storm water management, and a decrease in urban heat islands. For instance, the vast network of parks, gardens, and other green areas in Singapore not only increases urban resilience but also raises the standard of living for its citizens.

Science, technology, innovation, physical, and non-physical infrastructures help to make a city, urban area, or any space resilient to changing climate. Discussed below are some cases from Asia Pacific region. Here the use of science, technology and innovation are being put into use for climate change adaptation.

Technologies for climate change adaptation

- **AI for climate adaptation**

The integration of AI in climate action presents numerous opportunities to enhance our ability to combat climate change. By improving climate predictions, optimizing resource use, enhancing disaster response, and supporting sustainable practices, AI can play a pivotal role in mitigating the impacts of climate change and building a more resilient future. However, it is crucial to ensure that these technologies are deployed ethically and equitably, considering the potential social and economic impacts. AI can help Bangladesh adapt to the changing climate and mitigate greenhouse gas emissions. Climate AI can provide farmers with customized advice on crop selection, irrigation, and fertilizer use, based on weather data and soil conditions (Khan Shakil, 2023). Implementation of AI highly depends on the data integration and accessibility across the countries.

- **Earth observation for climate adaptation**

Earth observation uses satellites and other remote-sensing technologies to gather information about changes on Earth. Beginning in 2012, Australia's eReefs site, through remote sensing techniques using the sea surface temperature provide a quick, broad way to assess the risk of coral reef bleaching. The eReefs portal monitors the water quality and coral reef health of the Great Barrier Reef by combining a variety of data, such as sea surface temperature and chlorophyll concentration. NASA and the Indian Space Research Organisation (ISRO) have teamed up to create NISAR, a new satellite mission that will track the changing Earth in fine detail. Set to be launched in 2024 by ISRO from southern India, NISAR will observe nearly all the planet's land and ice surfaces twice every 12 days. Such facilities require huge financial support, which might not be available for small nations of Asia Pacific countries, and thus co-operation amongst the nations is important for climate change adaptation.

- **Advanced computing for climate adaptation**

Advanced computing involves using highly powerful computers with enhanced accuracy and speed. These include supercomputers – the world's biggest and most powerful computers that quickly analyze data and give us the best output. With a focus

on the world's most flood-prone regions, Bangladesh and India, Google.org's program is educating people on flood depth, including when, where, and how much floodwaters are likely to rise. They are exchanging data regarding depth in the user's village or vicinity in places where depth maps across the floodplain can be created.

- **Carbon Capture and Storage (CCS) for Climate Change**

CCS technology captures carbon dioxide emissions from industrial processes and power plants, then transports and stores them underground to prevent them from entering the atmosphere. This technology is crucial for reducing greenhouse gas emissions and mitigating climate change. Australia has been a leader in the deployment of CCS technology in the Asia Pacific region. One prominent example is the Gorgon CO₂ Injection Project, located on Barrow Island off the northwest coast of Australia. By capturing and storing CO₂ emissions, the project significantly reduces the greenhouse gas emissions associated with natural gas production, contributing to Australia's efforts to combat climate change.

- **Internet of Things (IoT) for climate adaptation**

IoT technology is being utilized to collect and disseminate new types of data, like temperature and air quality variations. People in the impacted area can receive notifications on their mobile phones from sensors that identify wildfires. Under Smart City Mission India- in Surat, IoT sensors monitor water levels in rivers and reservoirs to provide early warnings for floods and in Bangalore IoT solutions help in real-time tracking of parking spaces, making it easier for drivers to find available spots and reducing traffic congestion caused by searching for parking. In order to manage water resources in the face of shifting precipitation patterns, South Korea employs Internet of Things (IoT)-based water management systems that optimize water consumption and decrease waste through automated controls and real-time monitoring (FAO Home).

- **Renewable Energy Storage for Climate Change**

Advanced energy storage systems, such as lithium-ion batteries, solid-state batteries, and flow batteries, are critical for the efficient use of renewable energy. These technologies store excess energy generated from renewable sources and release it when needed, ensuring a stable and reliable power supply. The Hokkaido Battery Storage System is one of Japan's largest battery storage projects, aimed at stabilizing the region's power supply and enhancing the integration of renewable energy sources, particularly wind power. It has significantly improved the reliability of the power grid in northern Japan, reduced energy costs, and facilitated the integration of more renewable energy sources. This project demonstrates the critical role of advanced energy storage systems in supporting the transition to a sustainable energy future.

Innovation

- **Climate-resilient infrastructure**

Implementation of green infrastructure, and blue infrastructure to increase the capabilities of existing infrastructure are now part of adaptive and transformative governance. One such prominent example is the "Advancing Climate Resilience of Water Sector in Bhutan (ACREWAS)" project which aims to improve water governance and financing mechanisms, restore and sustainably manage the vulnerable water catchments of the Punatsangchhu River Basin, and increase the adaptive capacity of water infrastructure to challenges brought on by climate change through climate-proofing and technology deployment. Additionally, it seeks to strengthen awareness and knowledge-sharing mechanisms to support climate-resilient water management in four Dzongkhags of Bhutan.

- **Nature-based solutions**

It involves engaging nature to solve social, environmental, and disaster problems. For example, plantation stabilization of slopes in hilly regions helps prevent landslides and erosion, promoting environmental stability and safety. The Leyte Reforestation Project is a prominent example of a nature-based solution implemented in the Philippines. The project focuses on reforesting and stabilizing slopes in the hilly regions of Leyte,

an area prone to landslides and soil erosion. Initiated in response to severe landslides in the region, the project involves planting a diverse mix of native tree species to restore forest cover and stabilize slopes. The reforestation efforts are complemented by community involvement and sustainable land management practices. By engaging nature to solve these problems, the project promotes environmental resilience and community well-being. Promotion of NbS in major projects and financing of NbS projects should be brought into policy by the government. Inclusive policies to involve communities and other stakeholders in NbS projects will ensure the success of such initiatives.

- **Earth System Modelling**

Earth System Modelling (ESM) is a comprehensive approach to simulating and understanding the complex interactions within and between different components of the Earth system. These components include the atmosphere, oceans, land surface and biosphere. The CAS-ESM is a state-of-the-art Earth System Model developed by the Chinese Academy of Sciences to study and predict the complex interactions within the Earth's climate system. This model integrates various components, including the atmosphere, oceans, land surface, and biosphere, to provide a comprehensive understanding of climate dynamics. The CAS-ESM has been used in various climate studies and assessments, contributing to international climate modelling efforts such as the Coupled Model Intercomparison Project (CMIP). It simulates a wide range of climate processes and their interactions, providing valuable insights into climate change impacts, variability, and long-term trends. The model's outputs are used to inform decision-making on climate adaptation and mitigation strategies.

- **Circular economy & waste management**

The main concept of the circular economy is to reduce, reuse, and recycle to reduce waste generation and increase the lifespan of products. For instance, the new capital of Indonesia, Nusantara will establish a thorough and well-coordinated system that places a high priority on recycling, reuse, and reduction. By 2045, 60% of Nusantara's garbage is expected to be recycled, and by 2035, all of its water supply will be treated using a recovery system.

- **Advanced material & technology**

By using smart & modern materials, such as self-healing concrete, self-cleaning glass, Biodegradable Polymers etc. reduce maintenance costs and energy consumption. Various modern technologies are also available- 3D Printing, Piezoelectric Materials, precast, and many others. The rapid and economical construction of homes is being facilitated by the use of 3D printing technology in response to the housing shortages made worse by climate change. This technology is being investigated by nations like the Philippines and India to give robust housing options in areas vulnerable to disasters from natural hazards. Floating dwellings composed of strong, lightweight materials are being used in flood-prone areas. According to the UNFCCC, these houses are safe and sustainable since they can rise with flooding.

- **Renewable energy & energy efficiency**

Renewable energy sources are unlimited in amount and environmental impact (GHG emission) is also less. So future aim should be to utilize renewable energy sources like solar, wind, hydro, and geothermal for power production. Renewable energy boomed in 2023, with 50% more renewables capacity added around the world compared to 2022. China contributed about a quarter of the world's new solar capacity, and nearly 66% of the new wind capacity in 2023.

- **Electric vehicles**

Improvements in battery technology and charging infrastructure make EVs a more viable and sustainable option for urban transportation and also with lesser environmental impact. China has been at the forefront of electric vehicle (EV) adoption and innovation. A notable example is the city of Shenzhen, which has made remarkable progress in electrifying its public transportation system. The electrification of Shenzhen's bus fleet has resulted in substantial environmental benefits, including a reduction in GHG emissions and improved air quality. It serves as a model for other cities in China and around the world in promoting sustainable urban transportation. New Zealand with other countries from Asia Pacific region, China, India and Japan have joined a flagship Initiative of the Clean Energy Ministerial, the Electric Vehicle Initiative (EVI), to further accelerate the uptake of electric vehicles.

5. INNOVATION AND ENTREPRENEURSHIP FOR DISASTER AND CLIMATE RESILIENCE

Background

The Asia and Pacific region experience the highest number of weather- and climate-related disasters, suffering huge economic losses as well as considerable loss of life, every year. Country-specific consultations carried out from 2021-2024¹ demonstrated that challenges, problems, and needs are varied across sectors and geographic region. From water resources, farming systems and food security nexus to critical infrastructure vulnerabilities and climate risk financing solutions. However, the common denominator is that there is a demand for reliable climate information and analytics that are sector specific, climate smart agriculture, early warnings, risk financing mechanisms and water resource management. Concurrently, there also exists a market failure in developing and scaling innovative solutions to meet the demands and address climate resilience and adaptation needs of the SAR Countries primarily because of (a) awareness gap, (b) lack of capacity to pilot test newer technological solutions and (c) lack of investments in adaptation and resilience technology innovation.

The Asia Pacific Scientific and Technical Advisory Group (AP-STAG) of the UN Office for Disaster Risk Reduction (UNDRR) has been contributing to an enabling environment for disaster and climate resilience in the region, by improving the availability of regional data and knowledge, developing guidelines, tools, and capacities, and promoting climate-resilient decisions, policies, and investments across key sectors. Specifically, APSTAG members and its Secretariat has been proactively engaging in tech innovators and developers of disruptive technological solutions that are need-based and matched to the challenges faced by countries.

¹ National level consultation in almost 21 countries with support and guidance from UNDRR and World Bank

Innovation in Disaster Resilience

The sharp increase in the frequency and intensity of disasters resulting from Climate change is one of the greatest challenges of our time and concurrently the vulnerable communities need to adapt and build resilience to disasters on an urgent basis. The Sendai Framework for Disaster Risk Reduction (DRR) 2015-2030 calls for the “use and expansion of thematic platforms of cooperation, such as global technology pools and global systems to share know-how, innovation and research and ensure access to technology and information on disaster risk reduction”.

Emerging technology is one of the key tools for bridging the gap of adaptation and reducing disaster risk. Still, very few initiatives have been taken so far to pull together the two or understand the impact of innovative technology can have on reducing disaster risks and adapting to climate change. Recent experiences of witnessing a world of unprecedented challenges in the context of disasters and climate change augment the inherent need for innovative tech solutions.

To understand, appreciate and analyze disaster risks and climate impacts, great strides have been made over the last few years in developing technological solutions. The current scenario presents an urgent imperative and an opportunity for the national disaster management offices to derive the full potential of technological advancement to reduce vulnerability to disasters and climate risks.

Effective amalgamation of technology through regional cooperation and sharing of information among the countries would lead to eliminating data deficiency, more research, and enhanced risk reduction and adaptation activities by the government and communities.

Artificial Intelligence, Internet of Things (IoT), Blockchain, Robotics and others are critical to accelerate this process, making disaster and climate risk management smarter, more efficient, affordable and accurate. To make these functional trained people with right skillset in addition to resources for application of technologies is a must.

The iCARE initiative

In Asia and the Pacific region, the decision-making spaces are shared by science and policymakers with the local community. The shared decision space is characterized by co-learning and knowledge production. The World Bank-supported Climate Adaptation and Resilience for South Asia (CARE) project, implemented by the Asian Disaster Preparedness Center (ADPC), has been empowering decision-makers with tools, products, and services; to act locally on climate-sensitive sectors such as agriculture, water, and transportation. Specifically, it has enabled crowd-sourcing innovators and developers of disruptive technological solutions that are need-based and matched to the challenges faced by each of the seven countries where the technologies were deployed. The technical and financial support of \$3.5 million from the World Bank and UK government created the innovation in climate adaptation and resilience (iCARE) through the provision of grant to pilot proven transformative, scalable, affordable and accessible resilience technology solutions.

More than 30 innovations selected through the Climate Innovation Challenge (CIC) completed pilot deployment successfully in Bangladesh, Bhutan, India, Maldives, Pakistan, and Sri Lanka. The deployment of such innovations since 2021 leveraged cutting-edge and disruptive technologies, ranging from the Internet of Things, (IoT), AI, drones, deep-learning models and automatized land-use, to simpler but effective smart farming and digital systems for decision support in climate information and analytics. Also, low-tech Wi-Fi-connectivity radios ensure information access for remote communities.

The core component of the implementation was to build the capacities of the local governments and communities on the use of technology, operation and maintenance skills, data, and system management, and to apply them in high-risk areas. In Uttarakhand state of India, women were trained in audio recording, editing, device assembling, and related tasks, along with the youth. In Pakistan, farmers were trained and are operating weather gadgets and uploading daily weather data (via smart phones) to a local server for analysis; this is later translated into climate advisories for agriculture. In Nepal and Bhutan, deep learning models and AI are enhancing

understanding of infrastructure vulnerability to climate-related disasters, to improve critical infrastructure resilience. In Maldives and Sri Lanka, innovative farming techniques, coastal erosion and flood information enhancement were piloted.

Lessons Learnt

- Local demand matters: While this might sound rather obvious, tools and approaches tailored for developing country users often focus on supply, rather than being demand-driven. Conversely, it was found that pilot projects are more likely to be understood, accessed, maintained, and used by end users if they are providing solutions to demands by the same end users. It is important to convert the demand from the end users into ownership and integration into larger programs and projects, which are implemented by government ministries and departments at different levels.

Local markets and institutional capacity enhanced and adapted to build scalable and sustainable adaptation capacities and climate and disaster resilience. A core component of the pilot implementation was to build the capacities of the local governments and communities to build ownership and sustainability of the use of technologies and to go to scale. Given the technical nature of each pilot innovation, onboarding and capacity building of end user and local technical partners, (including government agencies) on the use of technology, operation and maintenance skills, data and system management were essential components of all pilot implementation.

Future Considerations for Upscaling

- The continuation and upscaling of the iCARE Innovations depends on the extent to which innovations can serve as a catalyst in system transition. During implementation, the pilot innovations adopted key criteria for selecting affordable, scalable, and replicable solutions that are most relevant to the demands and needs of each country. The uptake of innovations in the countries were built on the premise of meeting national priorities and endorsements by either a national or state public agency relevant to the sector or jurisdiction

under which the pilot was deployed. The climate innovation challenge innovators deployed in the countries have received specific endorsements from a sectoral ministry, department or local government, so as to implement the pilot solutions.

Building local partnership is key to successful deployment and integration into ongoing projects and programs. In Pakistan, a local partner played a key role in deploying the mobile flood dam administered by its innovators based in the Netherlands. Similarly, in Himachal Pradesh, India, local university students and faculty were trained in identifying appropriate locations to install DuckLink for early warning systems by a team of US-based innovators. Effective consultations and continued dialogue with relevant stakeholders are key to understanding national priorities and demands for resilience-building, while also maneuvering the nuances of policies that may challenge the deployment of innovation solutions.

- The innovative and disruptive solutions of the future must be based on the evidence of scalability and the strengthened capacity of communities, governments and organisations. The key lessons from the use of innovation grants provide an indication for future use. For example: In Bhutan, Tarayana Microfinance Pvt Ltd (TMF) deployed its climate risk financing solution and catalyzed Bhutan's financial institutions to make small loans for climate risk financing available to remote mountain communities and their members, especially female smallholder farmers and pastoralists.
- Continued linking and leveraging of investments and hand-holding are required to sustain the results of innovations and to grow to scale. Most cutting-edge technologies are private start-up companies with a need for continued investments in developing technologies, while iterating to the next phase. The completed innovations demonstrate the huge variety of ways in which the private sector and technology can provide communities with accurate and useful information on climate and disaster risks.

6. ADVANCING INNOVATION IN DISASTER RISK REDUCTION

Introduction

As per the Asia Pacific Disaster Report 2023², Asia and the Pacific region tend to be the world's most disaster-prone area. Since 1970, disasters in this region have wiped out over 2 million people, accounting for about 60% of the global disaster toll. This equates to 105 lives lost per day, or one life every 13 minutes (ESCAP, 2023). These numbers indicate the urgency for effective disaster risk reduction (DRR) innovations for the region. Previous research around innovations for disaster management highlights the potential of social and technological innovations to enhance public policies, facilitate communication between science and policy, and foster collaboration among various stakeholders in disaster risk management.

Acknowledging this importance, the Coalition for Disaster Resilient Infrastructure (CDRI) has set out on a mission to empower its Fellows³ (including graduate scholars, innovators, researchers and practitioners) spread across the world including the Asia Pacific region. CDRI is a partnership of national governments, UN agencies and programmes, multilateral development banks and financing mechanisms, the private sector, and knowledge institutions that aim to promote the resilience of new and existing infrastructure systems to climate and disaster risks in support of sustainable development. CDRI promotes the rapid development of resilient infrastructure to respond to the Sustainable Development Goals' imperatives of expanding universal access to basic services, enabling prosperity and decent work. For more information on CDRI, please visit www.cdri.world

The following section throws light on the vital contributions of CDRI Fellows to bridge a path for a more resilient future. It also highlights the key focus areas for further innovations in DRR, along with a glance at the status of innovations in the Asia Pacific region. Furthermore, recommendations for strengthening the implementation of innovative DRR projects are elaborated, along with the key challenges in this area.

² <https://www.unescap.org/kp/2023/seizing-moment-targeting-transformative-disaster-risk-resilience>

³ <https://cdri.world/fellowship>

Innovation in Disaster Reduction

1. Technology Integration

Leveraging emerging technologies such as Artificial Intelligence (AI), drones, remote sensors, and predictive analytics can significantly enhance disaster risk management capabilities (Saha, 2023). Some of the technological aids in disaster risk management and risk information as stated by Saha (2023) are as follows:

- Computing and AI: During emergencies, cloud computing offers immediate access to computing resources and storage, which helps with processing and understanding data. AI algorithms improve tasks, enhancing weather forecasts and earthquake predictions through predictive modelling.
 - Researchers at Cornell University utilized AI's brain machine learning (ML) to improve prediction of "slow-slip earthquakes" - a less intense type of tectonic movement that can extend over hours or days.
 - In the year 2021, Google's flood prediction program distributed 115 million flood notifications to 23 million individuals. Last November, Google increased the coverage of its flood forecasts to an additional 18 countries.
- Drones: Drones are essential in disaster response, offering aerial surveillance and logistical aid. They are extremely useful in situations like earthquake assessment, monitoring wildfires, and evaluating floods, by providing essential resources and assisting in search and rescue missions.
 - Following Typhoon Haiyan in the Philippines in 2013, the media focused extensively on the use of drones for mapping and disaster assessment, educating both public and first-hand responders about the potential applications of this technology. Drones were soon used by emergency response teams to evaluate structural damage after Cyclone Pam in Vanuatu in 2015; non-governmental organizations made extensive use of drones for post-disaster mapping, mapping shelters, and search and rescue operations after the earthquake in Nepal later that year (Greenwood, Nelson, & Greenough, 2020)

- Remote Sensing: Remote sensors provide instant data collection in distant or dangerous locations like monitoring dam walls or forested areas at risk of wildfires.
 - ISRO offers guidance in Remote Sensing and GIS for disaster management.
- Internet of Things (IoT): IoT enables the gathering and analysis of real-time data, aiding in disaster management and improving awareness in emergency situations.
 - HCLTech's Smart Consignment Inventory Management (SCIM) solution, developed by IoTWoRKSTM, offers a single view of the consignment inventory value chain, assisting hospitals and equipment manufacturers in monitoring and controlling medical devices, surgical kits, and consumables.

2. Knowledge Sharing Platforms

Creating new avenues for sharing knowledge promotes peer learning and co-creation among researchers, innovators, graduate scholars, public officials, and community stakeholders. Efficient sharing of information improves collaboration among stakeholders in disaster response operations. Having accurate and timely risk information is essential for making informed decisions and responding effectively. Having strong knowledge-sharing systems is crucial for guaranteeing the accessibility and availability of trustworthy disaster risk information (Chaminda, Rdg, & Richard, 2007).

3. Social Innovation

Incorporating social innovations into DRR includes implementing new methods and tactics to strengthen resilience and reduce disaster risks. The study done by Trejo-Rangel M A, et al., (2023) on the implementation of social innovation through public policies to promote flood resilience in Brazil, the following social innovation techniques are highlighted;

- Encompassing various aspects like communication during emergencies, disaster preparedness, and flood-prone area management (Angel, et al., 2023).
- Involving participation from various stakeholders, including governmental and non-governmental agencies, and the private institutions (Angel, et al., 2023).

- Prevention plans, vulnerable areas mapping, and community monitoring (Angel, et al., 2023).

4. Living Labs

Living labs function as real-life settings for testing and implementing innovative DRR solutions.

- Collaborative Innovation: Living labs help stakeholders work together to create and test new technologies and approaches that are customized for specific local needs through collaboration and quick prototyping (Concilio Grazia., 2022).
- Local-Centric Solutions: Living labs guarantee that DRR solutions are inclusive and responsive to community needs by including communities in the planning and testing phase. The efficacy and acceptability of ideas that are put into practice are improved by this collaborative approach (Concilio Grazia., 2022).
- Japan uses Living Labs, which are participatory spaces where various stakeholders come together to create cutting-edge disaster preparedness strategies. These laboratories were established in the wake of the devastating Great East Japan Earthquake of 2011 and are focused on improving community readiness, enhancing early warning systems, and rebuilding infrastructure (Kutty, 2024).

Contribution by CDRI in DRR innovation

CDRI's Mission is to support countries to upgrade their systems to ensure disaster and climate resilience of existing and future infrastructure. The Coalition's resilience programmes draw on the operational principles of collaboration, inclusion and focus on the most vulnerable, while considering the emerging priorities of its Members in the backdrop of a rapidly exacerbating context of climate extremes and disaster risk. CDRI's efforts respond to the Sustainable Development Goals' imperatives of expanding universal access to basic services, enabling prosperity and decent work.

CDRI promotes integrated and holistic approaches to mainstream DRI in support of the achievement of global sustainability, climate change and disaster risk reduction

goals. The Coalition is uniquely positioned to deliver on the agenda of climate and disaster resilient infrastructure through research, knowledge sharing, capacity building and in-country collaboration, and collectively advocates and champions DRI solutions to build a committed global constituency. To this end, CDRI convenes its annual flagship conference as well as participates in various regional and global platforms. As a thought leader and global voice on DRI, the Coalition aims to raise the visibility of its mandate and initiatives to deepen engagement on DRI, and garner new members and partners.

Accelerated climate action is critical to meet the enormous challenges posed to communities and ecosystems across the globe by the unravelling climate crisis. While most national governments have committed to meet the global goals and targets, these commitments need to be backed by decisive, credible actions. Enabling and amplifying local actions and on-ground solutions led by local actors and change agents with the potential to transform infrastructure systems will be critical to inform global responses. Through its Fellowship Programme, CDRI promotes local solutions which have the potential to address global resilience challenges.

The CDRI Fellowship Programme is a strategic initiative which explores pathways for innovations and action research. The Programme was launched in September 2020 with a vision to nurture a multi-disciplinary pool of professionals who will help shape a resilient future for global infrastructure systems. A 12-month seed grant of US\$ 15,000, the Fellowship provides financial support as well as peer learning and capacity development opportunities to foster transformative, actionable and scalable solutions for real world issues related to disaster resilient infrastructure. The Fellowship is open to all nationals/citizens of the Coalition's Member Countries. Winning proposals are selected through a rigorous multi-tiered review system including double-blind peer reviews and International Jury selection. As of date, the Fellowship pool comprises four Cohorts - 160 change agents and innovators from across 27 countries. Some of the promising solutions emerging from the Fellowship Programme, thus far, which have potential for application and scale include:

- Innovative lightweight and fire-resistant fiber-reinforced bearings for retrofitting

of hospital buildings under multi-hazard scenarios (IIT Delhi, India)

- Distributed optical fibre sensor network-based condition monitoring system facilitating early warning for road collapses (Uva Wellassa University, Sri Lanka-University of Southern Queensland, Australia)
- Cyclone classifier model to predict potential damages and risks along coastal zones (BUET, Bangladesh)
- Real-time scour detection and prediction during swollen river water period for structural performance and safety of bridges (Kyoto University, Japan)
- Development of real-time algorithm to enable decision making towards earthquake resilience of healthcare facilities (Gebze Technical University, Türkiye)

CDRI has promoted pathbreaking research by CDRI Fellows across IITs in India, more recently a project from Indian Institute of Technology Delhi, which deals with detecting flood inundation using deep learning and citizen science (Figure 5).

CDRI Fellows in the Asia Pacific region have been designing actionable and scalable solutions for DRI:

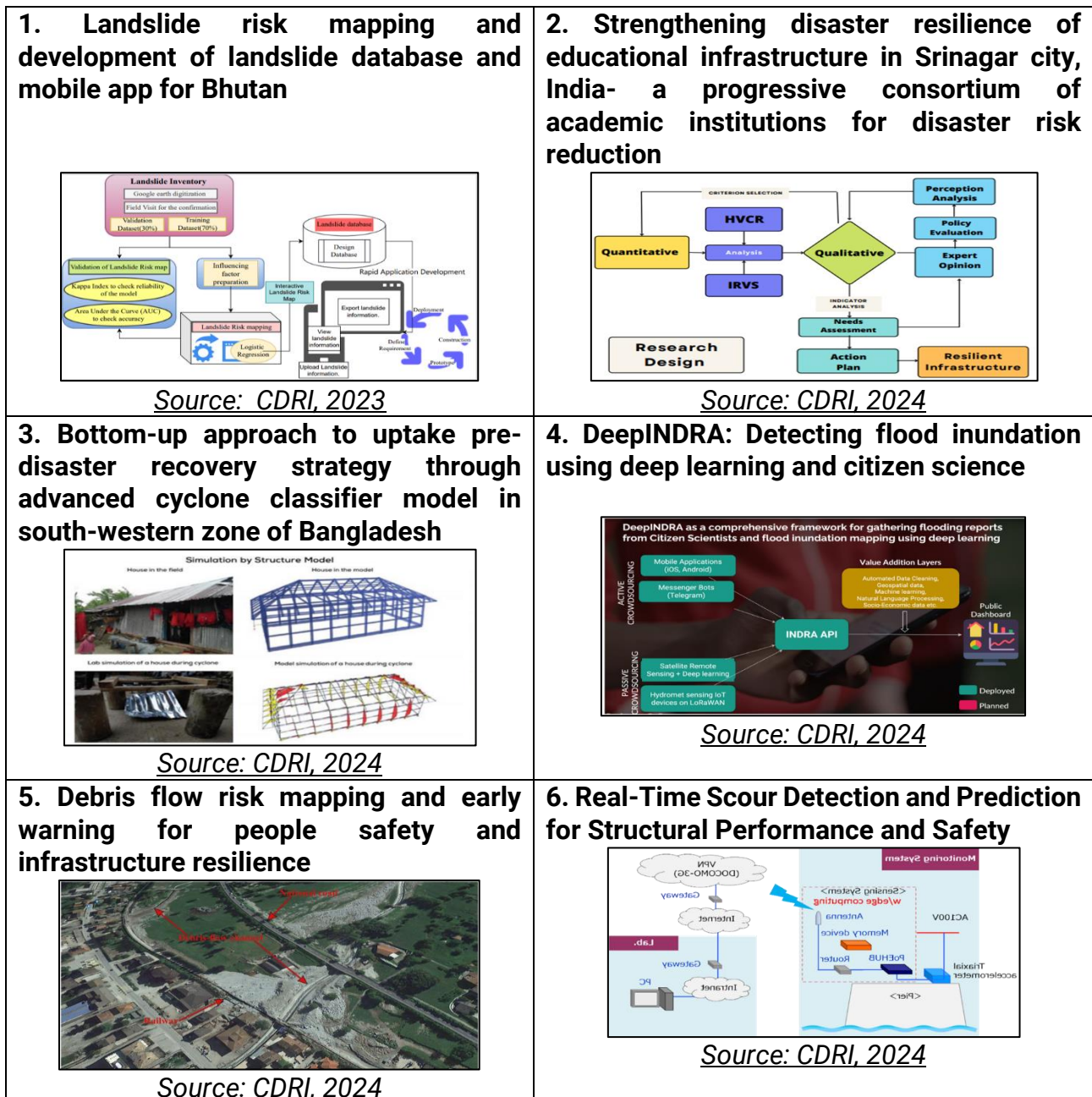


Figure 5: Examples of CDRI fellow's innovation

Role of Higher Education Institutes in DRR Innovation:

Higher Education Institutions (HEIs) have been instrumental in promoting scientific and technological advancements that have aided in disaster risk mitigation and management at different spatial and temporal scales for many years.

A few instances of national and regional university networks focused on disaster risk management and recovery are the Asian University Network on Environment and Disaster Management (AUEDM) in Asia, Training and Learning Circles India and the Philippines which promotes the networking of Indian and Filipino universities, and the University Forum in Indonesia connecting national universities. Some of the academic institutions that plays a crucial role in regional level strengthening of Disaster risk management includes the Asian Institute of Technology Thailand, which offers a Disaster Prevention, Mitigation and Management (DPMM), and Kyoto University's International Environment and Disaster Management (IEDM) program.

In case of India, NIDM has initiated several Self Study Programme (SSP) of E-learning which motivates and supports the young graduates to learn the different aspects of Disaster management from all corners of the country. IUINDRR is another effort launched by NIDM in accordance with Agenda 6 of the Honourable Prime Minister's 10-point DRR agenda. To stimulate the study of disaster management at the higher education level, IUINDRR-NIDM has introduced three DRRM-related course curricula at the undergraduate and graduate levels.

In addition to the courses, several higher educational institutes of Asia Pacific Region lead action projects in the realms of DRR, in collaborations with multiple organisations. For instance, the "Disaster Resilient Habitat" project, which was supported by the UNDP, was carried out by BRAC, the architecture department at BRAC University, and the postgraduate disaster management programs, in the southeast Bangladeshi districts impacted by cyclones. They planned and built houses, infrastructure, and schools for a community of forty-three people, combining local building expertise with scientific understanding from architects and engineers (Abedin, 2015).

The "Disaster Resilience and Sustainable Development Education Network in Asia" initiative, supported by ProSPER.Net, UNU-IAS, Japan, formed a working group of specialists from renowned universities in Asia Pacific region. This is an interesting initiative that is being led by the Asian Institute of Technology, Thailand, in

collaboration with three partner universities (University Sains Malaysia, Malaysia; Keio University, Japan; and Miyagi University of Education, Japan). The working group's objectives are to identify gaps in the present curriculum to promote resilience in colleges and universities and society, as well as to establish a connection between higher education and sustainable development and disaster resilience.

Challenges of DRR Innovation

DRR innovation and implementation is not immune to challenges. Some of the main hurdles faced in promoting innovation in DRR by key practitioners, scholars and policymakers are as follows:

- **Limitation in Funding:** DRR innovations might requires funding from the implementation stages, to monitoring and evaluation. Securing specialised funding is vital for developing innovative DRR projects and activities. A lack of financing can hamper the scaling up of successful pilot initiatives, ultimately restraining creative ideas and technologies.
- **Insufficient collaboration:** Successful implementation of all innovative DRR projects requires collaborative approach, where different stakeholders such as governmental organizations, educational institutions, businesses, and community organizations contributes equally. Cellular approaches hinder the developmental process of these approaches (Kutty, 2024).
- **Limited availability of data and information:** Accurate, authentic and timely risk information is necessary for making informed decisions during all stages of disaster risk management. The limitations in the availability of these data can delay the implementation of successful DRR initiatives.
- **Digital divide:** The Asia Pacific region faces certain technological gaps or digital divisions, especially when it comes to infrastructural availability, accessibility to technology, knowledge gap, and implementation. For implementing a successful DRR innovation project, these gaps and divisions should be taken into consideration and addressed timely.

Policy Implications:

The following is the policy recommendation for researchers and policymakers to encourage innovative methods in DRR among CDRI Fellows and graduate scholars in Asia Pacific countries.

- **Research Funding:** Earmark funds and provide research grants to novel DRR projects and initiatives, thus ensuring continued investment in technological as well as social innovational ideas.
- **Incentives and Recognition:** Introducing awards, recognitions and offering opportunities will further enhance the professional development of the best innovative DRR solutions, motivating better standards and knowledge sharing.
- **Policy Integration:** Integrate innovation-driven themes and framework with local, sub-national and national DRR policies, measures and action plans to enable DRR mainstreaming through innovative solutions across different sectors.
- **Partnerships and Collaboration:** Encouraging collaboration with local, regional and international stakeholders to harness best practices and lessons learned in cutting edge DRR. These partnerships will further facilitate the exchange of ideas, as well as capacity-building initiatives that will increase the disaster risk preparedness.



7. ROLE OF YOUTH AND INNOVATION AS MEANS TO ADVANCE ST IN DRR

Introduction

The Asia Pacific region is one of the fastest-growing regions of the world but at the same time is projected as one of the most prone regions to future shocks of extreme weather linked to climate change and other hazards. We are living in an interconnected world where disaster risks are systemic and increasing exponentially. Science and Technology play a crucial role in the progressive development of society and reducing the current & future risks. Realising this, the Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR) underlined the need to focus on Science and Technology as a key tool to confront such global challenges. The convergence of Science and Technology can foster innovations. In general, innovations can be in the form of a new method, product, creative idea, service, or a mix of more than one of these. In most cases, the use of Science and Technology supports in realization of the innovation. In the context of Disaster Risk Reduction, innovation should be linked to its social, physical, and economic value proposition across the disaster management cycle.

The Innovation Ecosystem in Asia Pacific

The Asia Pacific region is acting as the biggest investment hub of the world due to rapid technology growth, supporting regulatory frameworks, and the emergence of young entrepreneurs driving the innovation landscape. Countries like India, China, Japan, and South Korea are leading the technology advancements through cutting-edge research and development. The governments are creating incentives, introducing subsidies, and easing regulations to encourage young minds to explore innovative business pathways.

Australia offers one of the world's most startup-friendly ecosystems with government-supportive policies. Public sector organizations like Sunshine Coast Council, the Government of South Australia, Adelaide Economic Development Agency, the Western Australia Department of Jobs are leading this drive. Australia offers 5 years provisional business visa for budding entrepreneurs to stay in Australia.

Singapore is emerging as a leader in the startup ecosystem in Asia Pacific, especially in the Fintech sector, and emerging as a regional hub. For example, Action Community for Entrepreneurship (ACE), provides networking, resource sharing, and business know-how to support new enterprises. The public sector in Singapore is supportive of the startup ecosystem. To bring in global startups to interact with local startups events like Echelon Asia Summit, Singapore Week of Innovation and Technology (SWITCH), and Slingshot 2024 are being planned.

India has become an emerging leader in the startup ecosystem for driving economic development through innovation. Ranked third after the United States of America and the United Kingdom, India has focused on the technology skill base of its youth and young professionals for sectors like healthcare, defense, education, finance, and biotech. National Initiative for Developing and Harnessing Innovations (NIDHI) and the Atal Innovation Mission (AIM) aid aspiring entrepreneurs, offering efficient compliance procedures, and access to tax incentives and funding avenues. Under the AIM, Atal Incubation Centres (AICs) and Established Incubation Centres (EICs) are setup to nurture and offer grants for innovative startups in their pursuit to become sustainable entities (Startup India). A report by the India Brand Equity Foundation highlights the shift in focus on Indian startups on Deeptech in recent years. Among various Deeptechs' Artificial Intelligence (AI) is emerging as a favorite among the startups. The government of India through its Make in India drive is supporting the manufacturing and product assembly in India by channelling dedicated investments.

Youth and Young Professionals as Frontrunners of Science and Technology, Engineering, and Innovation for Disaster Risk Reduction

Youth and Young Professionals (YYPs) are the powerhouses of energy, creativity, and motivation. The engagement of YYPs varies across the region especially in the social entrepreneurship and innovation landscape. A report by UNDP on Youth Entrepreneurship in Asia and the Pacific suggests that *"Small businesses in Asia and the Pacific with younger owners are significantly more likely to grow than those owned by older entrepreneurs"*. The report thrust for complimenting regional and national policies to support young entrepreneurs. Awareness, Empowerment, and Access to resources are three important factors to drive the innovation ecosystem. The role of

universities is crucial for nurturing young talents, providing necessary entrepreneurial support, and aiding through infrastructure. The support system provided by the International Science Council through its scientific programs like Integrated Research on Disaster Risk (IRDR) in the Asia Pacific has been very effective in nurturing young talents. Furthermore, the YYP alliance and networks like the UInspire alliance which started with youth and young professional from 8 countries connecting on Science, Technology, Engineering, and Innovation (SETI), have spread their wings to 14 countries.

Input on youth and young professionals' empowerment for DRR:

There has been continued progress in youth engagement and empowerment in DRR since GPDRR 2022 in the Asia Pacific Region. As is shown in the IRDR Young Scientists Programme (YSP), the participation of young researchers remains most active in comparison with other regions (https://www.irdrinternational.org/irdr_community/young_scientists_programme/).

Of the total 45 newly selected young scientists in Batch 2023 of YSP, 22 are from Asia Pacific region. It is encouraging to note that the number of applications by female researchers has also increased, making YSP a more gender balanced network. The picture is the key words of research proposals submitted by the applicants of 5th batch, demonstrating a diverse but integrated research subject in DRR research (Figure 6).

It is encouraging to see that U-Inspire Alliance and IRDR have reached and signed MOU in November 2023 to cooperate for DRR youth empowerment. The Institute of Disaster Management and Reconstruction of Sichuan University of China also entered official cooperation agreement with IRDR for DRR education.

There have been other interesting models for youth innovation and empowerment. For example, Horizon Global Youth Programme under the Tsinghua University, China has been co-organizing with IRDR and UNESCO in 2023 and 2024 Youth Climate Action and Disaster Risk Reduction Hackathon. These activities have provided several thousands of university students with online lectures by leading experts identified from international organizations, research academies, policy institutions and business enterprises active in climate actions and DRR, and enabled more than 60 youth innovation working groups each year, and the competitions for best climate and DRR solutions from the youth working groups (<https://www.irdrinternational.org/news/758>). In 2023 and 2024, there have been a total of 30 Awards issued to young participants for their innovative solutions.

Input on the experience of the evolution of latest science, technology and innovation (STI) for multi-hazards early warning system

STI development, especially the rapid advancement of digital technologies has been a main focus of DRR communities in Asia Pacific Region. IRDR session on “New Data Technologies for DRR Early Warning and Early Actions” in the International Forum on Big Data for SDGs (FBAS 2023), provided opportunity for exchange in using digital technologies in support of early warning systems for cities, countries and regions, especially experience in climate-weather related and geohazards related early warnings.

While good progress has been made, the experts at the meeting underlined the following to further advancing Early Warning for All (EW4A):

- The systemic risk and complex impact attributes propose challenges for early warning systems. EW4A requires the co-production and co-creation. To navigate

complex climate risks, integrated data systems to collect, analyze, and share information are needed.

- Building human capacity through training and collaboration is key. Historical and disaggregated data provide insights to guide policy and risk reduction.
- The early warning systems are mostly grant-based without private sector participation and there is a significant funding gap. There are new mechanisms such as the Green Climate Fund that can provide support.
- The nexus of climate action, disaster risk reduction, and sustainable development enables holistic resilience. Early warning systems can minimize disaster impacts. Resilience must be strengthened at all levels - individual, community, and national.
- The effectiveness of early warning information is a key concern in the development of MHEWs. Impact-based MHEWs have a unique advantage in transforming from information to behaviors.
- The science stakeholders should continue to communicate between the scientific network and to different stakeholders. It is important to identify what people would like to listen to and what they won't. The efficiency of communication will be improved by using different languages for different audiences.

DRR communities in the region also looked into the perspectives in the use of AI, open science, big data and cloud, and new space observation instruments, and exchanged with international organizations and experts from other regions on both new opportunities and emerging risks including ethical concerns in the use of digital technologies. IRDR Workshop in May 2023 on “New Technology vs Disaster Risk Reduction: Opportunities and Emerging Risks” is one such example (<https://www.irdrinternational.org/news/698>). The establishment of this ecosystem of universities, YYP networks, and scientific programs is pushing the DRR agenda in the Asia Pacific region.



References

Abedin, M. A. (2015). The role of university networks in disaster risk reduction: Perspective from coastal Bangladesh. International Journal of Disaster Risk Reduction. (pg.72)

AHA Centre. (n.d.). ASEAN Coordinating Centre for Humanitarian Assistance on disaster management. <https://ahacentre.org> (pgs. 46, 50)

AI Sub-Group of Early Warnings for All Initiative, ITU (n.d.). <https://www.itu.int/en/ITU-D/Emergency-Telecommunications/Pages/AI-Sub-Group-EW4All.aspx> (accessed June 20, 2024). (pgs. 35- 39)

Miguel Angel Trejo-Rangel, Victor Marchezini, Daniel Andres Rodriguez, Daniel Messias dos Santos, Marina Gabos, Aloísio Lélis de Paula, Eduardo Santos, Fernando Sampaio do Amaral (2023). Incorporating social innovations in the elaboration of disaster risk mitigation policies. International Journal of Disaster Risk Reduction.

Asia Pacific Risk & Resilience Portal 2.0 | Resilience Portal, (n.d.). <https://rrp.unescap.org/> (accessed June 20, 2024). (pg. 35)

Asia and the Pacific SDG progress report 2024 : showcasing transformative actions, ESCAP (n.d.). <https://www.unescap.org/kp/2024/asia-and-pacific-sdg-progress-report-2024> (accessed June 20, 2024). (pgs. 29, 59)

Chaminda, P., Rdg, A., & Richard, H. (2007). Knowledge sharing in disaster management strategies: Sri Lankan post-tsunami context. (pg. 75)

Concilio Grazia., M. S. (2022). Innovation environments and risk management. Economics and Engineering of unpredictable events. 200-215. Compendium of multi-hazard early warning cooperation, ESCAP (n.d.). <https://www.unescap.org/kp/2023/compendium-multi-hazard-early-warning-cooperation> (accessed June 20, 2024). (pgs. 29, 53)

C. Prakasam, A. Rajasekaran, V. Kanwar, N. B., *Design and Development of Real-time landslide early warning system through low cost soil and rainfall sensors*, *Materials Today: Proceedings* 45 (2021). <https://doi.org/10.1016/j.matpr.2021.02.456>. (pg. 36)

D.H. Shugar, M. Jacquemart, D. Shean, S. Bhushan, K. Upadhyay, A. Sattar, W. Schwanghart, S. McBride, M.V.W. de Vries, M. Mergili, A. Emmer, C. Deschamps-Berger, M. McDonnell, R. Bhambri, S. Allen, E. Berthier, J.L. Carrivick, J.J. Clague, M. Dokukin, S.A. Dunning, H. Frey, S. Gascoin, U.K. Haritashya, C. Huggel, A. Kääb, J.S. Kargel, J.L. Kavanaugh, P. Lacroix, D. Petley, S. Rupper, M.F. Azam, S.J. Cook, A.P. Dimri, M. Eriksson, D. Farinotti, J. Fiddes, K.R. Gnyawali, S. Harrison, M. Jha, M. Koppes, A. Kumar, S. Leinss, U. Majeed, S. Mal, A. Muhuri, J. Noetzli, F. Paul, I. Rashid, K. Sain, J. Steiner, F. Ugalde, C.S. Watson, M.J. Westoby, *A massive rock and ice avalanche caused the 2021 disaster at Chamoli, Indian Himalaya*, *Science* 373 (2021) 300–306. <https://doi.org/10.1126/science.abh4455>.

D. Rawat, M.L. Sharma, D. Varade, R. Kumar, D.P. Kanungo, R. Ahmed, S.C. Gupta, H. Singh, N. Saxena, *Early Warning Potential of Regional Seismic Network: Seismic Assessment of One of the Precursors of Chamoli 2021 Disaster*, *Earth Systems and Environment* 8 (2024) 85–104. <https://doi.org/10.1007/s41748-023-00364-y>.

D. Perera, O. Seidou, J. Agnihotri, A.W. Mohamed Rasmy, V. Smakhtin, P. Coulibaly, H. Mehmood, *Flood Early Warning Systems: A Review Of Benefits, Challenges And Prospects*, 2019. <https://doi.org/10.13140/RG.2.2.28339.78880>.

Early warnings for all (EW4All) | UNDRR, (n.d.). <https://www.undrr.org/implementing-sendai-framework/sendai-framework-action/early-warnings-for-all> (accessed June 20, 2024). (pg. 28)

ESCAP. (2023). *Asia Pacific Population and Development Report 2023*. (pgs. 29,53)

Gender-responsive and disability-inclusive early warning and early action in the Pacific region | UNDRR, (2023). <https://www.undrr.org/publication/gender-responsive-and-disability-inclusive-early-warning-and-early-action-pacific> (accessed June 20, 2024).

Global status of multi-hazard early warning systems 2023, (2023).

<https://www.undrr.org/reports/global-status-MHEWS-2023#download> (accessed June 20, 2024).

Greenwood, F., Nelson, E., & Greenough, P. (2020). *Flying into the hurricane: A case study of UAV uses in damage assessment during the 2017 hurricanes in Texas and Florida*. PLOS ONE.

TU Disaster Response, ITU (n.d.). <https://www.itu.int/en/ITU-D/Emergency-Telecommunications/Pages/Response.aspx> (accessed June 20, 2024).

Solferino Academy | Year in Review, (n.d.). <https://solferinoyear.com/> (accessed June 20, 2024).

Kutty, N. (2024). *What Japan can teach us about global disaster preparedness*. World Economic Forum.

Le, H. D., Smith, C., & Herbohn, J. (2014). *What drives the success of reforestation projects in tropical developing countries? The case of the Philippines*. *Global Environmental Change*, 24(1), 334–348.

<https://doi.org/10.1016/j.gloenvcha.2013.09.010>

M.V. Ramesh, H. Thirugnanam, B. Singh, M. Nitin Kumar, D. Pullarkatt, *Landslide Early Warning Systems: Requirements and Solutions for Disaster Risk Reduction—India*, in: 2023. https://doi.org/10.1007/978-3-031-18471-0_21.

Nevo, S., Morin, E., Gerzi Rosenthal, A., Metzger, A., Barshai, C., Weitzner, D., Voloshin, D., Kratzert, F., Elidan, G., Dror, G., Begelman, G., Nearing, G., Shalev, G., Noga, H., Shavitt, I., Yuklea, L., Royz, M., Giladi, N., Peled Levi, N., ... Matias, Y. (2022). *Flood forecasting with machine learning models in an operational framework*. *Hydrology and Earth System Sciences*, 26(15), 4013–4032. <https://doi.org/10.5194/hess-26-4013-2022>

RIMES (Regional Integrated Multi-Hazard Early Warning System). (n.d.). <http://www.rimes.int>

Saha, J. (2023). *10 technologies reducing the impact of natural disasters*. Retrieved from HCLTech.

S. Dixit, S. Siva Subramanian, P. Srivastava, A.P. Yunus, T.R. Martha, S. Sen, *Numerical-model-derived intensity–duration thresholds for early warning of rainfall-induced*

debris flows in a Himalayan catchment, (n.d.).

<https://nhess.copernicus.org/articles/24/465/2024/> (accessed June 20, 2024).

Sufri, S., Dwirahmadi, F., Phung, D., & Rutherford, S. (2020). A systematic review of community engagement (CE) in disaster early warning systems (EWSs). *Progress in Disaster Science*, 5, 100058.

Steven, A. D. L., Baird, M. E., Brinkman, R., Car, N. J., Cox, S. J., Herzfeld, M., Hodge, J., Jones, E., King, E., Margvelashvili, N., Robillot, C., Robson, B., Schroeder, T., Skerratt, J., Tickell, S., Tuteja, N., Wild-Allen, K., & Yu, J. (2019). eReefs: An operational information system for managing the Great Barrier Reef. *Journal of Operational Oceanography*, 12(sup2), S12–S28. <https://doi.org/10.1080/1755876X.2019.1650589>

Trupp, M., Frontczak, J., & Torkington., J. (2013). The gorgon CO2 injection project - 2012 update. *Energy Procedia*, 37, 6237–6247. <https://doi.org/10.1016/j.egypro.2013.06.552>

UNESCO (United Nations Educational, Scientific and Cultural Organization). (2018). *Early warning systems: A state-of-the-art analysis and future directions*. <https://en.unesco.org> (pgs. 46, 50, 51)

UNDRR (United Nations Office for Disaster Risk Reduction). (2015). *Sendai Framework for Disaster Risk Reduction 2015-2030*. <https://www.undrr.org> (pgs. 46, 50)

UNDRR (United Nations Office for Disaster Risk Reduction). (2019). *Global Assessment Report on Disaster Risk Reduction*. <https://www.preventionweb.net> (pgs. 45, 50, 51, 52)

United Nations (2021) *Handbook on Risk-informed Governance and Innovative Technology for Disaster Risk Reduction and Resilience Curriculum on Governance for the Sustainable Development Goals 2021*. <https://unpan.un.org/sites/default/files/d8-files/DRR%20Handbook.pdf> (pg. 42)

University of Sydney (2006) *Collaborating4Inclusion. Disability Inclusive Disaster Risk Reduction (DIDRR) Framework and Toolkit for Collaborative Action*. Centre for

Disability Research and Policy, University of Sydney.

https://collaborating4inclusion.org/wp-content/uploads/2024/05/DIDRR_Framework_FULL-DOC_FINAL_2024.pdf

UNDP (United Nations Development Programme). (2021). *Strengthening early warning systems: A checklist for practitioners*. <https://www.undp.org> (pgs. 50, 51)

UN: *Early Warning Systems Must Protect Everyone Within Five Years* | UNFCCC, (n.d.). <https://unfccc.int/news/un-early-warning-systems-must-protect-everyone-within-five-years> (accessed June 24, 2024).

Community early warning systems: guiding principles -

<https://www.ifrc.org/document/community-early-warning-systems-guiding-principles>

<https://www.undrr.org/news/early-warning-systems-go-global>

<https://reliefweb.int/report/world/community-based-early-warning-systems>

Anticipatory action in 2023: a global overview - Anticipation Hub-

<https://www.anticipation-hub.org/advocate/anticipatory-action-overview-report/overview-report-2023>. (pg. 31)

Seizing the moment: targeting transformative disaster risk resilience | ESCAP (unescap.org)- <https://www.unescap.org/kp/2023/seizing-moment-targeting-transformative-disaster-risk-resilience>

