IRDR
Integrated Research on Disaster Risk

2010–2020

COMPILATION: A TEN-YEAR SCIENCE QUEST FOR DISASTER RISK REDUCTION

Mobilizing Science for
Disaster Risk Reduction and Development Safety

EXECUTIVE SUMMARY


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OE-XHL

Executive Summary

About the IRDR Compilation 2010-2020

The idea of having one single publication that features all significant achievements, the remaining gaps and the lessons learnt by the IRDR community during this ten-year cooperation first came out of discussions at the 21st IRDR Scientific Committee (IRDR SC) meeting in May 2019 in Geneva. In October 2019, at its 22nd meeting in Xiamen, IRDR SC officially decided to go forward with this proposal and set up an editing group. At the same meeting, the publication of IRDR Compilation was set as one of three priority tasks of IRDR in 2020 together with the preparation of new Global Disaster Risk Reduction (DRR) research agenda and the IRDR Conference 2020. In February 2020, at the request of IRDR IPO for support, Aerospace Information Research Institute (AIR), which hosts IRDR's International Program Office (IRDR IPO), provided three young scientists to IRDR IPO to assist with the collection of information from the members of IRDR community and to support the initial compilation and editing. In June 2020, at the 23rd IRDR SC online meeting, in the interest of wider distribution, it was further decided to make the Executive Summary of the IRDR Compilation more content substantive. The possibility of providing the Compilation in multiple languages versions was also discussed.

The IRDR Compilation is intended to be a comprehensive and sound record of IRDR and its work over the past 10 years. Further, to ensure transparency and accountability to IRDR sponsors, donors and members of the IRDR community and their partners, the IRDR Compilation provides a complete set of annexes for reference. In a broader sense, the Compilation also aims to help those who are keen to learn and further explore the international scientific cooperation in the fields of disaster risk research, to understand how an international scientific plan has been put in practice and played a catalytic role in mobilizing scientific forces for knowledge actions, and how to move further with the experience accumulated and lessons learnt.

All information and materials included in the IRDR Compilation come from the contributions of the IRDR community, both institutions and individual researchers, including IRDR SC and IRDR IPO, IRDR Working Groups (WGs), IRDR National Committees (NCs), IRDR International Centres of Excellence (ICoEs), Flagship Projects, IRDR Young Scientists Programme, and main partners of IRDR. The IRDR Compilation also use materials extracted from the records of IRDR related meetings, reports and publications. A comprehensive list of references is provided. The structures and narratives of the Compilation, including the uses of the contribution materials are of the collective work of the editing team.

2 The original mission of IRDR and its evolution

2.1 Understanding risk by integrated research[61]

The ICSU Priority Area Assessment on Environment and its Relation to Sustainable Development (2003) and the ICSU Foresight Analysis (2004) both proposed 'Natural and human-induced hazards' as an important emerging issue. In its assessment, the ICSU Planning Group emphasized that, despite all the

61 This session is mainly summarized from *ICSU (2008) A Science Plan for Integrated Research on Disaster Risk* http://www.irdrinternational.org/2012/12/29/irdr-science-plan/

existing or already planned activities on natural hazards, an integrated research programme on disaster risk reduction, that is sustained for a decade or more and integrated across the hazards, disciplines and geographical regions, would be imperative. The value-added nature of such a programme would rest with the close coupling of the natural, socio-economic, health and engineering sciences. The Planning Group recommended that the Research Programme be named IRDR – addressing the challenge of natural and human-induced environmental hazards (acronym: IRDR).

The rationale of proposing IRDR included the following aspects: 1) Natural disasters are a global issue, and can result in great loss of human lives, livelihoods and economic assets in both developed and developing countries. 2) Human interventions in the environment can also increase the numbers and types of hazards and vulnerability to natural hazards. 3) Climate Changes in global context will continue to alter the risk associated with natural hazards. 4) The international context and the HFA indicated that research to identify and analyse successful risk reduction programmes is very important. For the field of disaster risk reduction, there is neither an established and ongoing scientific assessment process, like the IPCC, nor an internationally planned and coordinated scientific research programme. IRDR would fill that latter gap.

The central mission of IRDR is to develop trans-disciplinary, multi-sectorial alliances for: in-depth, practical disaster risk reduction research studies, and the implementation of effective evidence-based disaster risk policies and practices. The research objectives of IRDR are three-fold: 1) understanding of hazards, vulnerability and risk and enhanced capacity to model and project risk into the future; 2) understanding of the decision-making choices that lead to risk and how they may be influenced; and 3) how this knowledge can better lead to disaster risk reduction. The overall global benefits of the IRDR Programme would be dependent on global capacity building and recognition of the value of risk reduction activities, which are likely to come through successful case studies and demonstration projects (Table 1).

Table 1. IRDR missions

Research Objectives	Cross-cutting themes
Characterisation of hazard, vulnerability and risk Effective decision-making in complex and changing risk context Reducing risk and curbing losses through knowledge-based actions	Capacity building Case studies and demonstration projects Assessment, data management and moni-toring

2.2 From Hyogo to Sendai: IRDR contribution

The Hyogo Framework for Action 2005-2015 (HFA): Building the Resilience of Nations and Communities to Disasters provided critical guidance in efforts to reduce disaster risk and has contributed to the progress towards the achievement of the Millennium Development Goals. However, the implementation of HFA highlighted a number of gaps in addressing the underlying disaster risk factors, in the formulation of goals and priorities for action, in the need to foster disaster resilience at all levels, and in ensuring adequate means of implementation. Ten years after the adoption of the HFA, disasters continue to undermine efforts to achieve sustainable development. Against this background, and in order to reduce disaster risk, the Sendai Framework for Disaster Risk Reduction 2015–2030 was adopted at the 3rd United Nations WCDRR.

IRDR actively contributed to and was integrally involved in the efforts to develop the Sendai Framework. IRDR, in partnership with CAST hosted the 2nd IRDR Conference from 7 – 9 June 2014 in Beijing, China focusing on the theme "Integrated Disaster Risk Science: A Tool for Sustainability". The conference placed emphasis on the importance of science as a tool to address hazard risks, integration and partnership. A key cross-sessional discussion considered the influence of science in HFA and preparations for a new DRR framework which developed into the Sendai Framework. The outcomes of the Conference covered issues on DRR research, education, implementation and practice, and policy implementation for Sendai Framework[62].

IRDR and ICSU acted as the Organizing Partner for the Scientific and Technological Community Major Group (STMG) for the 3rd WCDRR, starting from the First Preparatory Committee Meeting (PrepCom1) in July 2014. IRDR provided an independent collective response to the pre-zero draft, which identified three specific needs, namely to: 1) Develop, on the basis of state-of-the-art prospective knowledge, a forward-looking agenda, notably in terms of linking disaster risk reduction science with the SDGs targets; 2) Emphasise the need for stronger support for science as the foundation for action-oriented cutting-edge knowledge, including necessary monitoring activities; 3) Emphasise the need to better connect national and local levels for the collection and analysis of the necessary vulnerability and loss data as prerequisite for both responsive and preventive planning and investment[63].

Meanwhile, IRDR proposed a '4+2' formula through the statement of STMG to support the implantation of Sendai Framework at the 3rd WCDRR[64]:

- Assessment. Provide analytical tools to advance a comprehensive knowledge of hazards, risks, and underlying risk drivers → regular, independent, policy-relevant international assessment of available science on DRR, resilience and transformations.
- Synthesis. Facilitate the uptake of scientific evidence in policy-making →synthesize relevant knowledge in a timely, accessible and policy-relevant manner.
- Scientific advice. Translate knowledge into solutions → provide advisory capabilities integrating all S&T fields in collaboration with practitioners and policy-makers.
- Monitoring and review. Support the development of science-based indicators, common methodologies and processes → harness / make use of data & information at different scales.
- Communication and engagement. Develop closer partnerships between policy, science and society as well as between researchers → improve the communication of scientific knowledge to facilitate evidence-based decision-making (all levels of government; across society).
- Capacity building. Promote risk literacy through curricular reform, professional training and life-long learning across all sectors of society.

Box 1 Priorities and Targets of Sendai Framework

Sendai Framework[65] proposed four priority areas for sectors to take actions:

62 More details on the outcomes of 2014 IRDR Conference: http://www.irdrinternational.org/2014/08/21/planetrisk-irdrconference2014/

63 The detailed contribution from IRDR towards the Sendai Framework could be referred to the IRDR Annual Report (2014): https://www.wcdrr.org/wcdrr-data/uploads/579/IRDR%20Annual%20Report%202014.pdf

64 The detailed contribution from IRDR to the 3rd WCDRR could be referred to the IRDR Newsletter Vol. 6: http://www.irdrinternational.org/wp-content/uploads/2015/05/IRDR-Newsletter_Vol6-No2-April-2015.pdf

Priority 1: Understanding disaster risk.

Priority 2: Strengthening disaster risk governance to manage disaster risk.

Priority 3: Investing in disaster risk reduction for resilience.

Priority 4: Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation and reconstruction.

Seven targets were agreed upon to be measured at the global level and will be complemented by work to develop appropriate indicators:

(a) Substantially reduce global disaster mortality by 2030, aiming to lower the average per 100,000 global mortality rate in the decade 2020-2030 compared to the period 2005-2015;

(b) Substantially reduce the number of people affected globally by 2030, aiming to lower the average global figure per 100,000 in the decade 2020- 2030 compared to the period 2005-2015;

(c) Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030;

(d) Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030;

(e) Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020;

(f) Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of the present Framework by 2030;

(g) Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030.

2.3 Programme reposition and adjustment over time

The IRDR Science Plan originally published in 2008 was the fundamental document of the programme operations. After the establishment of IRDR programme, the strategic goals and activities to guide the operation of IRDR were further articulated through IRDR Strategic Plan 2013 – 2017[66]. The original three research objectives and three cross-cutting themes were framed into actions in six goals: Goal 1- Promoting integrated research, advocacy and awareness-raising. Goal 2- Characterizing hazards, vulnerability, and risk. Goal 3- Understanding decision-making in complex and changing risk contexts. Goal 4- Reducing risk and curbing losses through knowledge-based actions. Goal 5- Networking and network building. Goal 6- Research Support.

In early 2016, the three co-sponsors of IRDR commissioned an independent, forward-looking mid-term Review covering the first six years of the ten-year program period. The Review Report suggested “rethinking, reforming or reshaping IRDR’s strategy” and “operating IRDR as an ‘action network’ towards collective impact”. In response to these suggestions, the IRDR Scientific Committee presented a draft IRDR Strategic Plan of Action for 2017-2020 at the 16th IRDR Scientific Committee meeting. This was further shaped into the IRDR Action Plan 2018-2020[67], which was adopted in 18th IRDR Scientific Committee Meeting. The new Plan puts forth more forward-looking strategic actions employing evidence-based and science-

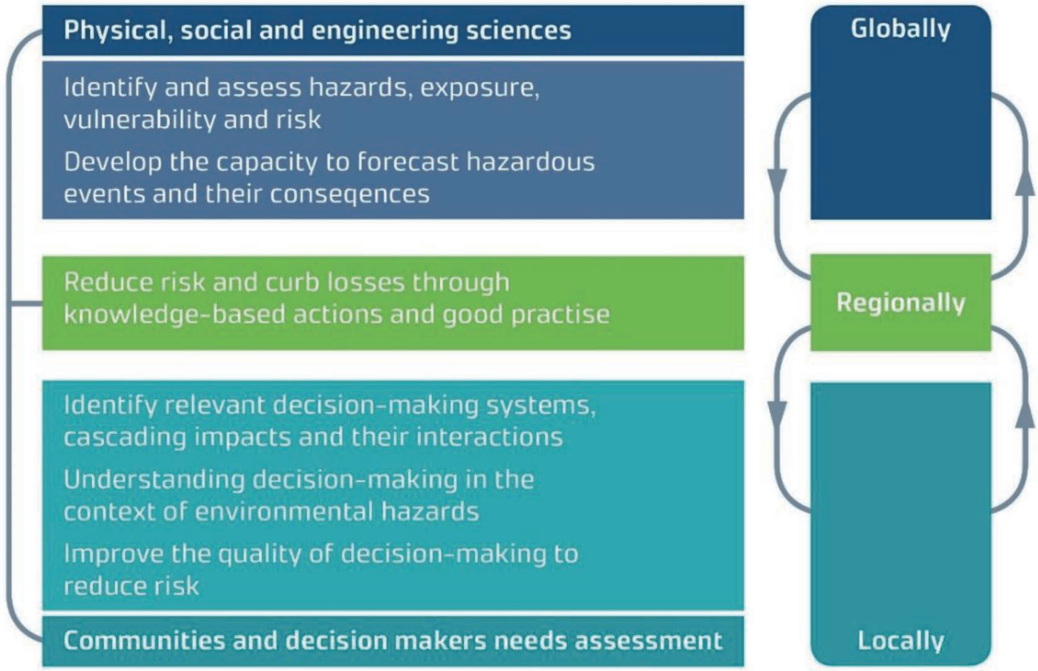
65 https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030

66 http://www.irdrinternational.org/2013/04/15/irdr-strategic-plan-2013-2017/

67 http://www.irdrinternational.org/what-we-do/action-plan-2018-2020/

based decision-making at a crucial time for implementing the Sendai Framework. A total of 23 actions on activities and deliverables were proposed on areas including 1) Science Advocacy at global, regional and national scales; 2) Sendai Framework indicators and strengthening national reporting system; 3) Thematic contribution by Working Groups; 4) Facilitating Associated Projects; 5) Strategic partnership with International Centres of Excellence (ICoEs); 6) Science capacity development: Young Scientists Program; 7) Science outreach by communication strategy and products.

Figure 1: Science behind IRDR: the foundational multi-hazard framework of IRDR to understand and characterize risk, risk production processes and governance, and damage and losses (Fakhruddin & Bostrom, 2019)



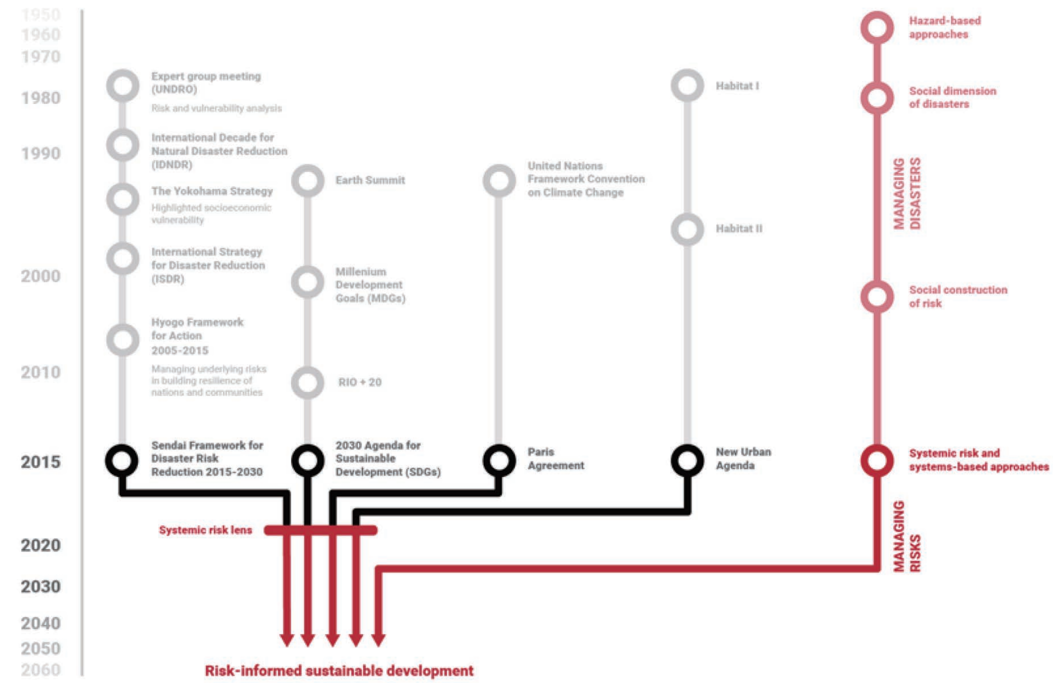
2.4 Further integration with UN 2030 agreements: coherence/ integration/ synergy

In 2015, a number of landmark international agreements were reached at the United Nations. Apart from the Sendai Framework, the world community agreed on Transforming our World: the 2030 Agenda for Sustainable Development (2030 Agenda), the Paris Agreement, the Addis Ababa Action Agenda (AAAA) and the NUA[68]. Each of these agreements has interconnections with the Sendai Framework. It is therefore natural that there have been calls for coherence and synergy to realize the goals and targets of the post-2015 agreements (Figure 2) and make major renovations to current approaches to risk assessment.

68The UN GAR: https://gar.undrr.org/

IRDR has started moving toward this direction. In 2018, IRDR established a new Working Group on DRR-CCA[69]-SDG under its Scientific Committee, to look into the Sendai Framework connections with the Paris Agreement and SDG 11 on cities and SDG 13 on climate change. IRDR also initiated its working paper series to further build the connections between the IRDR research objectives, Sendai Targets, Paris Agreement and SDGs. Increasing discussions and exchanges at IRDR related meetings are focusing on new risks of daunting multi-dimensional, systemic, cascading and transboundary risks and disasters, most recently and overwhelmingly demonstrated by the Covid-19 pandemic. It is clear that the inherent vulnerabilities of our environment and human societies will have to be addressed in transformative ways. In all of these IRDR will have roles to play and work to contribute.

Figure 2: Risk Reduction – a journey through time and space

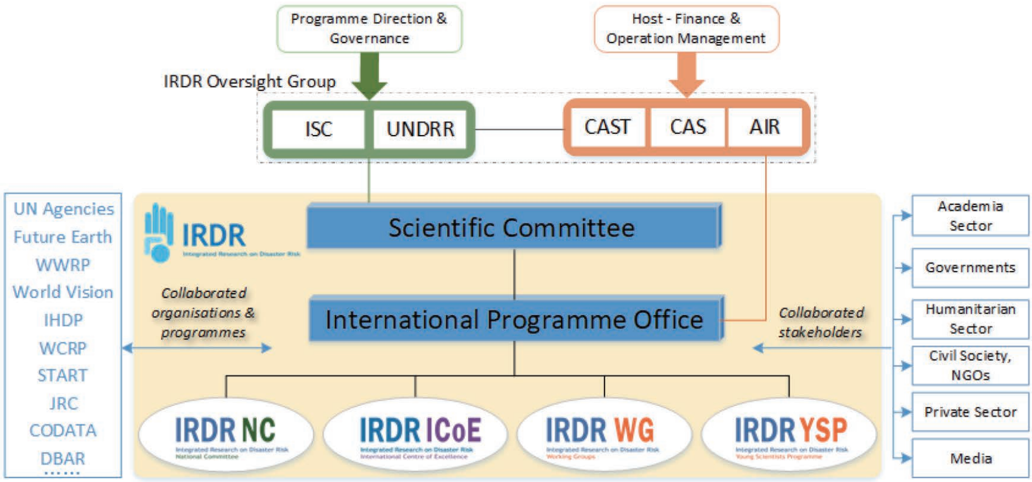


3 IRDR community in action

In line with the IRDR Scientific Plan and under the overall direction of Sendai Framework, IRDR actions are undertaken from its different programme platforms or delivery arms (Figure 3). These include IRDR's six Working Groups (WG) operating under the Scientific Committee, 13 National Committees (NC) and 1 Regional Committee (RC), 16 International Centres of Excellence (ICoE), partnerships with international programmes and organizations, a young scientist (YS) programme and a few cooperative projects. Actions taken by WG/NC/ICoE/YS are under the support of resources from their host institutions. Ownership of the deliverables are shared among host institutions and IRDR.

69 CCA: Climate Change Adaption

Figure 3: **IRDR network and community of practice**



3.1 Root causes of disasters from natural and social perspectives

There is a broad consensus among academics, managers and policy makers within the DRR community that there is insufficient understanding about the underlying or root causes of disasters, including their increased frequency and magnitude. The Forensic Investigations of Disasters (FORIN) Project was initiated by IRDR early in its project cycle as an international response (including both nongovernmental and intergovernmental organizations) to address this knowledge deficiency. The FORIN perspective formalizes the analytical space and agenda for root causality research, enabling a form of analysis that conceptualizes disasters as intrinsic to development and societal processes. Four research approaches are suggested by FORIN including retrospective longitudinal analysis (RLA), FORIN disaster scenario building (FDSB), comparative case analysis, and Meta-analysis(Oliver-Smith et al., 2016). The FORIN perspective and approach postulates that disasters are linked both by systemic causes and by their widespread and expanding consequences, and can be seen as an epidemiological approach to disaster study. IRDR has worked to increase and strengthen the knowledge that underlies evidence-based policy making for disaster risk management at all levels of governance and geographical scales.

3.2 IRDR Peril Classification and Hazard Glossary

In 2014, the IRDR Disaster Loss Data (DATA) WG produced a Peril Classification and Hazard Glossary. This glossary provides guidelines on event classification and a unified terminology for operating loss databases only(IRDR, 2014). Though not intended as a comprehensive list of perils or as a conclusive definitional standard of hazards, this technical paper details the classification scheme and hazard definitions used in loss database, and provides information that has been implemented over time by global databases such UN DesInventar, EM-DAT, NatCatService, and Sigma as well as in national databases such as SHELDUS (US).

Figure 4: Peril classification at the Family and Main Events levels

3.3 IRDR contribution to Sendai Hazard Definition and Classification Review

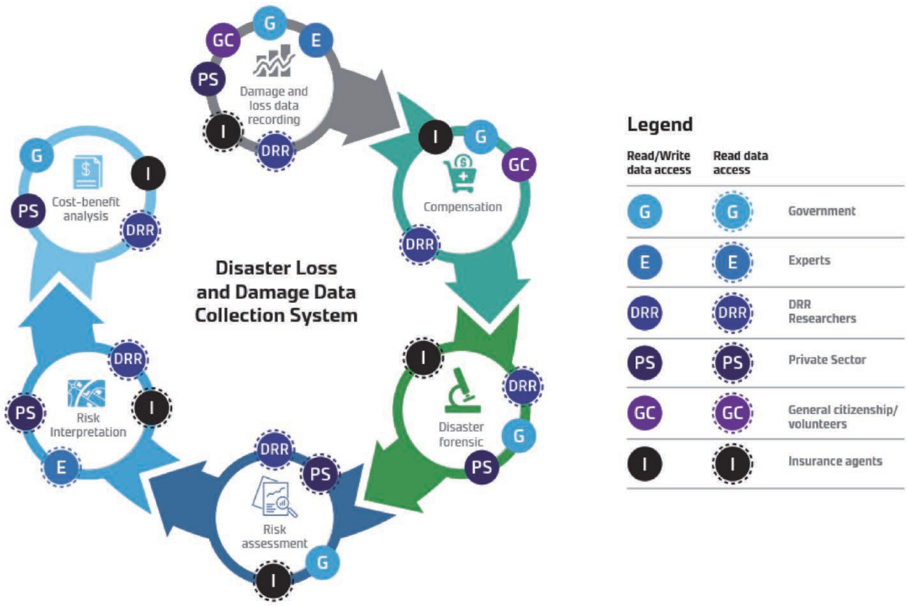
During the *International Conference on Integrated Science & Technology Contributions for Informed National Policy-Making and Action for the Implementation of the Sendai Framework*, a key component of the 20th IRDR SC meeting in 2018, IRDR and UNDRR STAG discussed on the category of Sendai New Hazards, in particular regarding Na-Tech. At the Science and Policy Forum at the 2019 Global Platform for Disaster Risk Reduction (2019GP), UNDRR and ISC announced a Joint Technical Working Group to identify the full scope of hazards relevant to the Sendai Framework and the scientific definitions of these hazards. IRDR actively participated in this working group. Within this context, the current iteration of the hazards list was reviewed during the 22nd IRDR SC meeting, and key themes were identified using a stakeholder survey. Approximately 20 DRR experts participated in this workshop. Five key points, including purpose of the hazards list, clear inclusion criteria, systematic thinking, dissimilarities across nations, and review of the template, were identified during this meeting. The Sendai Hazard Definition and Classification Review Technical Report was then issued on 29 July 2020.

3.4 Standardizing Disaster Loss Data

Disaster reconnaissance and loss data collection are fundamental for a comprehensive assessment of socially, temporal and spatially disaggregated loss data. Standardized loss data is quite useful for risk interpretation during loss forecasting and historical loss modelling, which in turn provide valuable opportunities to acquire better information about the economic, ecological and social costs of disasters. The **IRDR Disaster Loss Data (DATA) WG** is an initiative contributing to the solution of standardising disaster loss data. This project brings together stakeholders from across disciplines and sectors to study issues related to the collection, storage and dissemination of disaster loss data. The aim of this project is to establish an overall framework and protocols for disaster loss data and the collecting of such (Figure 5) for all providers, to establish nodes and networks for databases, and to conduct sensitivity testing among databases to ensure some level of comparability. This project proposed a standard data collection system, which has been adopted by many countries. The project has also led to the production of unified standards on disaster loss assessment and an integrated methodology for disaster loss assessment.

Two successful examples of IRDR's implementation of disaster loss databases include the New Zealand National Loss Database and the Pacific Damage and Loss (PDaLo) Information System. Additional countries that have implemented disaster loss databases include: Cambodia, Nepal, Iran, Timor-Leste, Vietnam, Myanmar, Philippines and Pakistan. The outcomes of this WG has been regularly published in the DRR and Open Data Newsletters

Figure 5: The Disaster Loss and Damage Data Collection System



released monthly by IRDR, CODATA, Public Health England and Tonkin+Taylor.

3.5 Science and technology roadmap to support the Sendai Framework

The science and technology community, as well as other stakeholders, came together at the UN Office for Disaster Risk Reduction (UNISDR) Science and Technology Conference held from 27- 29 January 2016 in Geneva. The outcome of the conference was a ‘Science and Technology Roadmap to Support the Implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030’ and accompanying partnerships. At the 20th IRDR Scientific Committee meeting 2018, a discussion was organized to review and contextualize the Roadmap with four key questions on 1) implementation of the roadmap, 2) monitoring mechanism, 3) link to national platforms, 4) advocacy messages. The discussion reviewed the original roadmap, developed an outcome matrix, synthesized and organized roadmap actions, integrated 2017 Tokyo Statement recommendations, integrated additional action points based on gap analysis, and restructured S&T roadmap actions and implementation strategies.

During the 2019 Global Platform for Disaster Risk Reduction, IRDR, together with UNDRR and ISC, organized a pre-conference “Science and Policy Forum for the Implementation of Sendai Framework for Disaster Risk Reduction”. In this Forum, the contextualized Global Science and Technology Roadmap was launched as a living document to be implemented by the S&T community with a strong partnership with other stakeholders. The core purposes for future development of the roadmap include: 1) Evidence-based policy and decision making; 2) Consolidation of science effort for collective impact; 3) Interlinkages and interconnection among stakeholders, including S&T community. Progress was suggested to be tracked and monitored via the Sendai Framework’s Voluntary Commitments online platform.

3.6 Policy recommendations for regional and national levels

IRDR is keen to enhance the role of science in policy development. To this end, IRDR has provided science-based evidence and advice to decision makers and policy makers. After Sendai 2015, IRDR has published policy briefs on critical issues relating to the implementation and monitoring of the Sendai Framework. At the 2017GP, IRDR published five policy briefs and added another two during the 2019GP (Figure 6). During the same year, IRDR launched the IRDR Working Paper Series[70] that called for authors to clearly indicate the contribution to targets of the Sendai Framework and SDGs and provide detailed recommendations to DRR policy (Figure 7).

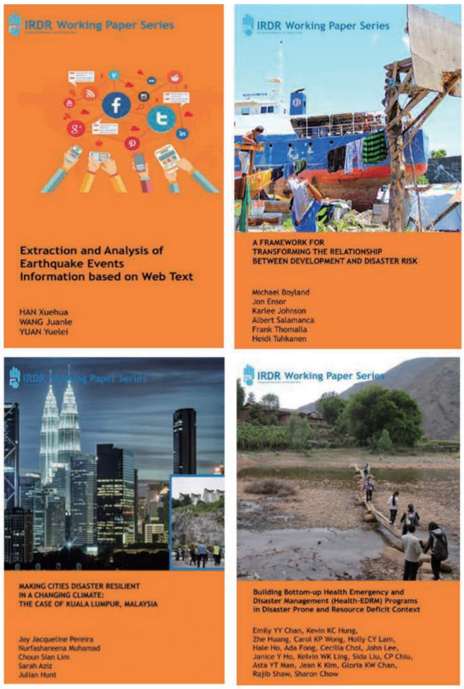
Box 2 IRDR Policy Briefs for Global Platform on Disaster Risk Reduction[71]

2017

- Coherence between the Sendai Framework, the SDGs, the Climate Agreement, New Urban Agenda and World Humanitarian Summit, and the role of science in their implementation (by Virginia Murray, Rishma Maini, Lorcan Clarke, Nuha Eltinay)
- Assessing country-level science and technology capacities for implementing the Sendai Framework (by Rajib Shaw)
- Disaster loss data in monitoring the implementation of the Sendai Framework (by Bapon Fakhruddin, Virginia Murray, and Rishma Maini)

Figure 6: **ISC-IRDR joint policy brief**

Figure 7: **IRDR Working Paper Series**



70 http://www.irdrinternational.org/2019/05/11/irdr-working-paper-series-volumn-1/

71 http://www.irdrinternational.org/2017/05/12/irdr-published-5-policy-briefs-for-2017-global-platform-for-drr/
https://council.science/current/news/isc-launches-policy-briefs-ahead-of-the-un-global-platform-on-disaster-risk-reduction/

- Forensic Investigations of Disaster (FORIN): towards the understanding of root causes of disasters (by Anthony Oliver-Smith, Irasema Alcántara-Ayala, Ian Burton and Allan Lavell)
- Cities and Disaster Risk Reduction (by Mark Pelling, Donald Brown and Fang Chen)

2019

- Disaster Loss Data In Monitoring The Implementation Of The Sendai Framework (by Bapon Fakhruddin, Virginia Murray and Fernando Gouvea-Reis)
- Achieving Risk Reduction Across Sendai, Paris And the SDGs (by John Handmer; Anne-Sophie Stevance, Lauren Rickards, and Johanna Nalau)

IRDR has also collaborated with UN APSTAG to examine the science and technology development status for DRR and recommended 14 priority actions for improvement (*Asia Science Technology Status for Disaster Risk Reduction* and *Science & technology into action: Disaster risk reduction perspectives from Asia*) in 2016 and 2018; and ISC ROAP and other sectors to illustrate the science and technology plan for DRR (*Science Technology Plan for Disaster Risk Reduction: Asian and Pacific Perspectives*) in 2017; Digital Belt and Road (DBAR) DRR Working Group on *Strengthening Science Capacities for Sustainable Development and Disaster Risk Reduction: Regional Research Strategy* in 2017.

In addition, **IRDR NC-Colombia** published a series of risk management guides for both public and decision-makers. The development of the Policy Guidelines for public, private and community sectors in disaster risk management guides the instruments for the actors involved in risk management, at all territorial levels and areas of action. Besides, a series of publications[72;73;74] that guide decision-making for the operation of the National Disaster Risk Management System at the territorial level, and used to achieve the public policy for disaster risk management in the nation. Among them, a short guide entitled "What You Should Know About Forest Fires[75]" aimed to inform, increase awareness and promote community participation on risk management of forest fires.

3.7 Characterization of hazards, vulnerability and risk in countries and regions

IRDR has also actively worked to identify and assess risks from natural hazards at global, regional and local scales, and develop capability to forecast hazardous events and their consequences. For example, **IRDR ICoE for Disaster Resilient Homes, Buildings and Public Infrastructure (IRDR ICoE DRHBPI, Canada)** has expertise in hazard mapping and risk mapping. It has worked on flood mapping and corresponding science-based report for public use, providing information on what flood maps are and their importance; how to address inundation and other hazards and risks and raise community awareness; and the availability of such maps in Canada (The Institute for Catastrophic Loss Reduction, 2019).

Another achievement is the development of the Social Vulnerability Index (SoVI®) and the Baseline Resilience Indicators for Communities (BRIC) due to the efforts of IRDR **ICoE Vulnerability and Resilience Metrics (IRDR ICoE-VaRM, USA)** in cooperation with the Hazards & Vulnerability

72 https://repositorio.gestiondelriesgo.gov.co/handle/20.500.11762/20604

73 https://repositorio.gestiondelriesgo.gov.co/handle/20.500.11762/27251

74 https://repositorio.gestiondelriesgo.gov.co/handle/20.500.11762/27698

75 https://repositorio.gestiondelriesgo.gov.co/handle/20.500.11762/28309

Research Institute (HRVI). Both indices provide empirically-based measurements for comparing the differential impact of disasters, as well as differences in the abilities of communities and the individuals who reside there to adequately prepare for, respond to, recovery from, and enhance resilience to present and future disaster risks[76;77].

Similarly, **IRDR Center of Excellence in Understanding Risk & Safety (IRDR ICoE UR&S, Colombia)** was involved in the development of the Global Risk Model for Global Assessment Report on Disaster Risk Reduction 2013 (GAR2013)[78]. The Centre further developed Brief Risk Profiles for over 200 countries and economies based on the update of the Global Multi-hazard Risk Assessment for the UNISDR GAR15[79], developed a Global Drought Probabilistic Hazard and Risk Model within the framework of the Comprehensive Approach to Probabilistic Risk Assessment (CAPRA)[80], and contributed to the improvement and integration of the UNISDR Risk Knowledge Section to the New Generation CAPRA Robot platform. Besides, the Risk Atlas of Colombia[81] has been prepared by the National Unit for Disaster Risk Management, which is the host of **IRDR NC-Colombia**, and by INGENIAR Risk Intelligence, a leading company in the country in risk management. This product arises given the need to advance in the knowledge of risk at the national and regional level, taking into account that the entity's mission is to improve people's quality of life and contribute to sustainable development. The Atlas provides a better understanding of disaster risk in its dimensions of hazard, vulnerability, degree of exposure, and characteristics of the environment in the country.

IRDR NC-China conducted a continuous tracking study on geological disasters in earthquake areas for more than ten years. Collaborated with the Cardiff University (UK) research team, NC-China studied the dynamic response of slope surface to mega earthquakes, the gestation and formation mechanism of large landslides, and the temporal and spatial evolution law of geological disasters after earthquakes and their long-term effects. It is the first time to combine geological disaster research with sociological research to deeply analyse the impact of geological disasters on the social, economic, and post-disaster resilience of people in the disaster-stricken area in emergency response, post-disaster reconstruction, and recovery stages (Fan et al., 2019).

76 http://www.sovius.org

77 http://artsandsciences.sc.edu/geog/hvri/bric

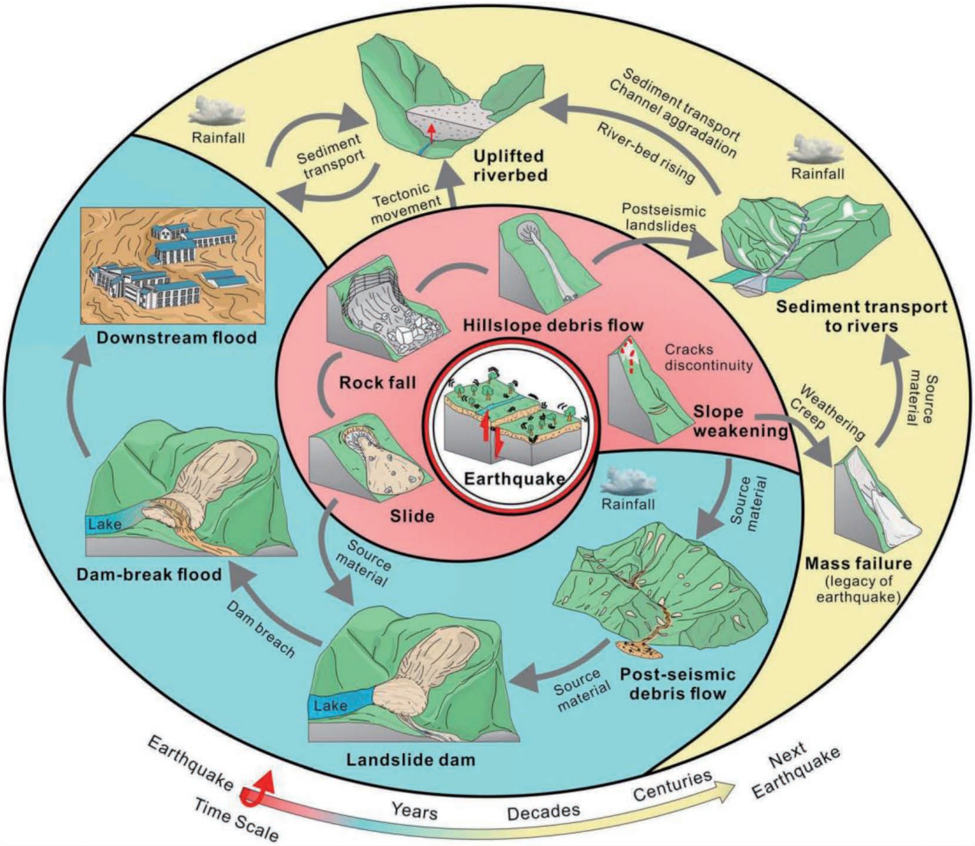
78 https://www.preventionweb.net/english/hyogo/gar/2013/en/home/download.html

79 https://www.preventionweb.net/english/hyogo/gar/2015/en/home/

80 https://ecapra.org/

81 https://repositorio.gestiondelriesgo.gov.co/handle/20.500.11762/27179

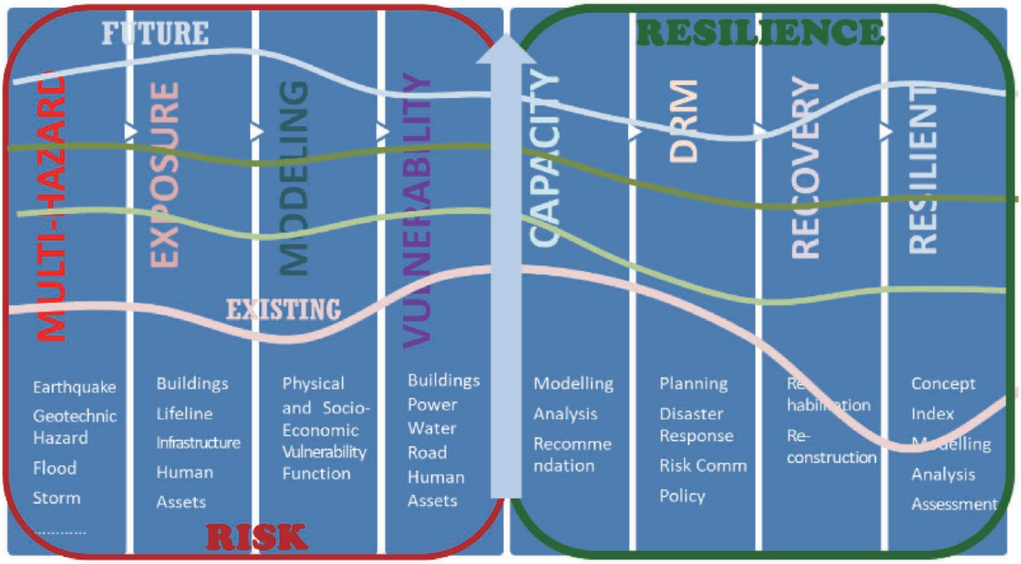
Figure 8: **Chains of geologic hazards triggered by a strong continental earthquake and reviewed in this work. Causal relations between hazards are indicated. Red background shows different types of coseismic landslides; blue background indicates the post-seismic cascade of hazards in days to years later; and yellow background represents the long-term impact of an earthquake, years to decades later, and perhaps longer.**



Triggering and controls on coseismic geo-hazards	Triggering and controls on post-seismic debris flows	Post-seismic landslides and their hazard	Long-term impact of strong earthquakes
• Mapping, spatial distribution patterns	• Case studies and inventory	• Distribution patterns and spatio-temporal evolution	• Weathering-related post-seismic landsliding
• Initiation and failure mechanism analyses	• Initiation and runout: mechanisms and modelling	• Controls on the post-earthquake geo-hazards evolution	• Sediment cascade and yield after a strong earthquake
• Evaluation of runout characteristics	• Observations and modelling of changing rainfall thresholds	• Susceptibility and hazard assessment	• Long-term landscape evolution: the mass balance problem
• Controls on formation and failure of coseismic landslide dams	• Structural and non structural risk management and mitigation	• Risk assessment and reconstruction strategies	• Tectonic control on landslide occurrence

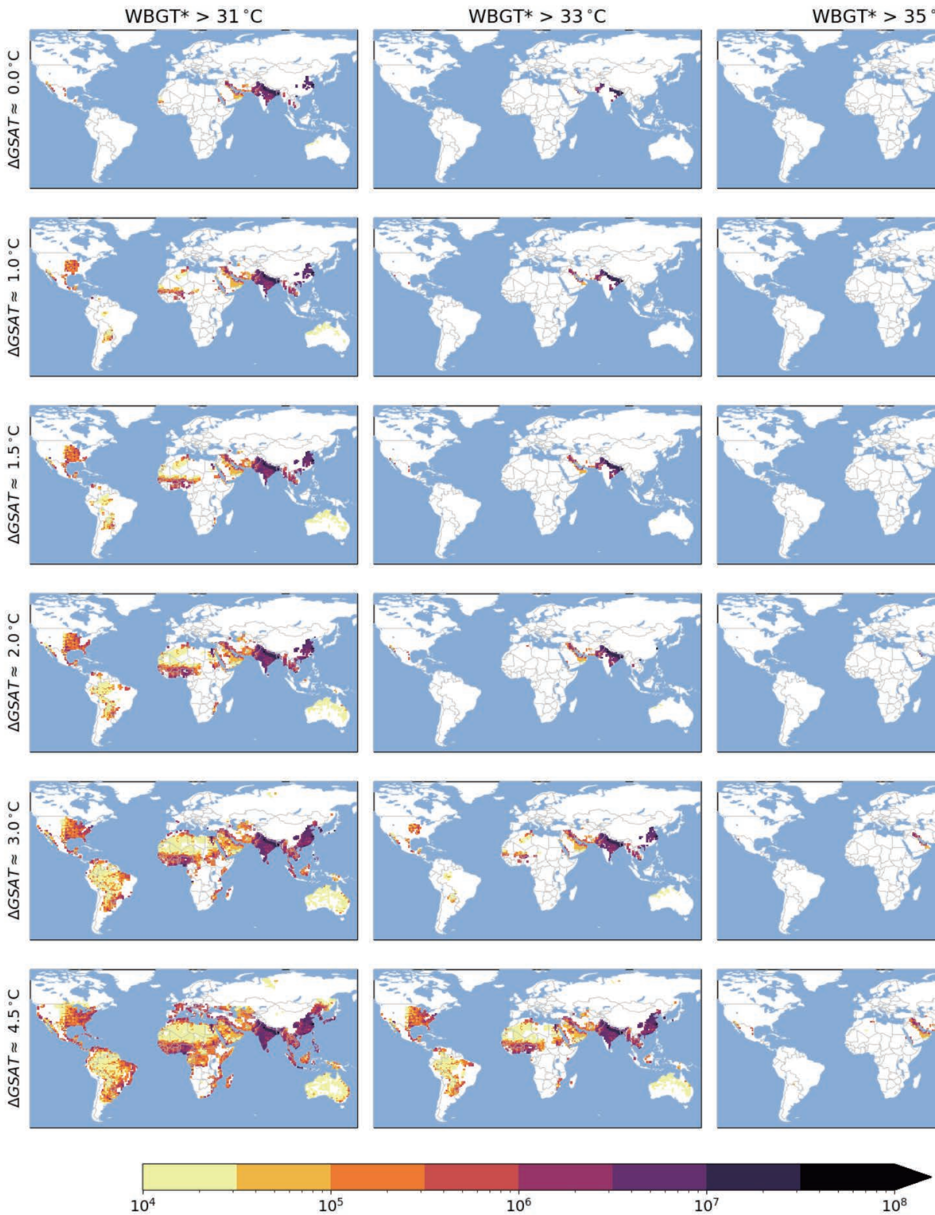
Currently an integrated and comprehensive Natural Hazards Risk and Resilience Model (Figure 9) for Iran is under development by **IRDR NC- Iran** targeting the quantification of actual risk (physical, social and economic loss); as well as definition of the acceptable level of risk and the target resilience with the emphasis on the main urban settlements (Atrachali et al., 2019).

Figure 9: Integrated and comprehensive Hazard, Vulnerability, Risk and Resilience Model



IRDR ICoE on Risk Interconnectivity and Governance on Weather/Climate Extremes Impact and Public Health (ICoE-RIG-WECEIPHE, China) developed a statistical model based on quantile regression approach to capture the joint distribution of temperature and humidity (Yuan et al., 2020). They found that the intensity of heat stress in a day at a given maximum daily temperature will increase in a warming climate due to the increase of humidity. Li et al. (2020) evaluated future changes in daily compound heat-humidity extremes as a function of increasing global-mean surface air temperature (GSAT). The historical ~1 ℃ of GSAT increase above preindustrial levels has already increased the population annually exposed to at least one day with WBGT exceeding 33 ℃ (the reference safety value for humans at rest per the ISO-7243 standard) from 97 million to 275 million. Maintaining the current population distribution, this exposure is projected to increase to 508 million with 1.5 ℃ of warming, 789 million with 2.0 ℃ of warming, and 1.22 billion with 3.0 ℃ of warming (similar to late-century warming projected based on current mitigation policies).

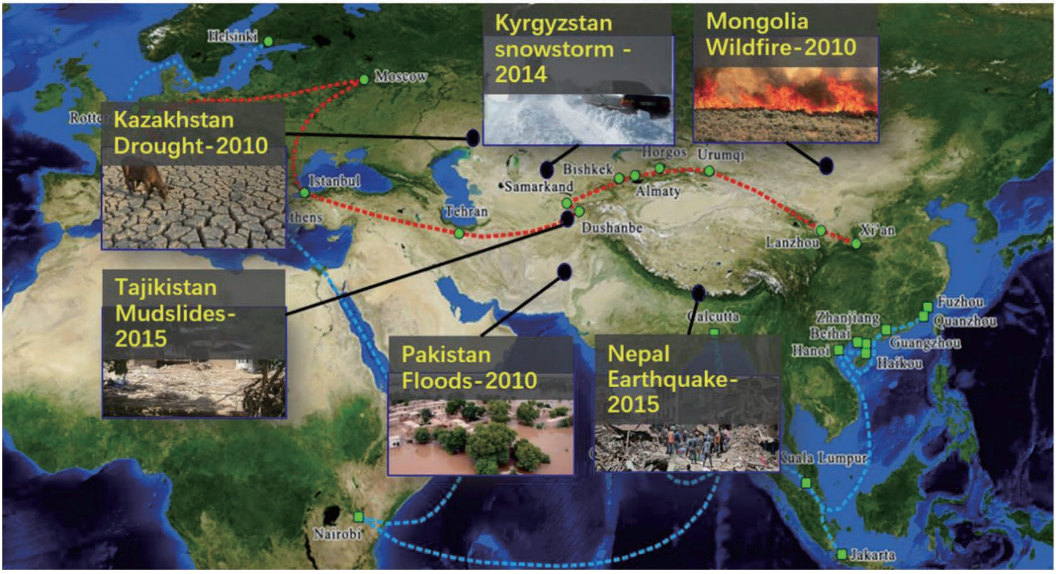
Figure 10: **Maps of population affected by at least 1 day per decade of WBGT*max greater than 31°C (left column), 33°C (middle), and 35°C (right). Colours represent population in each nominal 1 degree grid cell. WBGT* statistics is based on output from 40-member CESM-LE RCP8.5 simulations (Li et al., 2020)**



3.8 DRR data production and sharing

In order to be able to determine the consequences of environmental hazards and disasters in terms of their impacts and effects, **IRDR NC-China**, taking advantage of a wide variety of earth observation datasets including meteorological satellites (FY series), resource satellites (CBERS series, ZY series), ocean satellites (HY series), environment and disaster reduction satellites (HJ series), and high-resolution satellites (GF series),conducted collaborative researches to develop effective methods, models, and technologies for quick response to disasters. For example, NC-China analysed the systemic risks of various disasters in the completion of new type of urbanization processes, and recommended countermeasures and suggestions. The report was included in the UN Global Assessment Report on Disaster Risk Reduction 2019 (Chen et al., 2019). Besides, NC-China also carried out systemic spatial monitoring to characterize environmental effects of disasters on multi-regional and diversified geomorphology units in the Belt and Road region, and developed key regional disaster products for the areas where disaster statistics data were lacking or in low accuracy, benefiting from the CAS Big Earth Data Science Engineering Program (CASEarth)[82].

Figure 11: **Disaster risk in "One Belt One Road"**



3.9 Multi-scale disaster risk assessment

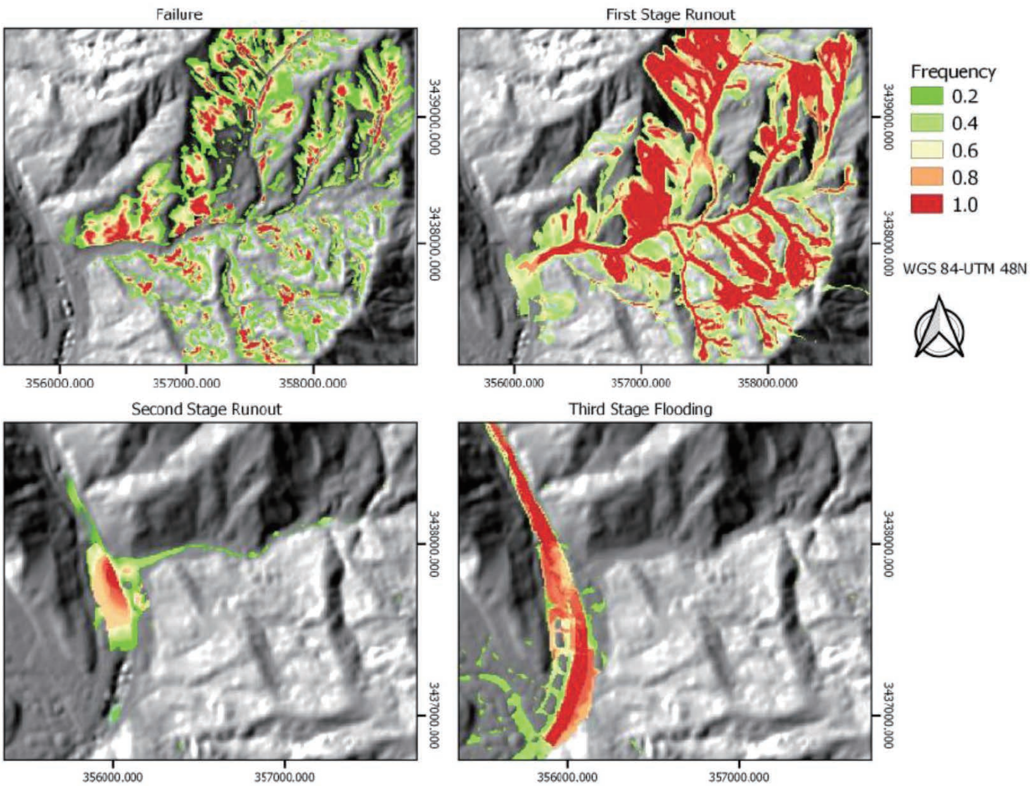
In line with the Sendai Framework and the 2030 Agenda, the Silk Road Disaster Risk Reduction (SiDRR) international research program was launched in 2016 (Lei et al., 2018) with the task of enhancing global actions towards the green and resilient Silk Road by joining forces with over 20 research institutes and scientists globally. As a Flagship Project of IRDR, the SiDRR aims to provide scientific suggestions and support for decision-makers in countries along the Silk Road

82 http://belt.china.org.cn/index.htm

to minimize disaster losses in their respective economic development. The program mainly assessed five types of hazards and corresponding risks including mass movements, floods, droughts, earthquakes, and ocean hazards at global, regional, local and infrastructure-oriented scales. The research results of SiDRR have been consolidated in the "Atlas of Silk Road Disaster Risk" and "Glance at the Silk Road Disaster Risk". These two publications provide important references to understand disasters and disaster risk from a multi-stakeholder perspective and aid stakeholders in scientific decision-making in line with the Sendai Framework and SDGs.

A single extreme weather event such as a tropical cyclone or monsoon can compound hazard effects, domino effects of hazard chains. Very often when we look at these situations, we use models for each hazard separately but this is not what stakeholders experience. Hence, **IRDR ICoE in Spatial Decision Support for Integrated Disaster Risk Reduction (IRDR ICoE-SDS IDRR)** is developing a multi-hazard model that can simulate a number of these processes simultaneously, whereby the landscape can change during the event. This model (**openLISEM**, https://blog.utwente.nl/lisem/) is free and opensource and is constantly under development as new areas are simulated (Van Den Bout et al., 2020). Such a model is hard to calibrate but at the time it gives a more realistic perspective on impact of hazard processes.

Figure 12: Example of domino effects simulated with openLISEM in Hongchun (China): First stage are slope failures, developing into debris flows (2nd stage) developing into a debris flow dam in the river (3rd stage) and causing a flash flood (4th stage) (Van Den Bout et al., 2020).



IRDR ICoE on Critical Infrastructures and Strategic Planning (IRDR ICoE-CI&SP, Germany) aims at exploring the resilience of Critical Infrastructures from various perspectives in order to provide a comprehensive platform for this evermore-important topic and to substantially advance the depths and breadths of the currently narrow approaches. In this regard, the analysis of the resilience of Critical Infrastructures, such as energy, water, transport, health services, will not primarily focus on technical details of the respective systems, but rather on cross-cutting and interdisciplinary challenges that are, for example, linked to the identification of interdependencies and cascading risks between Critical Infrastructures or to the shifting governance implications, including new organizational requirements and behavioural adaptations.

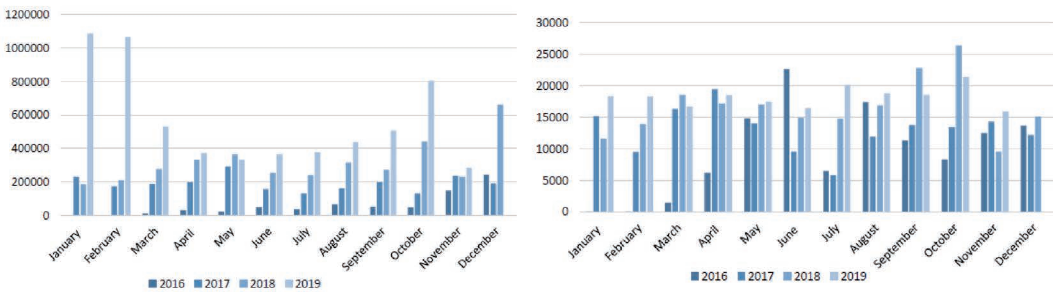
3.10 Knowledge exchange and service

To facilitate knowledge consilience on disaster and environmental risk reduction and to improve disaster resilience ability, an indispensable element of sustainable development, it is important to ensure that all stakeholders involved in disaster risk reduction have access to each other's contributions in various forms. **IRDR NC-Japan** provided such a platform, which is idea-specific in concept and designed to establish a national synthesis reporting system for disaster risk reduction. An internet-based system for collecting, analysing, publishing, re-analysing, critiquing, and reusing data and information for improving disaster resilience, it is a tool to promote "consilience" of knowledge and practice. This concept was first discussed at the Tokyo Resilience Forum 2017, where dozens of experts expressed their opinions and suggestions, acknowledged on the need for this periodic synthesis reports system (Hayashi et al., 2018).

Another important achievement is developing education materials to improve disaster knowledge and guide public response to disasters. For this purpose, the National Disaster Management Research Institute (NDMI) of Republic of Korea (the host of **IRDR NC-Republic of Korea**) developed DRR related education videos guiding public response to accidents from flood damages, a constant risk to human lives in the region during the summer season. In 2016 they also inaugurated a Web-GIS based data sharing tool 'Typhoon Disaster Information System (TCDIS)' to provide a comprehensive and integrated disaster information system. The system not only helps improve understandings of typhoons as natural phenomena and their impacts on the natural and social environment, but further strengthens international cooperation and information sharing of disaster management[83].

Similarly, **IRDR ICoE for Risk Education and Learning (IRDR ICoE-REaL)**, affiliated with the Partners Enhancing Resilience for People

Figure 13: **Left: Monthly searches performed on the ORC during Phase IV, Right: Monthly PDF view performed on the ORC during Phase IV**.



83 www.tcdis.org

Exposed to Risks (PERIPERI U), launched the Online Resource Centre, a digital database of disaster risk literature, articles, reports and other documentation. The primary goal of this initiative was to offer a platform to students across the partnership to access to disaster-risk related documents and to assist them with their learning and research. With increasing needs for systematic data management, the secretariat recruited a dedicated 'data capturer' in June 2017. This appointment strengthened maintenance support for the Online Research Centre (ORC)[84], as well as increased its capacity to upload and categorize electronic copies of reports, articles and documents onto the site. Since the launch of the ORC in early 2016, over 12.9 million searches have been conducted with over 660 000 PDF viewed (Francioli et al., 2020).

The Centre for Integrated Research on Risk and Resilience (CIRRR), which hosts **IRDR ICoE in Risk Interpretation and Action (IRDR ICoE-RIA, UK)**, brings together researchers from across disciplines in order to explore risk and resilience as ways of understanding and responding to social, ecological and political crises today. ICoE-RIA conducted a series of projects which were funded or partly funded by the Department for International Development (DFID) of UK. For example, the programme Urban ARK, led by King's College London with Professor Mark Pelling as Principal Investigator[85], focused in depth studies on a number of cities in Africa – each presenting different development and hazard contexts: Ibadan (Nigeria), Karonga (Malawi), Nairobi and Mombasa (Kenya), Niamey (Niger), Dakar (Senegal) and Freetown (Sierra Leone). The work highlights urbanisation processes that generate human vulnerability and exposure to a whole spectrum of hazards. Another DFID-funded programme, the Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED), helped people to become more resilient to climate extremes in South and Southeast Asia and in the African Sahel and its neighbouring countries[86]. To improve the integration of disaster risk reduction and climate adaptation methods into development approaches, BRACED seeks to influence policies and practices at the local, national and international levels.

3.11 Connecting science, practice with decision-making

It is important to provide decision-makers with the evidence, information and tools to make the necessary critical decisions. For example, for several years now, **IRDR NC-France** has been implementing territorial management approaches based on risk approaches. These approaches are often "hazard-centered", i.e. depending on the threat of the phenomena (e.g. earthquake, flood, ground movement, explosion, etc.), analysis of the territorial locations exposed to such hazards are characterized and vulnerabilities identified. These approaches strongly rely on the information from specialized hazard maps and prevention maps that are drawn up. In addition, hazards-forecasting approaches, decision-making systems, vulnerability assessments and capacity building have also been further developed and/or established. Others such as **IRDR NC-USA** have undertaken several research initiatives to understand decision-making and disaster management. One example of such is the publication of a report identifying stakeholder values in the context of Hurricane Michael using semi-structured interviews to understand what public and private stakeholders valued during different phases of the hurricane (Zhang, Pathak, & Ganapati, 2019). **IRDR ICoE for Collaborating Centre for Oxford University and CUHK (IRDR ICoE-CCOUC)** published a scientific report in partnership with IRDR and Asia Science Technology and Academia Advisory Group of the

84 http://lib.riskreductionafrica.org/

85 https://www.ucl.ac.uk/bartlett/development/research-projects/2020/nov/urban-africa-risk-knowledge-urban-ark

86 http://www.braced.org/

United Nations Office for Disaster Risk Reduction (UNDRR ASTAAG) titled"Co-designing Disaster Risk Reduction Solutions"in May 2017 which served as one of the core scientific evidence report in health and disaster for policy and decision making at the 2017 UNDRR Fifth Global Platform for Disaster Risk Reduction in Mexico.

Scientific networks are also critical in communicating and sharing important information with different stakeholders. **IRDR ICoE-Taipei** aims to build such networks that integrate scientific knowledge, policies, and practices, and seeks to connect young and senior scholars, decision-makers, and stakeholders. Towards this goal, the ICoE-Taipei, focusing on the "Communication and engagement"and"Capacity building"components of the"4 +2 formula" developed by IRDR and delivered through the STMG Statement (refer to Section 1.2), extended these two formulae into concrete tasks. These tasks include building the capacity for countries in the Asia-Pacific region, facilitating collaborative research, and establishing an effective open platform to connect scientists, engineers, government officers, practitioners, and stakeholders to roadmap Sendai Framework priorities (Table 2).

Planning for the future is also critically important for decision makers and to facilitate disaster preparedness. **IRDR NC-Australia** held an extensive discussion on the best knowledge to deal with the extreme hazards in the future that are of a nature and scale beyond our current experience during the June 2019 12th Australasian Natural Hazards Management Conference and worked through a strategic view on the current availability of such knowledge. A summary of the discussions during the conference extends the collective strategic view for scientific

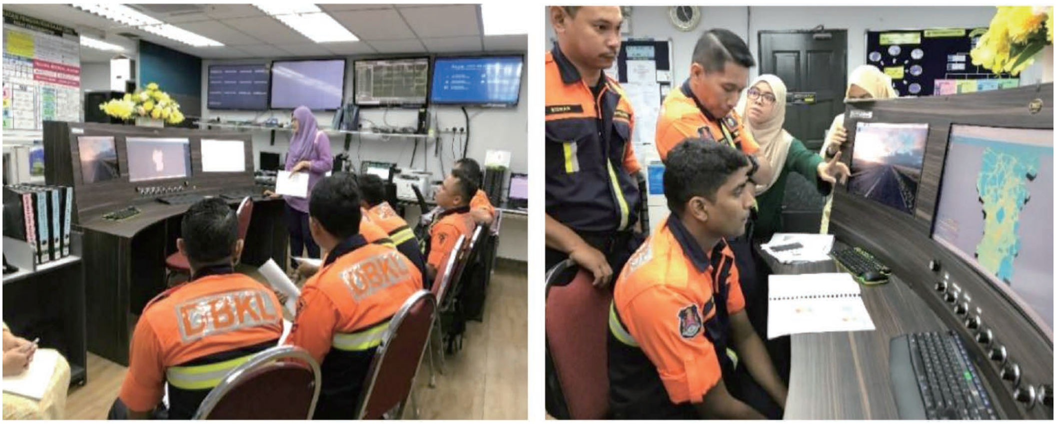
Table 2. 2011-2019 IRDR ICoE-Taipei Activity Roadmap for the Implementation of SFDRR[87]

SFDRR / IRDR ICoE-Taipei	Priority 1: Understanding disaster risk	Priority 2: Strengthening disaster risk governance to manage disaster risk	Priority 3: Investing in DRR for resilience	Priority 4: Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction
Capacity Building	• TW-NDRMA 2016 • AI-SOCD 2017 • AI-LRR&TS 2018 • TC-EHRA 2018 • AI-Hi-ASAP 2019 • AI-Hi-ASAP 2020	• TW-SAMD 2015	• TW-MFSWRST 2016	• AI-DATA 2012 • AI-FORIN 2012 • AI-DRRLM 2015 • AI-KBA 2017 • AI-SOCD heat 2018 • TC-EEW 2019 • TC-LIHM 2019 • AI-ACV 2019
Collaborative Research	• Seed Grant: AI-LRR&TS • Seed Grant: TC-EHRA • Seed Grant: AI-SOCD 2017 • Seed Grant: AI-Hi-ASAP 2019	• Seed Grant: AI-Hi-ASAP 2020		• Seed Grant: AI-DRRLM • Seed Grant: AI-SOCD heat • Seed Grant: AI-KBA 2017 • Flagship Project
Networking	• Young Scientists Conference • Workshop on Exposure Assessment	• PARR Fellowship • Workshop to Strengthen Scientific Advisory Capacities • Relevant Meetings	• CAR II 2011 • Flagship Project • Relevant Meetings • PIAD	• WSS-ISSC Seminar • PIAD • Relevant Meetings
Others	• Visiting Scholar	• SAB meeting • Visiting Scholar	• WSS-ISSC Seminar	• Report: FORIN case study • Article: Improved Evacuation Procedures • Article: Improved Evacuation Procedures

Note: AI-Advanced Institutes, TW-Training Workshops, TC-Training Courses

87 http://www.cfss.sinica.edu.tw/index.asp?url=102&cno=8

Figure 14: **The DBKL officers are being trained to use the Kuala Lumpur Multi-hazard Platform as part of their routine operations.**



research to improve decision-making to prepare for the future we are likely to encounter (Bates, 2020).

3.12 Risk assessment and planning in urban context

Urban areas are complex environments with interconnected services networks feeding economic growth but also facilitating stability and supporting large human settlements. With both high concentration of population and capital, planning for disasters in urban areas is more complicated and highly essential to ensure minimal mortality, economic losses and disruption of essential services. Kuala Lumpur Multi-hazard Platform, developed by **IRDR ICoE for Disaster Risk and Climate Extremes (IRDR ICoE-SEADPRI-UKM)**, which is now operational at the Emergency Response Department of Kuala Lumpur, Malaysia and provides forecasts of rainfall, temperature, wind, humidity, air quality levels at the street level, is a good example of disaster risk management, and a key product of the project titled "Disaster Resilient Cities - Forecasting Local Level Climate Extremes and Physical Hazards for Kuala Lumpur" (Pereira et al., 2019)(Figure 14). This open-access multi-hazard platform with crowd-sourcing capability will be a game changer in promoting transformative action to build community resilience as the climate changes (Pereira & Hunt, 2019). It is supposed to serve as an important legacy of the IRDR Program in the region.

Another important contribution is that of **IRDR NC-Germany** through the German Committee for Disaster Reduction (DKKV), which designed the Risk Assessment Model Simulation for Emergency Training Exercise (RAMSETE) "serious game" series. The exercises focus on the challenges highlighted by the Enhancing Synergies for disaster PRevention in the EurOpean Union (ESPREssO) project (Lauta et al., 2018). A series of RAMSETE have been published aiming to maximize the security and well-being of the population of a fictional country by integrating DRR and CCA policies, to manage a cross-border natural crisis, and to addresses three main challenges: 1) Find ways to make national and European approaches to DRR, CCA and resilience more coherent; 2) Improve risk management by bridging the gap between research and policy/law; 3) The management of cross-border crises is to be made more efficient.

In 1998, a mega-flood swept through China's major river basins, including the Yangtze, Songhua, Nen, Min, and Pearl Rivers, which caused 4150 deaths, and led to total economic losses of USD 70 billion (in 2015 USD). In 2016, the middle and lower reaches of the Yangtze River suffered the worst flooding since 1999, involving

5 provinces. China is expected to suffer two-thirds of the global direct production losses caused by floods, totalling USD389 billion during 2016-2035 (Willner et al., 2018). In order to curbing losses from floods, **IRDR NC-China** put forward to pay high attentions to post-disaster reconstruction and actively advance the comprehensive water governance mode of human-water harmony; take the approach of systematic governance for middle and small rivers and change 'passive governance' to 'positive governance'; strengthen the basic research (Cheng et al., 2018). Novel flood adaptation policies are required to address the (uncertain) future challenges. Such policies should be based on a well-established and up-to-date risk assessment, which accounts for future changes in climate and socioeconomic conditions (Du et al., 2019).

3.13 "Build back better": learning from catastrophes and disasters

The Christchurch earthquake in February 2011 was a turning point for both researchers and policy makers. **IRDR NC-New Zealand**, the global leader in the development of post-disaster recovery indicators, published a Canterbury Wellbeing Index and Survey and contributed to international recovery knowledge(Morgan et al., 2015). The Canterbury earthquakes also highlighted the pivotal role provided by Iwi and Māori stakeholders in recovery efforts (Kenney & Phibbs, 2015). A research program examining the impacts of liquefaction, soil profiles and triggering factors was initiated. Researchers have updated the Detailed Seismic Assessment Guidelines for building materials, and developed Guidelines for Earthquake Geotechnical Engineering Practice in New Zealand. The lessons from Christchurch were put to good use following the 2016 Kaikoura Earthquake[88].

Figure 15: Left: Dislodged boulders near the RSA clubrooms following the Feb 2011 Christchurch earthquake. Photo: Margaret Low, GNS Science; Right: Rockfall following the Christchurch earthquake. Photo: GNS Science.

88 https://www.naturalhazards.org.nz

After Nepal was stricken by a magnitude 7.8 earthquake on 25 April 2015, the National Reconstruction Authority (NRA) of Nepal (the host of **IRDR NC-Nepal**) envisioned the "establishment of well-planned, resilient settlements and a prosperous society". The NRA has been leading and coordinating multi-hazard resilient reconstruction, retrofitting and restoration of damaged infrastructures and houses, as per the Sendai Framework that recognizes the post-disaster reconstruction as an opportunity to build back better. It is identifying appropriate sites to resettle displaced communities, building resilient communities and developing opportunities for economic growth[89]. In addition, **IRDR ICoE for National Society for Earthquake Technology- Nepal (IRDR ICoE-NSET)** developed a "Shake Table Demonstration and Landslide Demonstrator" (Figure 16). This is an awareness tool used for demonstrating and convincing people on the effectiveness of earthquake- and landslide-resistant construction practices. Following the principle of "Seeing is Believing", NSET successfully organized more than 100 demonstrations in more than 10 Asian countries including in Japan during the UN World Conference on DRR in 2015[90].

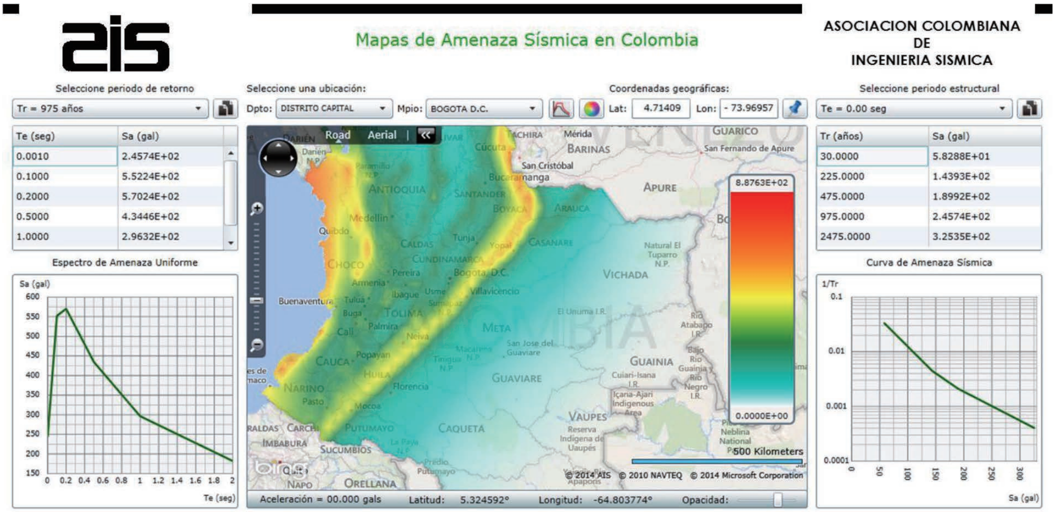
Concerning the general seismic hazard study, **IRDR NC-Colombia** describes a new methodology used to estimate different expected seismic intensities for designing and constructing earthquake-resistant buildings in Colombian territory. The Committee in Colombia (named as AIS-300) has evaluated the seismic hazard at the national level using updated information in

Figure 16: Shake-table demonstration set up of NSET (Source: NSET, Safer Society Report 2018)

89 http://202.45.147.136/np/resources/details/AbZnecDkSg-o91EuriI2HENgq_XAvy_ZYCvQiuiKEao

90 https://www.nset.org.np/nset2012/images/publicationfile/Safer_Society_2018.pdf

Figure 17: AIS platform to obtain the parameters of the country's seismic threat



the framework of the update of the Colombian Seismic Design Code of Bridges. In terms of the catalog used, five more years of information and strong motion attenuation ratios calibrated from local records. This update evaluated the seismic hazard with a probabilistic and spectral approach to establish the values of the seismic design coefficients associated, with a probability of exceedance of 7% in 75 years, which is roughly equivalent to an average recurrence period of 975 years[91].

The Indonesian Institute of Sciences (Lembaga Ilmu Pengetahuan Indonesia; LIPI; the host of **IRDR NC-Indonesia**) took part in the Community Preparedness (COMPRESS) Program in 2006-2012. The Indonesian Tsunami Warning System (InaTEWS), landslide warning system and related disaster policies at national and local level came out during this time. InaTEWS is an operational activity carried out by Agency for Meteorology, Climatology and Geophysics as a part of governmental duty which provides meteorology, climatology, and geophysics services including public information, early warning, and specific information (Harig et al., 2020).

IRDR ICoE-DRHBPI, affiliated with the Institute for Catastrophic Loss Reduction (ICLR), also has been addressing priority issues related to the risks for homeowners, such as basement flooding, construction of disaster-resilient homes and enhancing the resilience of existing homes (Kyriazis et al., 2017).

3.14 Assessment of Integrated Research

The concept of IRDR became cleared through series of researches made by the **IRDR AIRDR WG**. Integrated research examines problem - focused, socially - driven research questions that cannot be adequately addressed by one or a small number of research disciplines, or without collaborative problem solving and real - world engagement of non - academics. Integrated research permits a more comprehensive understanding of the construction of a particular disaster situation, context, or problem and also provides policy - relevant information for social interventions designed to reduce risk. An integrated research approach requires diverse epistemologies, theories, and methodologies, with no prior assumptions about the primacy of each in

91 https://repositorio.gestiondelriesgo.gov.co/handle/20.500.11762/19790

addressing the problem.

The need for integrated research follows from the complexity of disaster risk, which cannot be understood comprehensively by a single discipline alone. Integrated research is the foundation and the evidentiary basis for the development of effective disaster risk reduction strategies. The AIRDR WG reviewed the state-of-the-art knowledge about disaster risk. Its results provide an empirical basis for tailoring research agendas and informing the post-Hyogo Framework. The objective is to assess: 1) How does our present understanding of hazards and disaster risk, the result of research undertaken during the past 10 to 20 years, help us understand past and present patterns and trends in disasters? 2) What is well-known within the research community in terms of capacity, technology, tools, methodologies, and translation of findings to actions? What is less well-known in the research and where do these shortcomings come from (e.g., hazards or perils studied, regional understanding, spatial or temporal coverage of topics)? 3) How does our existing scientific knowledge help us to understand disaster risk under conditions where disasters may be increasing in frequency and intensity and where vulnerability and exposure heighten the impacts of disasters?(IRDR_AIRDR_WG, 2014)

3.15 Key innovations in DRR

IRDR DRR-CCA-SDGs WG in collaboration with Tohoku University, Keio University, and United Nations University conducted an online survey from December 2018 to January 2019 to identify 10 most important innovations, from the global to local level, dealing with impacts of climate risks employing improved/expanded livelihood strategies (Izumi et al., 2019). The list of innovations provided options between 30 innovative products (14) and approaches (16) that have already contributed to reducing disaster risks and are considered to be extremely effective at it. The survey involved non-traditional actors such as local communities, SMEs, NGOs and received a total of 228 responses from universities (145), government (30), NGOs (24), the private sector (6), international organizations (16), and others (7). The survey requested to select three innovations considered most effective. The top ten innovations selected were as follows (table 3):

Table 3. The top ten innovations from the global to local level

	Innovations
1	Community-based disaster risk reduction/risk management
2	Hazard mapping
3	GIS and remote sensing
4	Assessments and index approach: Vulnerability assessment, resilience, sustainability
5	Disaster risk insurance
6	National platforms for disaster risk reduction
7	Social networking service/system (SNS)
8	Drones
9	Disaster resilient materials
10	Indigenous DRR technology
11	Crowdsourcing

3.16 Risk Interpretation and Action – Multi-hazard early warning systems

Decision-making under conditions of uncertainty is inadequately described by traditional models of rational choice. Traditional models do not consider how people's interpretations of risks are shaped by their own experiences, personal feelings and values, cultural beliefs and interpersonal and societal dynamics, and how these interpretations of risks affect the choose of actions an individual may take.

To improve the understanding on these matters, one of Flagship Projects **the Risk Interpretation and Action (RIA) WG's** has prioritized is the enhancement of impact-based early warning systems for countries vulnerable to multi-hazards. IRDR, together with the World Meteorological Organization, International Science Council (ISC) and Tonkin and Taylor International, promoted an end-to-end early warning system-based guideline comprised of ten essential elements that work together to create a single, cohesive and robust warning system. Multi-hazard early warning system projects have been commissioned for more than 25 countries including nations in the Caribbean, Africa, South-east Asia, and the Pacific. Multiple nations have successfully implemented or improved their Early Warning System (EWS) using this philosophy.

Figure 18: The concept of multi-hazards early warning systems

The RIA working group made three observations: (1) Risk interpretation and action is not just psychological, but also social and cultural; (2) effective communication of risks is relevant for numerous policy domains, especially with regard to the goal of effectively informing individual decision-making, but there is an ongoing need to shift from risk communication to risk engagement across these domains; and (3) there is a continued need for collective, multiscale, multi-actor, multi- and transdisciplinary exploration of risk interpretation and action, in addition to the need to further explore risk interpretation and action at the individual, psychological scale. Each of these observations previews themes that have been important in disaster risk research historically, as well as in recent advances (Fakhruddin & Bostrom, 2019).

3.17 Mobilization of and investment in young professionals

The IRDR Young Scientists Programme was first conceived in 2014 with a World Social Sciences Fellows Workshop at the IRDR ICoE-CR, and formally started in 2016, with applications accepted twice a year. Already 162 young researchers from 46 countries have been involved in this programme, including 43 female researchers following 4 batches of selection. The academic background of these young scientists ranges from traditional disciplines such as Geography, Biology, Engineering, Computer Science, Architecture, Anthropology, Economy, and Law, to the integrated and cross-cutting disciplines such as Disaster Risk Management, Climate Change and Adaption, Social Resilience, DRR Communications, Disaster and Emergency Health, and Disaster Nursing. The application proposals accepted by IRDR focus on the mechanisms of disaster processes, and the development of a comprehensive understanding of disaster risk, community resilience, and public awareness.

The IRDR Young Scientists Programme establishes a network for the capacity building of a new generation of DRR specialists and researchers. Not only are the participants active in their respective research fields, but they are also contributing to communicating DRR knowledge to local communities. IRDR encourages young scientists to build and promote regional and national DRR young scientists' networks. The IRDR has connected young researchers to its network of professionals and practitioners, and encouraged them to participate in IRDR-related training programmes. Some IRDR young scientists have published their research results in academic books or special reports in collaboration with IRDR Scientific Committee members (e.g., Sword-Daniels et al., 2016) and IRDR partners such as the UN Major Group for Children & Youth (UNMGCY). More than 40 of these young researchers since 2016 have joined training programmes organized by the IRDR ICoEs, such as ICoE-Taipei and ICoE-CCOUC in Hong Kong, and the IRDR partnership with the Digital Belt and Road (DBAR) programme of CAS. Together with UNESCO and IDMR of Sichuan University, the U-INSPIRE Alliance was established and several national chapters were also organized, with IRDR young scientists playing leading roles in their establishment.

4 IRDR capacity building for DRR Science

In IRDR Science Plan, capacity building is considered as one of the cross-cutting themes. Capacity or capability can be defined as a combination of all the strengths and resources available within a community, nation or region that can reduce the level of risk, or the effects of a disaster. It includes physical, institutional, social or economic means such as financial, political and technological resources, as well as skilled personal or collective attributes such as leadership and management at different levels and sectors of the society. Capacity building aims to develop knowledge, human skills and societal infrastructures within a community, nation or region in order to reduce the level of risk. Over the last ten years, IRDR indevoured the capacity development for DRR science in two dimensions: 1) through a structure approach, IRDR developed a science community to connect IRDR Science Plan with Sendai Framework by concrete actions. 2) through diffusion of knowledge and technical solutions to enhance DRR institutions and individuals in countries and communities.

4.1 Capacity within IRDR

IRDR is co-sponsored by the International Science Council (ISC, which was created in 2018 as the result of a merger between the ICSU and the ISSC) and the United Nations Office for Disaster Risk Reduction (UNDRR, former acronym is UNISDR). The execution of IRDR programme promotion, coordination and related functions is undertaken by the IRDR IPO. The IPO is located in Beijing, China and is hosted by the Aerospace Information Research Institute (AIR, formerly the Institute of Remote Sensing and Digital Earth (RADI)) of the CAS. Funding is provided by the CAST.

IRDR is governed by a Scientific Committee (SC) set up by and on behalf of the Co-Sponsors. In the past ten years, IRDR SC embraced in total 41 outstanding experts from a diverse range of disciplines with regional and gender balance. Its responsibilities are to define, develop and prioritise plans for the IRDR, guide its programming, budgeting and implementation, establish a mechanism for oversight of programme activities, and disseminate and publicise its results on behalf of the co-sponsors.

13 IRDR National Committees (NCs) and one Regional Committee (RC) were established to support and supplement IRDR's research initiatives, and help to establish or further develop crucial links between national disaster risk reduction programmes and activities within an international framework. NCs and RC helped foster the much-needed interdisciplinary approach to disaster risk reduction within national scientific and policy-making communities, and served as important national focal points between disciplinary scientific unions and associations.

16 institutions joined IRDR as ICoEs and provided regional and research foci for the IRDR programme. In particular, each established ICoE enabled regional scientific activities through geographically-focused contributions based on more localised inputs, and by being visible centres of research to motivate participation in the IRDR programme.

IRDR established six Working Groups (WGs), to meet IRDR's research objectives and cross-cutting themes and to formulate new methods in addressing the shortcomings of current disaster risk research. 162 young scientists joined the IRDR Young Scientists Programme, an initiative started from 2016 to promote capacity building of young professionals and to encourage them to undertake innovative and needs-based research which strengthens science-policy and science-practice links.

4.2 Institutional capacity, technical trainings and Partners

Working with ISC, UNDRR and partners

IRDR collaborates with other ISC Interdisciplinary Bodies (IBs), members and regional offices on numerous DRR activities. There is a close and long-term collaboration between IRDR and CODATA through IRDR DATA Working Group. A large number of policy briefs, webinars, workshops on the DRR data issues have been developed in collaboration and a regular DRR and Open Data Newsletter is published. IRDR, Future Earth and World Climate Research Programme (WCRP) have been involved in the discussions that led to the creation of the Knowledge Action Network on Emergent Risk and Extreme Events, with some IRDR scientists still involved as the members of Development Team and co-chairs of Working Groups. One example of joint activities between IRDR and WCRP was a 3-week advanced course entitled "Institute of Advanced Studies in Climate Extremes and Risk Management" for 39 young researchers from 17 countries (Figure 19). IRDR SC members and ICoEs have also worked with the DRR working groups of ISC regional offices in Latin America

Figure 19: Group discussions and research communications

and the Caribbean and in Asia Pacific on several projects and events. In particular, IRDR and ISC ROAP successfully helped 12 countries in this region to develop the Science Technology Plan for Disaster Risk Reduction for implementing the Sendai Framework.

Besides UNDRR and its branches, IRDR works with other UN agencies to addressing DRR among multi-stakeholders. IRDR has worked hand in hand with UNDRR STAG to coordinate scientific inputs into the Sendai Process. IRDR has organized science and policy dialogues with the support of UNDRR and ISC in the bi-annual global and regional platforms, regional ministerial conferences and regional science and technology conferences on DRR. Together with the UNDRR regional office in Asia and Pacific and AP-STAG, IRDR and academic stakeholders examined the Science and Technology Status for the implantation of Sendai Framework every two years. As to other UN agencies, for example, IRDR cooperates with UN-SPIDER to promote the digital technology and space data sharing and applying in DRR, with UNESCO to protect World Heritage properties through DRR solutions, and with WMO on the development of International Network on Multi-hazard Early Warning Systems (INMHEWS).

IRDR also signed agreements or memorandum of understanding with parties from different sectors to better conduct the DRR research and practice. IRDR and Disaster Risk Reduction Knowledge Service Sub-Platform (DRRKS), International Knowledge Centre for Engineering Sciences and Technology of the Auspices of UNESCO signed a MoU to promote the DRR data and knowledge sharing. IRDR helped World Vision review the theories and methodologies adopted in its community DRR practice and training. START International Inc. provided seed funding for young researchers through joint projects initiated by IRDR ICoEs. In the Belt and Road Region, IRDR collaborated with Silk Road Disaster Risk Reduction and Digital Belt and Road on science and technology capacity building through transboundary research activities and DRR data sharing.

Essential roles of IRDR NCs and ICoEs in capacity building

IRDR NCs and ICoEs are deeply engaged in DRR capacity building on research and practice at the regional, national and local levels. They provide DRR knowledge and solutions through educational events and trainings targeted towards researchers, decision-makers, investors, and the public to strengthen science and technology capacity and increase DRR awareness. Since 2012, ICoE-Taipei has held twelve Advanced Institutes (AIs) focusing on integrated approach and hosted more than 300 scientists and/or practitioners in these training courses. Between 2016 – 2019, ICoE REaL (based in South Africa) through its host Periperi U expanded its academic programmes and modules boosting the consortium's academic portfolio to 47 offerings. A particular milestone for PERIPERI U was achieving 40.6% female student representation across its various academic offerings, as a major challenge in a field which has been largely dominated by men and across a continent in which women's participation in academia still face many obstacles and challenges (Figure 20). NC China together with CAS-TWAS Centre of Excellence on Space Technology for Disaster Mitigation (SDIM) provided a series of remote sensing technology trainings for over 150 early career young scientists from developing countries. NC Nepal implemented several specific Community Based Disaster Risk Management (CBDRM) programs through NSET and NRA of Nepal on the localization of DRR to link science, technology and national and global policy frameworks to the last mile. NC-Iran provided a "Safe Schools, Resilient Communities" Programme to raise awareness of resilience at local level and engage local communities in DRR activities and empower them to become prepared to respond to potential earthquakes(Amini-Hosseini & Izadkhah, 2020). NC-Australia has hosted a series of free public forum on the International Day for Disaster Reduction (13 October) since 2014 focusing on the latest research, policies and practices targeted at reducing the number of people affected by natural disasters around the world.

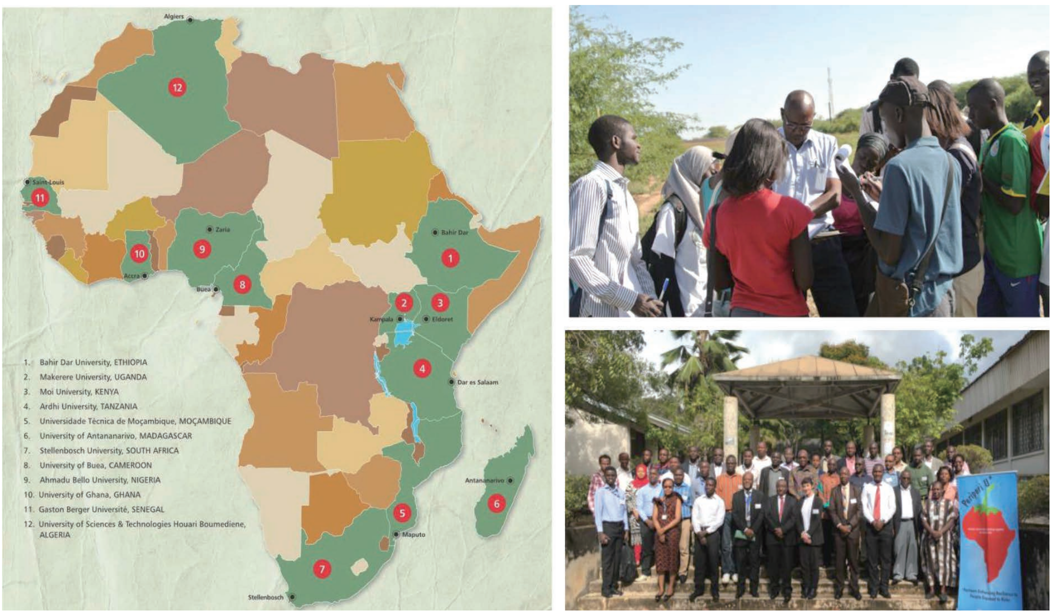
5 Gaps and Challenges

5.1 The legacy envisaged

In the IRDR Science Plan, the legacy of the IRDR programme would be "an enhanced capacity around the world to address hazards and make informed decisions on actions to reduce their impacts. This would include a shift in focus from response–recovery towards prevention–mitigation strategies, and the building of resilience and reduction of risk, and learning from experience and avoidance of past mistakes". An important part of the legacy would be the repository of coordinated and integrated global data and information sets across hazards and disciplines that would be of continuing availability and value to communities at all levels, from local to global.

IRDR makes great efforts in framing and establishing an integrated approaching to disaster

Figure 20: Periperi U partner universities and the activities



risk. The community and the research cover the natural, socio-economic, health and engineering sciences. Through its actions and capacity building, IRDR has to some extent shaped some global and local discussion on the multi-stakeholders' engagement in DRR.

The global science landscape on DRR and the context has changed rapidly. One of the key revolutions is the formulation of Sendai Framework and other important global frameworks in particular SDGs, Paris Agreements, New Urban Agenda. The IRDR Science Plan was formed at an early stage of Hyogo Framework, and strongly reflected its alignment with HFA with a keen focus on hazard research. However, the trend has now changed to resilience related research, and focus more on the socio-economic context. Complex, cascading disasters, climate risks become more prominent in recent years, and policy research on these has become increasingly important. Though IRDR adjusted its strategy and actions in the second half of the decade, it still faces new challenges to reorient itself toward 2030 and beyond.

5.2 Research Gaps: new uncertainty and new agenda

As was underlined at the Global Platform for Disaster Risk Reduction in May 2019, the world is increasingly threatened by the occurrence of both familiar and unfamiliar transboundary, systemic and cascading hazards and disaster risks in a hyperconnected and rapidly changing world. In the brief period since 2019, we have witnessed extensive wildfires, extreme weather events, outbreaks of desert locusts crossing continents and, worst of all, the Covid-19 pandemic. The pandemic in particular has clearly highlighted the underlying vulnerabilities ingrained in our social, economic and financial systems, thereby supporting the call of the Sendai Framework for a new, more comprehensive, multi-hazard and systemic approach to disaster risk reduction and resilience. The need for science and its application for evidence informed policies and related legal and regulatory frameworks and action across all sectors and communities has never been greater.

In the oversight committee meeting of2019, ISC and UNDRR suggested the development of a global research agenda to guide the work of scientists, researchers, academics, technical institutions in both the public and private sectors, and to build the evidence base needed for risk-informed decision-making in all geographies, sectors and scales. The Agenda proposed new strategic areas of cooperation in DRR science and policy, namely in: Data and knowledge; New and existing technologies – development, application and access; Scientific understanding on increasing risks and uncertainties; Science, policy and society engagement, dialogue and action; Institutional capacity development; Collaborative global and regional governance of transboundary risks; and Private sector impetus towards DRR.

5.3 Challenges and lessons learnt in IRDR programme management

The 2016 IRDR Mid-term Review panel's overall assessment of the IRDR programme was that upon its establishment, IRDR was a well-conceptualized, timely and innovative - potentially even pioneering - initiative in the increasingly important domain of disaster risk reduction. Its design was ambitious. It reflected the effort needed to bring to fruition a global research program that had to promote and demonstrate new ways of thinking and working in order to influence policies and practices that benefit societies and vulnerable communities around the world.

Meanwhile, the Review delivered a critical assessment of the achievements of the programme to date, and in particular, the limited scientific outputs demonstrating the value of integrated research for disaster risk reduction, issues with the governance and management arrangements of the programme, and a lack of funding beyond the core funding for the secretariat to support impactful scientific activities. The Review urged to take actions to enhance IRDR NCs and ICoEs in the overall programme delivery.

The Review Panel made five key suggestions: 1) Adjust the program scope and direction, 2) Improve the business model, 3) Sharpen governance, 4) Improve management, 5) Move towards collective impact. The panel further suggested that more direct and regular interactions between the sponsors, the IPO, the scientific committee chair and the host was needed.

Furthermore, while lack of regular project funding remains a critical problem, the roles and position of NCs and ICoEs in the programme governance has not been fully addressed. Due to NCs' and ICoEs' institutional capacity and functions in DRR practice, their opinions on the development of IRDR and the research strategic areas should be fully considered and adopted. The current operational management and decision-making in IRDR mainly through Scientific Committee Meeting has affected to certain degree the full participation of NCs and ICoEs. A new form of programme management needs to be envisaged to ensure all elements of IRDR community engaged in the decision-making process of the programme development.

In the past decade, IRDR essentially functioned as a network that promote community building and collaboration across scientists from a range of countries and disciplines. Some have suggested that IRDR would have been the "IPCC" in DRR community with resourcing and expanded science community to delve into the unresolved issues of DRR to inform the GAR and other UN agendas such as the New Urban Agenda and Paris Climate Agreement. The role of any research performing organization should be enhanced when operation and management mechanisms are improved. At the same time, new organisations or groups have emerged such as the Risk KAN, and UNDRR has also established Scientific and Technical Advisory Groups at the global and regional levels. This requires IRDR to conduct a strategic assessment of research gaps in DRR and an institutional mapping to re-position itself and promote better synergies with existing initiatives.

6 Further remarks

The purpose of this compilation is to give a comprehensive reflection IRDR's 10-years of work, both achievements and identifying gaps and challenges from missing components. It is hoped that the Compilation will serve as the main reference for all who want to have an overall understanding what IRDR is, and how it has worked over the past decade. Recording the past 10 years of this international endeavour with transparency and accountability, the Compilation aims to recapitulate the programme achievements and lessons learnt. It is hoped these can be used as a basis toward designing the future IRDR 2.0 if the new global DRR Research Agenda currently under development be endorsed by ISC and UNDRR as well as international scientific communities.

The information summarized in this IRDR Compilation has shown that, over a span of 10 years, the research communities in DRR have been stimulated by the calls of ISC and UNDRR through IRDR, and produced tangible results and undertaken a broad range of actions toward the overall IRDR objectives which are aligned with the priorities and targets of Sendai Framework.

Although not a research-intensive programme, some work of IRDR through its own leadership or in cooperation with its partners has had global significance. These include the development of the 2014 Peril Classifications and Definitions, one of the bases for new work of the Sendai Hazard categories and terminologies, and FORIN, a broadly adopted methodology to look at the integrated underlying courses of disasters. The re-contextualized ST DRR Roadmap developed together with STAG in 2018-2019 will help DRR research institutions to align their effort with Sendai Framework further and facilitate the reporting. IRDR has also made series of important policy recommendations on subject related to climate change, urban resilience, social impacts, science policy and support toward risk science, and technical contributions in inception and development regional multi-hazard early warning systems.

It is important to underline that IRDR has been a programme with actions at regional, national and community levels and over thematic risk domains. Although not often reported on in the past, IRDR NCs and ICoEs have been demonstrated to play strong roles in connecting global agenda to national and regional needs and contexts. Among other roles, NCs are best placed in assisting countries in their reporting toward the implementation of Sendai Framework, and ICoEs are both producers of knowledge and capacity builders in different regions and fields. A strong sign of youth engagement in DRR and building safe and resilient societies has been demonstrated through IRDR Young Scientists scheme.

Meanwhile important lessons have also been learnt in terms of programme governance, operation, resource mobilization and uses, synergies and partnership development. This comes with the growing demands for understanding systemic, cascading and transboundary risks and concerns, and aspirations for common safety, resilience and sustainability in our societies.

Together, these serve as building blocks toward a future stage of international cooperation in DRR and risk science, as the mission started in 2010 in IRDR is not yet fully accomplished.

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