**InsuResilience
GlobalPartnership**

Analysing Stakeholder Needs
for Enhancing Climate and
Disaster Risk Data

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Executive Summary

As the world sees an increase in the frequency and severity of catastrophes, developing countries are disproportionately affected. Higher rates of population growth, significant and unplanned urban expansion as well as inadequate infrastructure to cope with this increase in exposure to disaster risk, make these countries more vulnerable and pose substantial challenges in becoming more resilient for future disasters. Meanwhile, the poor and vulnerable, measured in terms of daily income of a few dollars or less, have few options to become more self-resilient. Governments face tough political choices in how to budget, design and deliver solutions that reduce risk. As a result, reliable and accurate climate and disaster risk data is essential to support decision makers in implementing policies and financing emergency response, recovery and reconstruction.

Against this backdrop, stakeholders from local communities, through to international organisations are using available data to assess vulnerability to multiple hazards to better understand – where and when disaster could strike. The framework for this is not yet structured to allow for easy and open access to what data does exist and, despite best efforts, the availability of tools to assess disaster risk and assist in building capacity to enhance resilience in those areas, where the poor and vulnerable are most exposed, is incomplete. Demand for data is growing and this is fuelled by initiatives like the Sendai Framework for Disaster Risk Reduction and the Paris Agreement. At the same time, data is becoming more complex, there is more of it and more challenges as a result. Open-data, common standards and interoperability are increasingly needed and being used to solve these challenges.

Report Objectives

This study provides an overview of data, modelling and analytics in the context of disaster risk finance through the lens of a stakeholder analysis in order to identify supply- or demand-side gaps. It supports the InsuResilience Global Partnership ('the Partnership') as a point of departure to address these gaps, and to improve data production, access and application for better climate and disaster risk management and to assist with developing risk financing solutions.

Catastrophes are increasingly affecting the poor and vulnerable where the protection gap – the difference between economic losses sustained and insurance losses recovered – are high. To manage disaster risk, stakeholders must develop awareness of the components of risk, which requires knowledge of exposure, hazard, and related physical and social vulnerability together with the associated uncertainty through each step of the process of risk assessment.

Inter-cropping on the flood plains of river Bagmati, in Muzaffarpur, Bihar, India. © Metro Media / IWMI (4)

The level of data required for each hazard may be a topic that the Partnership can play a role in improving. Risk assessment examples from Rwanda and Ethiopia provide insights into single-hazard risk analyses that developed into more sophisticated multi-hazard approaches to managing disaster risk. These demonstrate how stakeholders are working together to execute on the results that these risk analyses can bring, informing decisions on the development of comprehensive disaster risk financing strategies, including risk reduction, risk retention and risk transfer mechanisms, such as agricultural insurance schemes.

This gap analysis highlights which data is necessary against what is available. Frequently, data, where it does exist, is not in formats that can be readily shared and re-used. This lack of interoperability between systems contributes to a knowledge gap as to how risk components have been blended in the calibration of the model output to reflect actual loss experience. The definition and detail required to support sub-national and district-level analyses, as in the inputs to a model, leads to gaps in the availability or in the accuracy of this data. Frequently, stakeholders report that relevant data are either lacking or are of poor quality. This includes lack of mapping resources, unreliable validation data and difficulty in obtaining high-resolution census statistics to understand the social vulnerability.

The challenge is made more complicated as data users in the hierarchy of stakeholders may not be aware of what is possible, even from the limited data available, to build collective understanding on the vulnerability to hazards or to assist with enhancing disaster risk resilience. Without these insights, the user may not know what end-use might be possible to achieve with the information or what their new wants or needs might be; indeed, what they need or what the next steps are can only be determined as each new insight is gained. So not only is it a hierarchy of risks, it is also a hierarchy of gaps, both in terms of data required and work to be done, in some cases for tasks that have yet to be identified. This is a symptom of the challenge in being able to clearly define stakeholder needs for disaster risk data and then what the gaps are.

Looking at how stakeholders are helping build resilience through disaster risk finance and insurance, while there have been many successes in bringing countries together in risk pools to assist with post-disaster funding (e.g. in Africa, the Caribbean and Pacific), there is currently a lack of evidence on the long-term impacts of insurance on resilience. Does insurance do enough to change disaster risk management by encouraging more diversification or risk preparedness? The study reviews a number of the schemes in place, but there is a lack of sufficient data and loss experience currently to know for certain that current approaches are working.

Main Findings

The sharing of data is becoming the new normal and seen as an opportunity and not a threat. Open-source data and how information can be re-used in support of multiple goals together with combining the benefits of wider ownership of "smart" mobile phones, API connectivity, blockchain technology, crowd-sourcing (whether deliberate or harvested) and platforms that support this interoperability, provides intriguing opportunities for the future of insurance, particularly in developing markets. The main findings include:

› Demand-side stakeholders want better data, better models, better communication and training on how to use models. These stakeholders demand peer users to assist with training on how to understand the data, how to get more from the data, and how models could influence better use of climate adaptation methods to improve resilience.
› Supply-side stakeholders are gradually building the tools to deliver the data required, but more could be done to develop tools in an organised way that leverages the combined knowledge and skills of the entire community of practice.
› Insurance solutions do not always protect the most vulnerable and more needs to be done to strengthen accessibility and resilience impact for the poorest and most vulnerable, and improve visibility of these benefits to individuals and governments.
› Risk assessments highlighted both the depth of stakeholder engagement and complexity in producing hazard, risk and vulnerability profiles. Often, individual countries face natural and other hazards that have a human-induced component, for which insurance solutions rarely exist.
› Many countries are developing risk models to provide more insights into disaster risk, but financial loss models are needed to better understand uncertainty of outcomes and to more accurately determine the cost-benefit of climate adaptation measures and disaster risk financing options.
› Open-source data and models provide opportunities to building ownership and trust of the data inputs, while automatically increasing the return on investments of generating the data.

› Interoperability of data and tools and building standards that allow for the sharing of data is paramount; significant challenges remain to share "legacy" data, often held in paper form or hard to access environments. Recording and then sharing data that can be accessed freely, using open-source tools may bring more immediate value than just developing more models.

› Monitoring systems using an index approach provide valuable means of comparing hazards, vulnerabilities and coping capacities at a country level. Opportunities exist to enhance these approaches and use more granular data that in turn will enhance transparency of risks. Increased transparency lowers uncertainty and reduces the cost of financial protection.

Recommendations

› The report recommends that the Partnership continues to support the development of climate and disaster risk data that will lead to more opportunities to develop risk financing solutions.

› The Partnership should evaluate various country risk assessments that have been completed (e.g. Ethiopia, Rwanda, Uganda) and assess how applicable their findings would be for similar countries at the same or earlier stages of DRR reporting. This would create benchmarks and potentially assist those countries who have yet to embark on risk assessments or are struggling to meet Sendai Framework Monitoring requirements.

› The Partnership should validate the InsuRisk Assessment Tool, which it proposed and updated for the COP24 meeting in December 2018. The Information for Risk Management (INFORM) Risk Index could be used as a benchmark, to look at correlations that confirm the Residual Risk scores and to understand the implications of more data that are granular and whether this might produce different scores at a sub-national level, hence guide the future targeting of DRFI solutions.

  › Readiness for Insurance scores should be validated against countries that have participated in existing disaster risk financing schemes (e.g. ARC, CCRIF, PCRAFI)

  › Future scheme members should be targeted using data from the Sendai Framework Monitoring (SFM) and leverage other networks to see how readiness for insurance can be enhanced

› The Partnership should support initiatives to develop catastrophe models that facilitate evaluation of climate and disaster risk to critical infrastructure.

› Climate Smart Agriculture: The Partnership should continue to work closely with organisations such as World Business Council for Sustainable Development (WBCSD), with their launch of Data Enabled Climate Solutions, and CIAT, in support of their Agriculture Risk Management approaches, where "digital agriculture" at the level of individual farmers on specific plots of land is becoming a reality.

  › Building partnerships with mobile network operators and companies in the mobile application development market and studying how this influences insurance purchases is highly recommended.

› The Partnership should continue supporting and contributing to existing interoperability initiatives, through collaboration with entities such as the IDF who have shared goals in this area.

› Support Risk Model Tool Development: Support the development of probabilistic catastrophe models, targeting the perils of riverine flood and storm surge from tropical cyclones and agricultural drought risk in Africa, Asia and elsewhere, and earthquake in seismically active regions.

  › Review how the Partnership can support the development of tools to model both natural hazards and human-induced risks.

  › The Partnership should continue to support initiatives to develop open-source exposure data schemes and databases.

› The Partnership should review the Global Risk Assessment Framework, Mapping and Gap Analysis Working Group survey outcomes with UNDRR to see where it can provide specific support to meet the needs expressed by those who completed the survey. One area of immediate need expressed is training on the InsuResilience Risk Talk tool (see Section 4.1.1). The Partnership should continue to promote use of the tool, enable more technical depth of responses and supply experts to respond to user questions.

› Review where basis risk is an issue for index-based insurance and how to minimise this by capturing local data through mobile data or networks of weather stations.

Table of Contents

List of Abbreviations

ADB	Asian Development Bank
AfDB	African Development Bank
AI	Artificial Intelligence
AIR	AIR Worldwide Corp [formerly Applied Insurance Research]
API	Application Program Interface
ARC	African Risk Capacity
ARV	Africa Risk View
ARDIS	African and Asian Resilience in Disaster Insurance Scheme
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung, Federal Ministry of Economic Cooperation and Development, Germany
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CIAT	International Center for Tropical Agriculture
CRED	Centre for Research on the Epidemiology of Disasters
CSA	Climate Smart Agriculture
DEM	Digital Elevation Model
DFID	Department for International Development, United Kingdom
DFF	Drought Financing Facility
DRFI	Disaster Risk Financing and Insurance
DRFIP	Disaster Risk Financing and Insurance Program
DRMKC	Disaster Risk Management Knowledge Centre
DRR	Disaster Risk Reduction
DTM	Digital Terrain Model
ECA	Economics of Climate Adaption
FLM	Financial Loss Module
FEWSNET	Famine Early Warning System Network
GAR	Global Assessment Report
GDP	Gross Domestic Product
GEM	Global Earthquake Model
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GPS	Global Positioning Satellite
GRAF	Global Risk Assessment Framework
GFDRR	Global Facility for Disaster Reduction and Recovery
HRV	Hazard, Risk and Vulnerability
IDF	Insurance Development Forum
IPCC	Intergovernmental Panel on Climate Change
IPCC SREX	Intergovernmental Panel on Climate Change 2012 "Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation"
KfW	Kreditanstalt für Wiederaufbau, German Development Bank
Matlab	Matrix Laboratory: a programming language
MGA WG	Mapping and Gap Analysis Working Group
NDRA	National Disaster Risk Assessment
NGO	Non-Governmental Organisation

ODA	Official Development Assistance
OpenDRI	Open Data for Resilience Initiative
PCRAFI	Pacific Catastrophe Risk Assessment and Financing Initiative
PEB	Positive Exposure Bias
PGA	Peak Ground Acceleration
PGE	Protection Gap Entities
PIC	Pacific Island Countries
PPP	Public-Private Partnerships
RMS	Risk Management Solutions
SDG	Sustainable Development Goals
SFM	Sendai Framework Monitoring
Sigma	Swiss Re Institute research publication
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
USGS	United States Geological Survey
V20	Vulnerable 20 Group
WBCSD	World Business Council for Sustainable Development
WFP	World Food Programme
WRSI	Water Requirement Satisfactory Index
WRMF	Weather Risk Management Facility

Middle East at Night

© Stuart Rankin

1. The need for climate and disaster risk data

Data used for disaster risk management focuses on modelling and downstream analytics of disaster risk, shedding light on how improved access to current data, with more targeted production in the future, can assist all stakeholders in capacity development and increasing resilience. Understanding the data requirements and gaps from geological, geophysical and hydro-meteorological risks is key to facilitating the Partnership in enhancing the resilience of the poor.
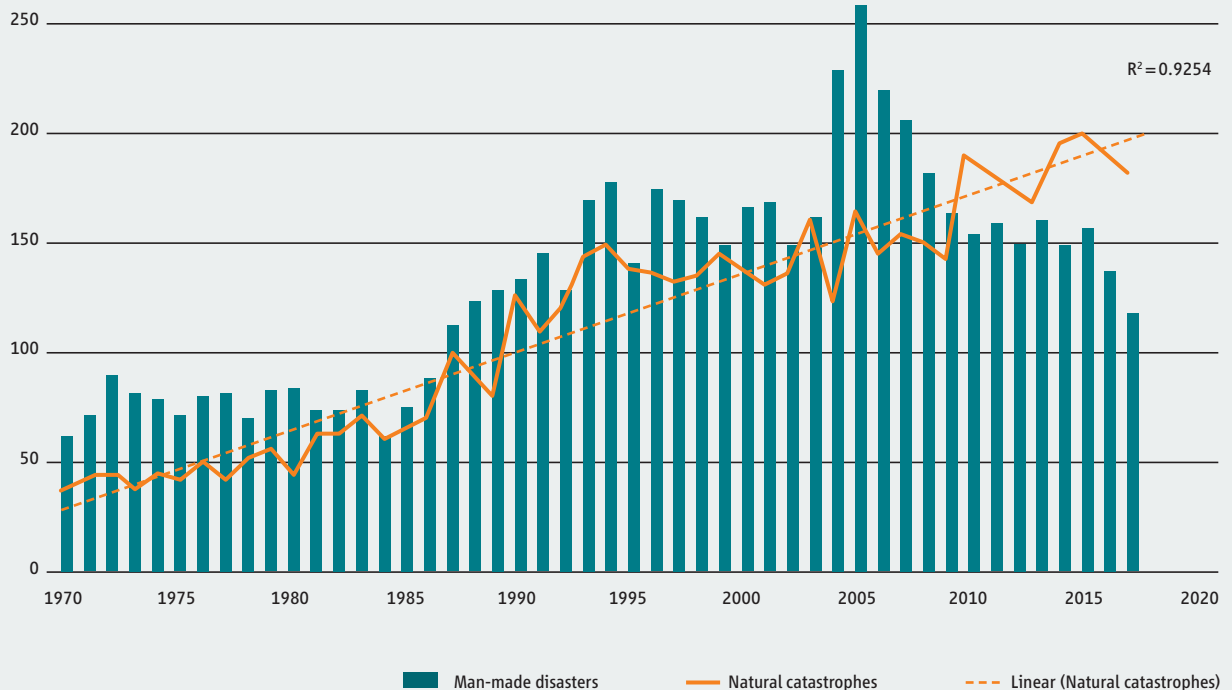
As our ability to capture and monitor all types of catastrophic events have greatly advanced since the 1970's, and the trend in the increase in natural catastrophes demonstrates the impacts of climate change over the last fifty years. High quality data is increasingly available and essential to managing risk.

Using GDP as a measure of the impact of loss on society shows that the poorer a country is, the greater the impact a disaster will have on their gross domestic product GDP. The Centre for Research on the Epidemiology of Disasters (CRED) report on Economic Losses, Poverty and Disasters 1998-2017 notes that absolute loss amounts in monetary terms can mask the relatively greater burden on the poor (Wallemacq, et al., 2018). Following a major disaster, the vulnerable tend to suffer most as their only assets (be it housing, food crops or livestock) are either immediately impacted or must be traded to cope with the short-term outcomes of disaster.

Thus, the greatest impact of the losses are falling on low income countries. Different levels of poverty are exacerbated
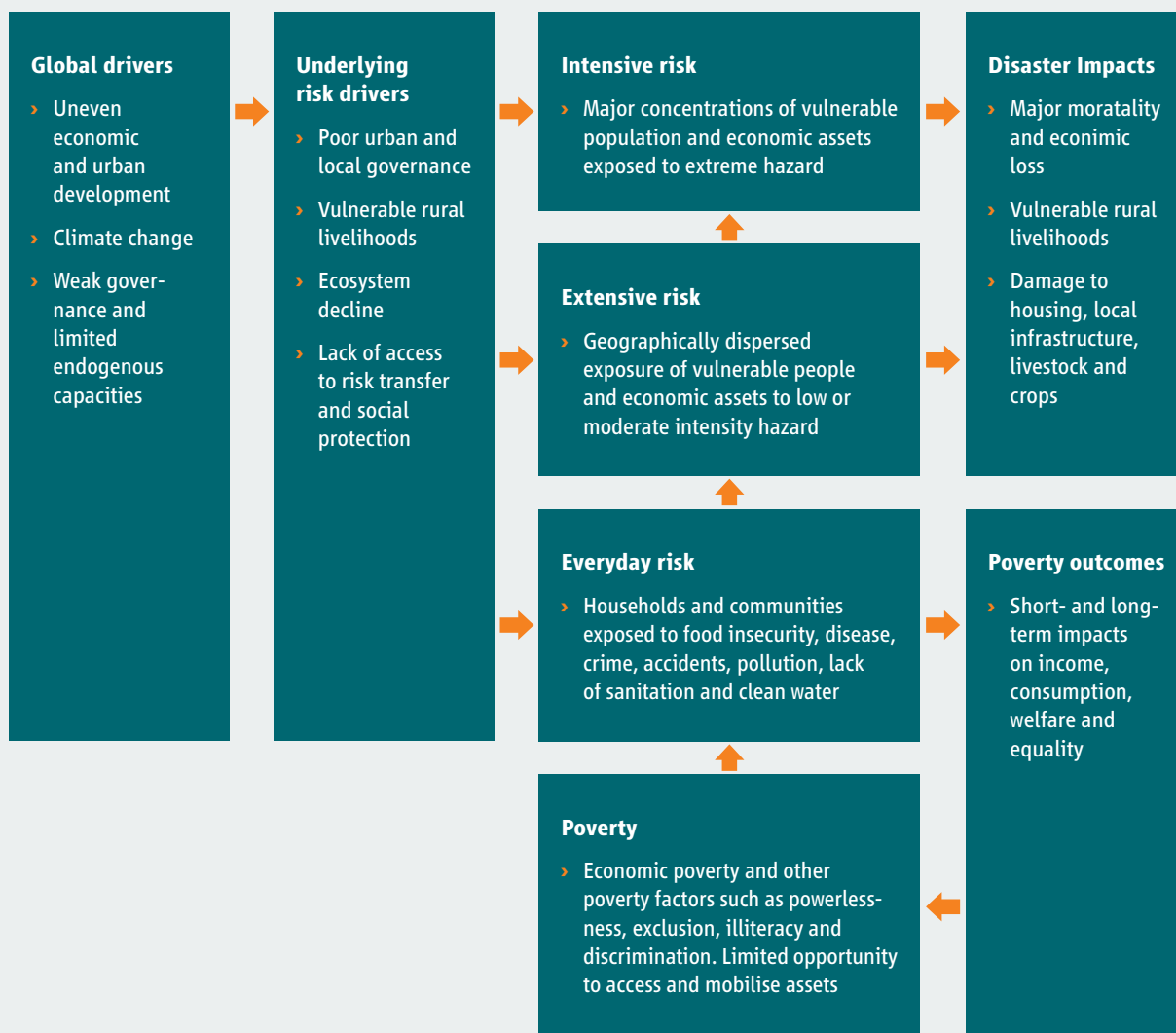
Figure 1

Number of catastrophic events 1970 – 2017

$R^2 = 0.9254$

Legend: Man-made disasters | Natural catastrophes | Linear (Natural catastrophes)

Source: Swiss Re, sigma 1 (2018)

Figure 2   11

Disaster Risk-Poverty Nexus, UNISDR, 2009

Global drivers

› Uneven economic and urban development

› Climate change

› Weak governance and limited endogenous capacities

Underlying risk drivers

› Poor urban and local governance

› Vulnerable rural livelihoods

› Ecosystem decline

› Lack of access to risk transfer and social protection

Intensive risk

› Major concentrations of vulnerable population and economic assets exposed to extreme hazard

Extensive risk

› Geographically dispersed exposure of vulnerable people and economic assets to low or moderate intensity hazard

Everyday risk

› Households and communities exposed to food insecurity, disease, crime, accidents, pollution, lack of sanitation and clean water

Poverty

› Economic poverty and other poverty factors such as powerlessness, exclusion, illiteracy and discrimination. Limited opportunity to access and mobilise assets

Disaster Impacts

› Major moratality and econimic loss

› Vulnerable rural livelihoods

› Damage to housing, local infrastructure, livestock and crops

Poverty outcomes

› Short- and long-term impacts on income, consumption, welfare and equality

Source: UNISDR (2009)

through everyday risks such as food insecurity and access to clean water, which then become more extreme with each level of increase in or recurrence of hazard. The Sendai Framework includes "Target C" that aims to reduce direct disaster economic loss in relation to global GDP by 2030, which is in recognition of this fact.

To understand what this means in practice, Figure 2 lists the main drivers, referred to as the Disaster Risk-Poverty Nexus in the UNDRR Global Assessment Report, and explains why poverty can become a trap for the poor and vulnerable. The drivers can be global, such as climate change, or local underlying risk drivers where the vulnerable have a lack of access and ability to transfer their risk.
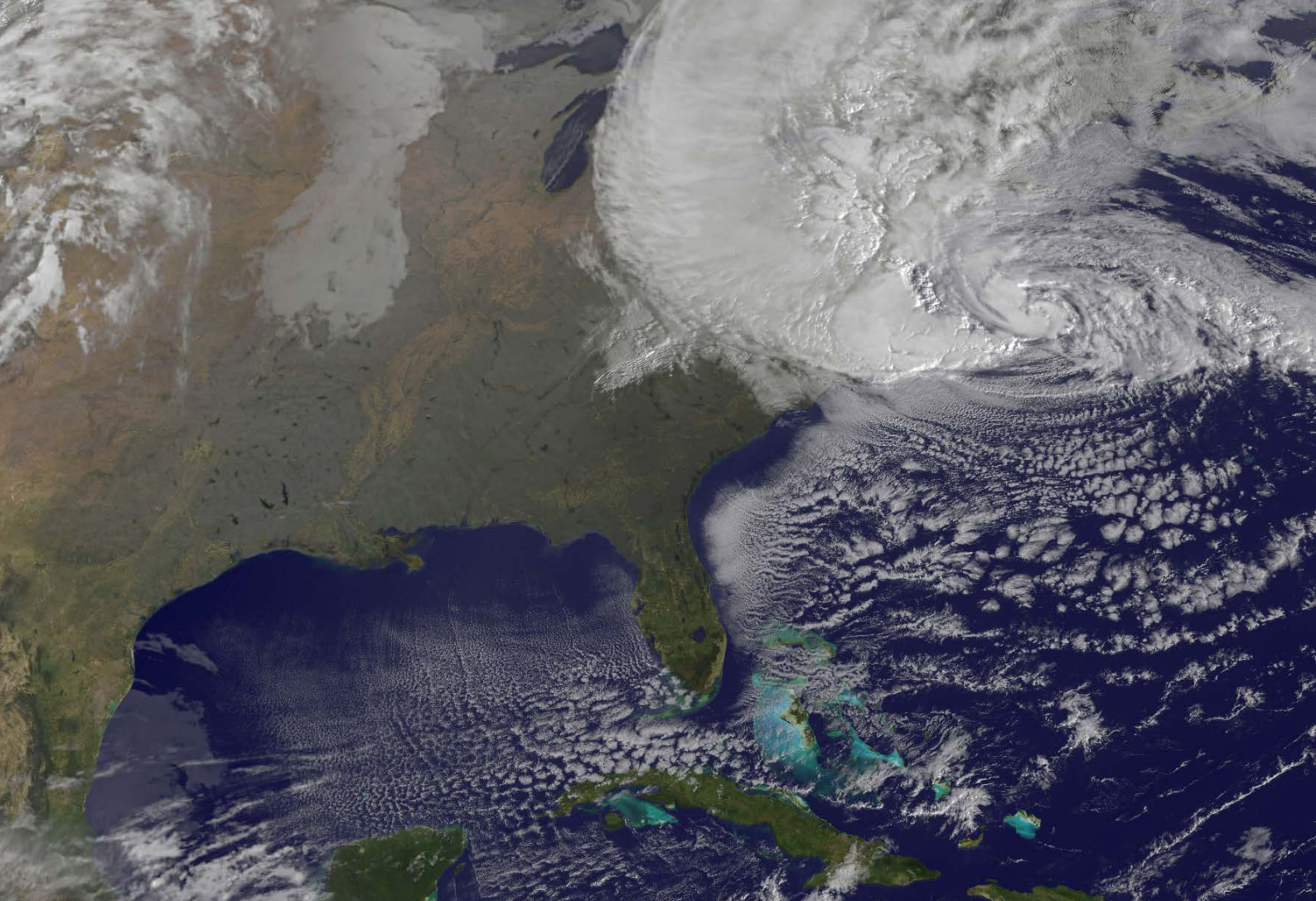
Satellite View of Hurricane Sandy on Oct. 29 2012

The total economic losses from these events are not just increasing; they are frequently outstripping GDP growth in some regions, despite efforts of both governments and international organisations to improve disaster risk resilience. As a result, the poor have little chance of pulling themselves out of poverty or risk as disasters increasingly set them back.

Significantly, almost all aspects of disaster risk management (vulnerability, the capacity to cope and recover) underserve the poor. For example, Winsemius et al. (2015), in their study of whether poor and non-poor people are more or less exposed to flood and drought risk, and whether risk increased with climate change, showed that over all but one of the 52 countries surveyed the exposure of poor people is higher than non-poor. Poor people are generally over-exposed to drought and urban flood, with Africa particularly exposed to both flood and drought perils, and both Africa and South-East Asia were strongly exposed to poverty caused by drought.

Developing countries that have successfully built in-depth risk profiles of their hazards and vulnerabilities to disaster risk are helping inform stakeholders to more transparently map and model disaster risk to help build capacity to protect against future losses. Some of this profiling work is driven by agreements made by the countries who signed up to the Sendai Framework in 2015. The reporting of the global indicators to measure progress towards the achievement of the global targets of the Framework and relevant targets of the Sustainable Development Goals (SDG) obliges these countries to act and put in place or enhance existing systems. The production of this data enhances their ability to be more resilient against future disasters and should help define the long journey ahead to reduce the current gaps in data that all stakeholders need to overcome in order to assess, report and to implement DRR strategies.

The Sendai Framework Monitoring (SFM) analytics database allows users to follow the progress that countries are making in reporting the seven global targets and thirty-eight indicators of the Framework. To illustrate the enormity of the task ahead, only 6 countries had uploaded data that had so far been validated (by March 2019) and 100 countries out of the 195 who are due to report have yet to start the reporting process. To further illustrate the complexity of the task itself, the European Commission Joint Research Council Science for Policy report on disaster damage and loss reporting (the responsibility for which was assumed by the Disaster Risk Management Knowledge Centre (DRMKC)) in 2015 found:

"The current practice in disaster loss data recording across the EU shows that there are hardly any comparable disaster damage and loss databases (Joint Research Centre, JRC, 2015). Differences exist in the methods of data recording and in the governance approaches to managing disaster damage and loss data. The lack of standards for damage and loss data collection and recording represents a key challenge for damage and loss data sharing and comparison, especially for cross-border cooperation within the EU." – Marín Ferrer, Montserrat et al. (2018), p.5.

Bearing in mind the relative wealth of historical loss data that exists in Europe, this confirms the enormity of challenge for all countries, particularly the least developed countries, small Island states as well as landlocked and middle-income countries, as they face conditions that exacerbate vulnerability and where the risk to the poor and vulnerable in society is greatest.

Notwithstanding these challenges, the Open Data for Resilience Index (OpenDRI), which tracks data by country and globally, is allowing more local understanding of risk and how this stimulates more ownership of potential solutions. By harnessing local ownership and using open-source data with common standards to allow for easier interoperability, the scale of adoption and the ability to build datasets to support DRR will be enhanced.

2. The Protection Gap

The consequences of natural hazard and man-made losses can be estimated by calculating the "protection gap": the difference between insured and uninsured losses: between 80 % – 100 % of economic losses in emerging markets remain uninsured (Swiss Re, 2015). This compares to around 55 % in industrialised nations, where individuals are also choosing to self-insure, even though more insurance capacity exists to assume this risk.

Swiss Re´s sigma 2/2019 report includes estimates for the total economic loss from events, breaking out insured from uninsured losses. Figure 4 shows that the proportion of total loss being insured is increasing.

By 2018, insured losses were more than 51 % of the total combined loss for the first time in more than 20 years. The reality though is that this could just be a reflection that there have been more losses impacting the USA, particularly from tropical cyclones Harvey, Irma and Maria in 2017, and where

insurance penetration is higher than other parts of the world. Overall, more than 60 % of losses for the last five years have been uninsured, against over 65 % for the last ten years. However, the true social impact, as referenced in the CRED report above, is likely far higher.

Significantly, those least able to build resilience are often faced with the greatest threats from natural and man-made hazard. The Lloyd's of London City Risk Index report, which tracks 22 threats hitting 279 of the world's largest cities, uses GDP at risk across economics and trade, finance, geopolitics and security; health and humanity; natural catastrophe and climate; as well as technology and space. Their model estimates the total cost for non-financial threats at over US$350bn, split evenly between man-made and natural hazard risks. Lloyd's estimates US$163bn of annual economic loss remains underinsured, of which over 80 % emanates from Asia, affecting over 2.25 billion people – or 30 % of the world's population. Bangladesh, Philippines and Vietnam are

Figure 3

Insured vs. Uninsured catastrophe losses 1998−2018
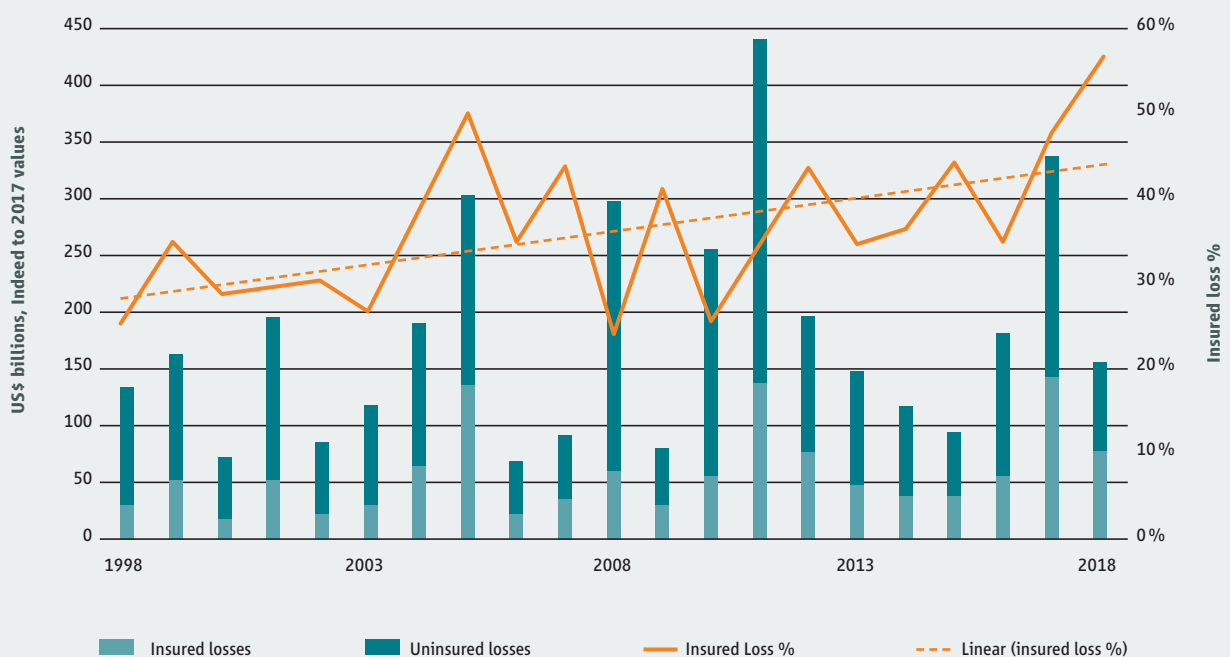
Source: Swiss Re sigma 1 (2018)
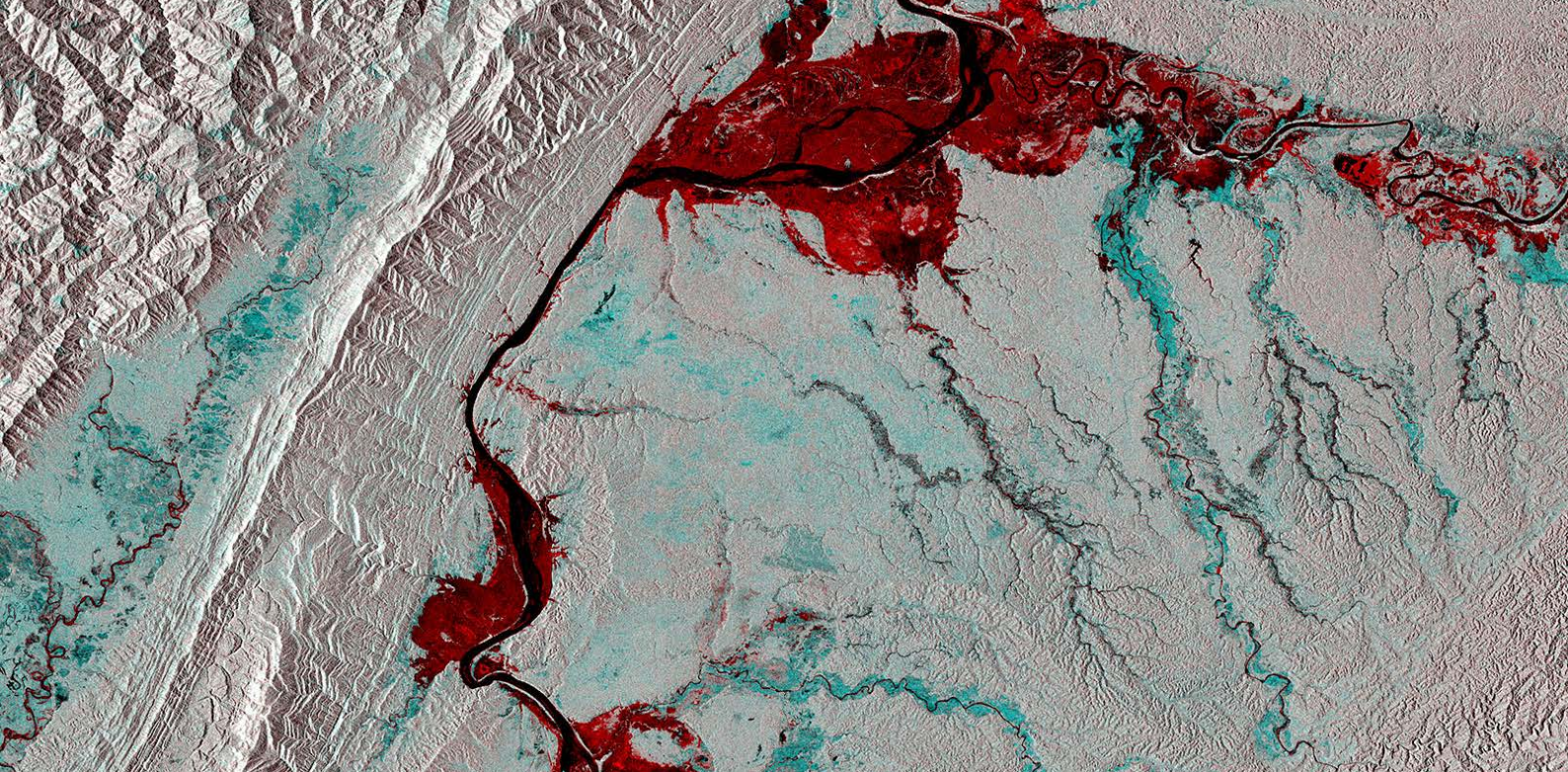
Sagaing Division, Myanmar   contains modified Copernicus Sentinel data (2015), processed by ESA, CC BY-SA 3.0 IGO

expected to be among those most affected, as members of the Vulnerable 20 (V20) Group; indicating they are systemically vulnerable to climate change.

AIR Worldwide Corporation (AIR, 2018) reached similar conclusions showing the modelled loss from natural hazards for property losses, which suggested that only 23 % of the annual estimated economic loss of US$366bn is currently insured. Further, up to 50 % of the economic loss could be insured. AIR's results are striking for two reasons: first, the results exclude Africa, which is not included in the modelled loss analysis (highlighting both demand for insurance and supply of catastrophe models issues too). Second, there remains a huge opportunity for insurers, even in the developed world, to have more of an impact and reduce the protection gap.

RMS (Muir-Wood, 2018) defines three distinct Protection Gaps that should be treated differently:

(1) **The High-Risk Protection Gap**
The potential loss may be greater than the insurance industry is able or willing to commit more capacity to the market at the price regulators or policy-holders are willing to accept. War, terrorism and certain natural hazard risks have overwhelmed the market and Protection Gap Entities have been established to fill the void. Examples include the California Earthquake Authority (CEA) and the Earthquake and War Damages Commission (EQC) in New Zealand.

(2) **The Emerging Markets Gap**
Lack of disaster risk reduction planning in many countries, combined with a rapidly growing population in urban areas, have resulted in insurance being unavailable or too expensive for a majority of people and businesses to purchase. The emergence of micro, meso and macro sovereign protection schemes are starting to bridge the gap of uninsured losses.

(3) **The Intangibles Protection Gap**
This reflects the massive change in how the world has developed from essentially having physical things to insure to now creating significant amounts of intangible "Non-Damage Business Interruption" risk, as society becomes more dependent on technology in almost every aspect of life. Ultimately, some of this risk can be captured under Cyber insurance policies, but that really only addresses the malicious intent to steal data, rather than the intangible nature of how a business actually operates.

For these three types of Protection Gaps, we must further distinguish "penetration gap" from "coverage gap". The former is the difference between those wanting insurance but lacking ability to pay for it. The "coverage gap" is the impact of exclusions and financial terms of coverage resulting in uncovered losses.

2.1 Disaster Risk Finance and Insurance

In 2010, a joint initiative was established to formalise the Disaster Risk Financing and Insurance Program (DRFIP) (World Bank, n.d.). It brought together the World Bank's Finance, Competitiveness, and Innovation Global Practice and the Global Facility for Disaster Reduction and Recovery (GFDRR), who joined together to help support governments establish structures to facilitate sovereign disaster risk financing, social protection programmes as well as insurance solutions for both agriculture and property risk.

The World Bank (2014) outlined five key policy messages:

› Minimising cost / optimising post-disaster funding is a priority.
› DRFI is an integral part of disaster and climate risk management.
› Successful implementation requires strong financial discipline from governments.
› Private sector can bring expertise, innovation and capital.
› DRFI is a long-term solution, requiring political will, expertise and time.

Figure 4

World Bank: Disaster Risk Management Framework

1 Risk Identification — Improved identification and understanding of disaster risks though building capacity for assessments and analysis

2 Risk Reduction — Avoided creation of new risks and reduced risks in society through greater DR consideration in policy and investment

3 Preparedness — Improved capacity to manage crises through developing forecasting and disaster management capacities

4 Financial Protection — Increased financial resilience of governments, private sector and households through finacial protection strategies

5 Resilient Recovery — Quicker, more resilient recovery through support for reconstruction planning

Source: World Bank – GFDRR Disaster Risk Management Framework (2014)

Table 1   **17**

Pre/Post Event Finance Measures

Pre-Event Measures	Advantages	Disadvantages
Indemnity Insurance	Insurance pay-out matches loss	Needs loss assessment and longer time to pay out
Parametric Insurance	Quick pay-out / low cost	Basis risk, regulatory issues
Contingent Financing	Small payment upfront, guaranteed access and pre-defined pricing	Repayable and interest costs
Reserve Funds	Builds financial strength, high flexibility in fund allocation	Costly / misappropriation possible
Post-Event Measures	**Advantages**	**Disadvantages**
Budget	Autonomous fund allocation	Funds diverted
Raising Taxes	Government flexibility	Politically sensitive / potentially undermines economic recovery
Debt	Proven solution	Costly / requires credit rating
Donor Aid	Inexpensive	Slow and not guaranteed

This report sets out a framework, shown in Figure 5, which builds on the fundamental principle of empowering both citizens and governments to understand their risks and make informed choices about how best to address them. These five pillars highlight that the process of DRR requires interdisciplinary connectivity: each pillar relies on a network of people, processes and actions working together.

Weingärtner et al. (2017) explain that there were three types of dividends that disaster risk insurance brings:

› Avoiding the impact of a loss when disaster hits.
› Boosting economic activity as actual and even perceived disaster risk is reduced.
› Creating social, environmental and economic benefits associated with specific DRM investments

They caution that not all of the target audience would benefit. Women, in particular, are less likely to purchase insurance due to lower wages, and more pressing responsibilities of home, children, and work.

Swiss Re (2016) in their "Closing the Protection Gap" report highlight advantages and disadvantages of pre / post loss financing measures, set out in the table below.

Overall, the pre-event measures likely outweigh post-loss measures. The report concludes that sovereign risk transfer is a better solution for governments than post-disaster financing for the following reasons when the risk layer is with the highest severity of risk:

› Guaranteed access to funds
› Diversified funding
› Speed of delivery (when using parametric solutions)
› Budget planning certainty
› No payback obligation
› Provides credit rating history

3. Risk Data, Risk Assessment and Modelling

This section reviews the components of risk (exposure, hazard and vulnerability) and the complexity of capturing data for each component. Risk assessments and the types of risk models that can be used to assist with the evaluation of disaster risk are explained together with – why probabilistic catastrophe modelling, in the context of Disaster Risk Financing and Insurance, is required. The gaps in the availability of catastrophe models, using Risk Indices as proxies to highlight the need, is shown. Finally, an analysis of the InsuRisk Assessment Tool, where readiness for insurance and residual risk are computed, is compared against those countries participating in the African Risk Capacity pool and countries impacted by Tropical Cyclone Idai.

To identify the gaps and challenges in obtaining and providing open access to climate and disaster risk data, one must distinguish the components of risk: **exposure, hazard and vulnerability**. While each component is separately measured and has specific attributes, they intersect to form risk. The intersection is a complex combined risk that remains uncertain in outcome.

The following sections define each of these components of risk and how they interrelate.

3.1 Exposure

Exposure is the primary determinant on how the other components of risk will respond. Defined using the UNDRR terminology, exposure describes the situation or location of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas. Exposure is represented by various types of infrastructure used for residential, commercial, industrial and agricultural use. Population, its socio-economic makeup and location, is crucial for determining the risk factors of hazard and vulnerability.

Exposure data needs, including the granularity of resolution and the frequency of updates, is critical to inform decisions on disaster risk. For example, population growth around a city can change significantly between times when census data is captured. In the insurance world, exposure is used to capture the value of an asset at a specific location, with the granularity of that location being critical to assess the vulnerability of the asset to specific hazards, depending on the peril being analysed. For perils associated with windstorm, a relatively coarse level of data granularity might be sufficient. For flood, knowing as precisely as possible where exposure is, measured in centimetres, together with additional attributes on land height above a river or sea-level or the slope gradient of surrounding land could be crucial to determine whether a location is exposed. Earthquake exposure also requires a fine level of granularity due to the importance of soil type / quality at a location.

Open source data schemes are being developed for the three components of risk. One of these is the Global Exposure Database for Multi-Hazard Risk Analysis (GED4ALL), which will enable standards to be adopted by all stakeholders to capture the following information:

GED4ALL has four main deliverables:

› Develop an exposure database scheme allowing third-party integration (inputs, outputs, visualisations) and interoperability with other exposure databases
› Develop the classifications for assets and hazards

Figure 5

Components of Risk – Exposure, Hazard and Vulnerability

› Populate the database with information from other open-source data
› Develop exposure datasets, using well studied countries as references (e.g., Tanzania)

The GED4ALL schema is simpler than that used by GED4GEM and allows for exposure models to be added incrementally. In addition, the storage space requirements increase in proportion with the size of the stored models. Feedback from stakeholders ensures that the taxonomy used to quantify assets is simple, but robust enough to capture the information necessary to model them from a multi-hazard perspective. Databases were populated from various open-source datasets, such as WorldPop and OpenStreetMap, illustrating the challenge of using crowd-sourcing approaches to capture information. Individual contributors may classify building attributes differently, which ultimately will lead to some manual intervention and could require supplemental information from other sources to validate the data.

The biggest challenge remains the development of exposure datasets. With the exception of a few countries[1], datasets are not publicly available and/or fit for the purpose of disaster risk management and development of risk financing/insurance solutions. Two main approaches for capturing data were utilized. The first is a modelled approach where a mixture of land parcel data is combined in a model with population census and satellite imagery, which can then be used to calculate the number, type and value of the built environment. It is useful at a regional or national scale but less practical for detailed analysis. The second method, involving the use of site visits and using GPS data from mobile phones allows for a richer set of data, but is significantly more time-consuming, potentially expensive and harder to achieve on a national and international scale. Both approaches are valuable for planning and policy-making, and tracking exposure changes over time provides useful data.

The UK Space Agency launched a three-year project, METEOR with the goal of improving the ability of Earth observations to capture exposure data "by developing and delivering rigorous and open routines (protocols) and standards to allow quantitative assessment of exposure, with explicit uncertainties". METEOR is a consortium of eight companies, including the British Geological Survey who were behind

the GED4ALL initiative, and companies with expertise in DRR, humanitarian aid, remote sensing, flood modelling, earthquake modelling and using open-source systems. METEOR will focus initially on Nepal and Tanzania, and once the data has been tested and validated, it will deliver open-source data for the least developed 47 Official Development Assistance (ODA) countries.

Exposure is not just about the physical structure of buildings and infrastructure: it also includes the people and communities who own or inhabit them. While the global growth rate of population is slowing[2], many countries in Africa and Asia are seeing sustained annual growth in population rates of 1.5 % to 2.5 %. This rapid growth, combined with a lack of urban planning, and continued move to cities by rural populations in search of food and work significantly increases disaster risk potential. The biggest growth is particularly pronounced in countries already most at risk for increased cyclones, floods, and droughts and in cities with swelling peri-urban slums that are sited in the most vulnerable areas.

GED4ALL:
Assets and Hazards Captured

Assets	Hazards
› Buildings	› Drought
› Infrastructure & Lifelines	› Earthquake
› Crop, Forestry, Livestock	› Flood
› Socio-economic data	› Tsunami
	› Wind
	› Volcano

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1   GED4ALL: Australia, Canada, Italy, Portugal & United States are some of the few countries with open exposure data.

2   World Growth Rate: http://www.worldometers.info/world-population/#growthrate

Thunderstorm over the Fouta Djalon – Taken on 16 June 2013 in Guinea near Bantala-Bac Lafou (DSC_9254)   jbdodane

Population is a good illustration of the overlap of exposure, hazard and vulnerability. In Latin America, over 80 % of the population lives in cities (Adrienne Arsht Latin America Center, 2014), doubling since 1950 (40 %). According to GEM (2018), roughly half of urban population live in just 14 cities. Further, around a quarter of the world's population lives in moderate to high hazard seismic areas, particularly along the Pacific Rim. The challenge for stakeholders working in DRR is to understand how these changing dynamics in population and urbanisation will play out in future seismic events to which these vast numbers of people are exposed.

Exposure records of population are based on census data, which may be years out of date as they are normally completed every ten years. Effective DRR requires current data so that better planning in advance of potential losses could take place. The IPCC SREX report, explicitly warns of the risk to DRR from unplanned urbanisation: "There is high confidence that rapid and unplanned urbanization processes in hazardous areas exacerbate vulnerability to disaster risk (Sánchez-Rodríguez et al., 2005). The development of megacities with high population densities (Mitchell, 1999) has led to greater numbers being exposed and increased vulnerability through, inter alia, poor infrastructural development (Uitto, 1998) and the synergistic effects of intersecting natural, technological, and social risks (Mitchell, 1999)" (IPCC SREX, 2012, p. 78).

3.2   Hazard

Hazard is defined as a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation (UNDRR, 2017). Natural hazards include the following groups:

› Geological and geophysical
  › Earthquake, landslide, tsunami, volcano
› Hydro-meteorological
  › Cyclone, drought, flood, landslide following rain, bushfire, convective storms, hail

Man-made or human-induced hazards include the following groups:

› Pandemic / Human Health Virus
› Human / Famine
› Biological, pestilence, virus in animals or crops
› Technological, including cyber, chemical accident, nuclear, radiological, transport
› Systemic risk
  › Agriculture systems, food insecurity, political instability

Anthropogenic or human-induced hazards likely influence the frequency and severity of hydro-meteorological hazards, although "the severity of the impacts of climate extremes depends strongly on the level of the exposure and the

vulnerability to these extremes" (IPCC SREX, 2012, pp. 8-10). In addition, socio-natural hazards are associated with both natural and human-induced hazards as they grow in risk in combination with environmental degradation and climate change. Over-exploited or degraded land contributes to increasing risk from hazards such as landslides, flooding and drought. These risks could be mitigated with better land-management policies.

The range of hazards, their interaction, connectivity, cascading nature and the absence of historical loss history to inform hazard modelling, thereby increasing uncertainty in estimating impacts, all limit the stakeholders who have the capacity to capture, analyse and record their influence on components of risk. Data acquisition is costly and although increasing use is made of remote tools to perform the analysis, the institutional capacity and willingness to share data limits the ability of other stakeholders to use data for DRR or other purposes.

Hazard assessment involves capturing perils that are likely, their possible location, probability, potential frequency, and impact characteristics (e.g. flood depth, wind strength, peak ground acceleration). Building maps and identifying zones that are exposed to each hazard is part of the risk assessment process. The challenge to assess the hazard depends on what data that is available by peril.

3.2.1 Human-induced hazards

The scope of this study is restricted to reviewing the data for hazards that are likely to be covered by DRFI solutions of interest to the Partnership. However, it should be noted that frequently in the risk assessment reports (see Section 3.4), it is human-induced hazards that rank high in the list of hazards that communities face, for example pestilence in crops as well as diseases in animals. Overall, human behaviour influences the overall impact of natural hazards. Accordingly, human behaviour across political, institutional and socio-cultural dimensions should always be considered in the hazards that communities face.

3.3 Vulnerability

Vulnerability is a "hypothetical and predictive term, which can only be 'proved' by observing the impact of the event when, and if, it occurs" (Wisner et al., 2003).
 It reflects the conditions determined by physical, social,

economic and environmental factors or processes that increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards (UNISDR, 2009). Vulnerability is the exposure of people or physical things to the occurrence of a hazard. Vulnerability has significant implications for disaster risk management including preparation, risk transfer, response and recovery.

The vulnerability of a population is linked to its capacity to cope: UNDRR (2017) defines this as "the ability of people, organizations and systems, using available skills and resources, to manage adverse conditions, risk or disasters. The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during disasters or adverse conditions. Coping capacities contribute to the reduction of disaster risks." Vulnerability data capture is probably the most lacking of the three components of risk and where more data is needed by all agencies. The various global databases that record loss history currently do not support very granular information, such as lives lost by event, and usually only at a country level.

Vulnerability assessment can be split into two parts: first, the segmentation of vulnerability itself (e.g. social, political, environmental, infrastructure / buildings, and the economy); and second, the kind of data being used to assess the vulnerability (census, disaster loss databases, remote sensing, crowd sourcing, ground surveys, modelling (e.g. of building performance). Vulnerability data indicators for a population as a whole can be captured using a multiplicity of inputs including economic, environmental, physical and social indicators, albeit all requiring in-depth local surveys to gather the data.

As discussed in the section on the Disaster Risk-Poverty Nexus (Figure 2), natural catastrophes more greatly impact poor countries, with small and vulnerable economies. For example, the vulnerability of the African continent (GFDRR, 2010) is linked to its poverty and structural issues including:

› Limited fiscal space and options to access financing to invest in risk reduction and recovery
› An economic foundation based on rain-fed agriculture
› Weak infrastructure to manage resources and recover from disasters
› Weak governance structures and institutional capacities
› A limited knowledge base to forecast and respond to catastrophes

This report emphasised that vulnerability, which was being augmented by environmental degradation and climate change, will likely increase with the frequency and magnitude of extreme weather events.

Swiss Re, in their "Closing the Gap" publication (Swiss Re, 2015) highlighted the different fortunes of those impacted in Haiti in 2010 and New Zealand in 2011 from two earthquakes of similar magnitude (Mw 7.0). More than 200,000 people died in Haiti, while 185 died in New Zealand. The economic impacts also differed significantly, with losses exceeding 120 % of GDP for Haiti of which less than 1 % was insured, compared to less than 20 % of GDP in New Zealand of which over 80 % was insured. Haiti's use of concrete, seen as a material for economic progress and good hurricane protection, contributed to the number of deaths due to its weight, causing unreinforced house roofs to collapse. For Africa, the challenge is just as great as that in Haiti, with significant numbers of people living in informal as opposed to formal construction.

The INFORM Index discussed in more detail in Section 3.7 captures data at a sub-national level in some regions and could potentially provide even greater detail as the data capture process for the index matures. Presently, it only provides an indication about vulnerability rather than data that could directly be used in risk models. Social protection systems could be useful in the context of DRR, especially for early-warning systems, but the data is not always reliable. Like much government data, often the data is not sharable or is difficult to access in a format that could be useful. Often data is captured in paper format or stored in PDF.

Vulnerability data of infrastructure (housing, roads, and bridges) is limited and is not always available in an open-source format. Vulnerability data is essential for effective insurance mechanisms and is powerful input data for early-warning systems. For example, CAT 4 Hurricane Mathew hit Haiti in September 2016 and destroyed the Petit-Goâve Bridge, which cut off southwest of the country for weeks and hampered relief efforts. Knowing the weaknesses of key infrastructure in advance of an approaching storm might have allowed better pre-disaster planning as well as allowing for longer-term measures to improve critical infrastructure.

Building a vulnerability database to reflect critical infrastructure and risks from different types of event pre-loss is a major gap that would significantly help planning of DRR efforts.

3.4   Risk Assessment

Many countries have already or are in the process of shifting the focus from traditional emergency response and disaster relief to more proactive management of their disaster risk. Commitments, albeit non-obligatory, to the Sendai Framework to report progress towards the various targets have necessitated the creation of risk assessment systems to record measures taken. Countries, such as Uganda, with support from International organisations like the United Nations Development Programme (UNDP), have developed multi-hazard, risk and vulnerability profiles for various districts around the country. These risk assessments include the collection of field data using GIS data to build hazard maps showing the distribution of risk across districts and the creation of hazard risk and vulnerability (HRV) profiles encompassing both natural and human-induced hazards, using a system of risk matrices to highlight the probability and severity of risks.

The exercise reveals the extent of hazards to which cities are prone, the high level of risk for some categories and how many risks are not restricted to natural hazards. Many of these hazards are beyond the usual scope of perils captured within risk models. Indeed, these risk assessments highlight how many "non-modelled perils" generally are outside the scope of current insurance/DRFI solutions. While environmental degradation and flood rank highly in the risk matrix, so too do human diseases, fires, accidents, land conflicts, crime and air pollution.

There is a strong case for suggesting that some of these are gaps that are not being filled by supply-side stakeholders, both in terms of enhanced tools to look at these risks, for example across regions or the ability to find alternative solutions to mitigate the financial impact of these risks.

In terms of how data has been captured, many countries rely on external expertise from international organisations to perform analyses. Over time the skills to perform these tasks will need to transition to local governments and research institutes for them to be able to fully take ownership of their risk. In terms of data to complete the risk assessments, use of a combination of spatial layers such as DEM, slope, aspect and flow accumulation and hydrology are used to capture information for flood profiling. Similar data attributes including land use, soil type, population, roads, utilities, socio-economic, health and meteorological data would contribute to assessing the respective hazards included in the risk assessment.

Figure 6   23

Risk Matrix HRV Profile Kampala

Hazard	Central	Kawempe	Nakawa	Makindye	Lubaga
Soil erosion	D	C	C	C	C
Earthquake	E	E	E	E	E
Flood	A	A	A	A	A
Storm	E	C	C	C	C
Drought	D	C	D	D	D
Plant pests & diseases	E	C	C	C	C
Livestock diseases	E	C	C	C	C
Human diseases	A	A	A	A	A
Vermin & wildlife attacks	E	C	C	C	C
Invasive species	E	C	C	C	C
Land conflicts	B	C	C	B	C
Fires	B	B	B	B	B
Environmental degradation	A	A	A	A	A
Air pollution	C	M	M	C	M
Water pollution	C	B	B	B	B
Noise pollution	D	C	B	C	C
Accidents	B	B	B	B	B
Crimes	C	B	B	B	B

Efforts to capture exposure, hazard and vulnerability information in countries like Ethiopia (Wereda Disaster Risk Profiling[3]), Rwanda (the National Risk Atlas[4]) and Uganda[5] provide useful benchmarks for other countries to emulate. Countries seeking to assess their susceptibility to natural hazard disasters would gain time in their work by following similar analyses.

The Rwanda Atlas captures a nationwide data set that informs risk assessment of hazard, exposure and vulnerability to loss, yet providing different users with information for different purposes. It was designed to "create a set of hazard and risk information for specific policy and decision making in disaster management, agricultural development and food security, and urban development, settlement planning, land use and relocation of population from high-risk zones." From a disaster risk reduction perspective, the goal was to assist with emergency planning and response, and included mitigation steps and early-warning systems. Specifically, these included actions, amongst others to:

> › Use population and vulnerability profiles to estimate impacts from drought, earthquake, landslide and windstorm by district
> › Build or enhance early-warning systems for each district exposed to flood and windstorm
> › Increase education at a sub-district level on disaster risk
> › Use profiles for resource mobilisation to support diverse projects aimed at DRR, addressing vulnerability and building resilience

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3   Wereda Disaster Risk Profiling: http://profile.dppc.gov.et/Default.aspx
4   Rwanda National Risk Atlas: http://midimar.gov.rw/uploads/tx_download/ National_Risk_Atlas_of_Rwanda.pdf
5   Uganda: http://www.undp.org/content/dam/uganda/docs/ UNDPUganda%202014%20Teso%20HRV%20Report%20-%20Kumi.pdf

Like most countries in Africa, food security is the most significant risk and the population is hugely dependent on rain-fed agriculture. Drought was the only peril in the Atlas that captures the risks to food security. A key recommendation was to extend and upgrade irrigation systems in drought-prone areas. **Significantly, drought risk profiles would support development of comprehensive disaster risk financing strategies, including risk retention and risk transfer mechanisms, such as agricultural insurance schemes.**

The Rwanda Atlas is a good example of stakeholders working together, with The Ministry of Disaster Management and Refugee Affairs (MIDIMAR) leading the engagement with various government ministries and agencies including the Ministry of Agriculture and Animal Resources (MINAGRI). The Rwanda Housing Authority (RWA) updates building codes and land use plans. External collaborators include the World Food Programme (WFP), who assisted Atlas with their planning and resource management.

The Ethiopian Wereda profiling, based on the Hyogo Framework for Action (HFA), is designed to elicit comparable statistics by district highlighting the combined index for hazard, vulnerability and capacity to cope. The latter piece captures the population's "exposure" and includes economic status, technology, infrastructure, knowledge and skills, health status, institutions and social capital. The indexing process enables both positive (e.g. distance to a road) and negative features (literacy or access to electricity) to be combined in a process that also removes bias of scale. The index can then highlight, on a scale of 0-1, those districts with the highest exposure to disaster risk. The survey includes a range of indicators to capture vulnerability across physical, environmental, economic, social and health sectors, and a range of indicators to capture capacity to cope with disaster risk incorporating economic, infrastructure, technology, social capital, and institutional dimensions.

These risk assessments performed in Ethiopia and Rwanda show the level of sophistication that already exists in these countries to produce exposure, hazard and vulnerability assessments. However, these are almost all related to single-risk hazards viewed in isolation to other risks. They do not provide enough information about uncertainties and probabilities of loss, combination or correlation with other losses, or cost-benefit calculations to inform alternative risk reduction methods.

3.5   Risk Modelling

Risk modelling quantifies uncertainty and loss probability, which require extensive analysis using a probabilistic model that risk assessments alone cannot perform. A probabilistic model can be run on a single-risk hazard, but its value is far greater combining multi-hazards. Probabilistic models produce output reflecting the loss cost on an annual basis; these "annual average losses" are additive, meaning the average losses from multiple perils can be summed. This enables comparing the relative probability of hazards and the cost of risk reduction. To understand how components come together to define risk, it is often modelled as a function of:

Risk = Exposure X Hazard X Vulnerability

Other variations include adding coping capacity or deficiency of preparation, which refers to pre-existing conditions that prevent a community or a country from responding quickly and effectively post-event to minimise the impact of a disaster (Villagrán, 2006).

To calculate overall risk, several key attributes must be known for each component:

› Exposure: construction, occupation, protection, age, location
› Hazard: frequency, severity, duration, spatial extent
› Vulnerability: how does exposure respond to hazard in terms of loss of life, injuries, damage to structures and movable property, and impact on business

There are two approaches. The first, but more limited, approach is building a scenario or deterministic analysis of a known event that has happened in the past or one that is likely to happen in the future, such as the risk of a town being hit by a flood or a storm. This approach may capture an authentic description of a typical event at a known location, but it cannot capture the inherent uncertainty associated with the event. No two events are exactly the same; there are usually differences in the severity or duration of an event or the extent to which an area is impacted. For example, the time of day when a specific event occurs can influence its impact on people's lives, not least in terms of the amount of warning that can be given or the time taken to respond. An earthquake at night may entrap more people in their homes, which could be less resistant to shaking. The inverse is also true: the increased accumulation of people at work during daytime can worsen the impact of an earthquake, especially if the building lacks adequate seismic design and is not built to save lives.
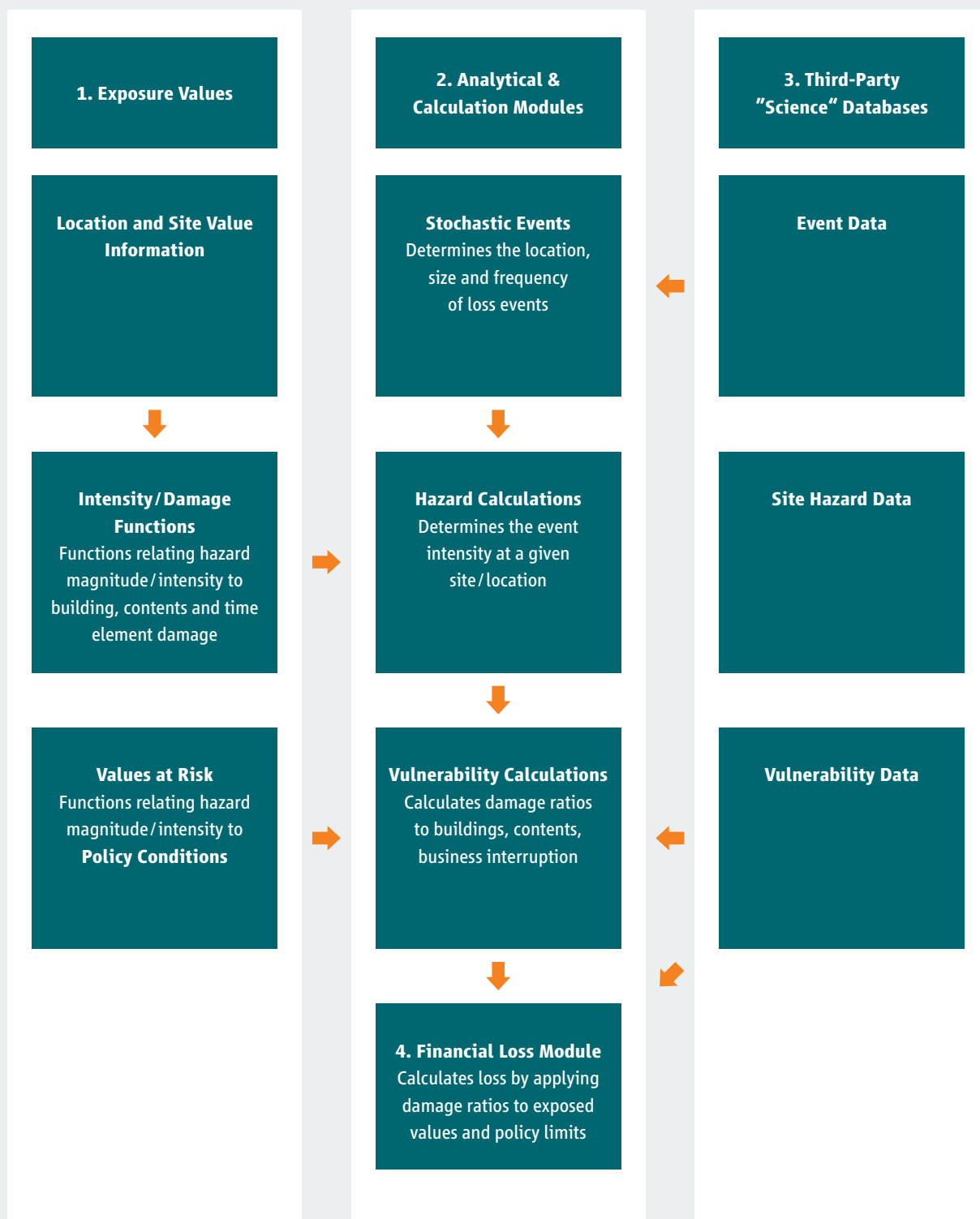
Figure 7

25

Catastrophe Risk Model Components

1. Exposure Values	2. Analytical & Calculation Modules	3. Third-Party "Science" Databases
Location and Site Value Information	**Stochastic Events** Determines the location, size and frequency of loss events	**Event Data**
Intensity / Damage Functions Functions relating hazard magnitude / intensity to building, contents and time element damage	**Hazard Calculations** Determines the event intensity at a given site / location	**Site Hazard Data**
Values at Risk Functions relating hazard magnitude / intensity to **Policy Conditions**	**Vulnerability Calculations** Calculates damage ratios to buildings, contents, business interruption	**Vulnerability Data**
	4. Financial Loss Module Calculates loss by applying damage ratios to exposed values and policy limits	

Table 3

Key Components of a flood model

Component	Data Requirement	Detail	Calculation
Hazard	› Topographic Maps	› Bare earth maps › 5 m vertical resolution › 10 m horizontal resolution	Meteorological model
	› Flow Rates	› River discharge	Hydraulic model
	› Surface roughness		
	› Data / Calculation	› Historical data by station	Statistical simulation of river flow
Exposure	› Assets / Infrastructure	› Location / Value	Damage calculation linked to construction, occupancy, protection, exposure
	› Population	› Urbanisation	
	› Crops	› Drought index	
Vulnerability	› Construction	› Primary modifiers › Secondary modifiers	Mean damage ratio calculation (e.g. for a given flood depth / return period)
	› Occupancy		
	› Protection		
	› Exposure		
Loss Model	Hazard, Exposure, Vulnerability Inputs	› Insurance conditions (optional)	Damage estimation by event › Gross / Ground Up Loss › Insurance Loss
Loss Validation	Historical Event Data › Frequency › Severity	› How often › How deep › Which areas impacted	Loss model calibration and validation with past events

The second, but more complicated, approach is building a probabilistic model to capture all the available inputs to risk. The benefits of using a probabilistic model are described in the National Disaster Risk Assessment (NDRA) Words in Action Guidelines publication (UNISDR, 2017) and include the ability to artificially recreate historical losses as well as those that are likely but may not have occurred in the historical record. Using a combination of the understanding of the physical drivers of hazard and using statistical techniques to analyse known past losses, simulations of new events can be developed. The advantage with this approach is that a full mathematical distribution of event probabilities can be produced, which allows the consumer of the output to

look at a range of loss scenarios depending on the severity of the occurrence or the frequency of when it happens. These models can also account for some of the uncertainty of impact at a given location if an event occurs, by using exposure and vulnerability information to evaluate how hazard characteristics of different intensities impact results. Model uncertainty still exists due to not knowing the intricacies of every detail about the components of risk or how they respond to the unique circumstances of a loss.

3.5.1 Catastrophe Insurance Modelling

Deterministic and probabilistic modelling can provide useful insights by simulating the different components of risk and their interactions. Disaster risk financing and insurance initiatives follow the same processes, using probabilistic models to calculate the cost of risk:

(1) Exposure values and insurance policy information are captured
(2) Analytical models perform complex mathematical or "brute force" arithmetic calculations produce statistical analysis
(3) Proprietary information informs the "science" being modelled for specific perils

A further step in the process reflects the structures of DRFI being modelled:

(4) A financial loss module (FLM), into which other modules feed, prices risk for the DRFI structure

The diagram in Figure 8 shows how these components inter-relate. The catastrophe model takes the exposure location, exposure type and value information, overlays the stochastic event set, determines the hazard event intensity, calculates the damage based on the vulnerability of the insured property and derives a loss evaluation. Depending on the structure of DRFI coverage, the appropriate calculations are performed in the FLM.

A well-designed model accounts for risk differentiating results depending on perils, geography, and coverage. Current gaps for (re)insurers include the **lack of interoperability of data between systems** and often the knowledge gap of how components of risk are factored in the model output to reflect actual loss experience.

The challenge for all stakeholders in the process of building a model is to accurately reflect the true exposure of the built environment or a population at a specific location. **More sophisticated models have greater data requirements, resulting in gaps in the availability or accuracy of data.** Coupled with potential gaps in knowledge of the hazard itself, especially if historical information is lacking or socio-natural elements change over time, poorly designed assumptions on vulnerability and the uncertainties of the model output become apparent.

The components of risk help complete the recipe required to build a model. Table 6 shows a simplified view of the components required, what this means in terms of detail and the calculations performed.

3.6 Geographic Gaps in Probabilistic Catastrophe Model Availability

This analysis inventoried probabilistic catastrophe models available from model vendors, either as open-source tools or with a commercial licence, to determine whether specific gaps exist in coverage relative to the InsuResilience focus on V20 countries. The goal was to identify outstanding demand-side needs for models, using guidance deduced from various risk indexes. Supply-side availability was compared with demand by country and by peril. The absence of a hazard model would then represent a gap if the risk index revealed greater than a low hazard of risk by peril. The aim was to capture a full, current list of probabilistic models, not just deterministic or scenario models or maps. Many companies offer bespoke services of scenario modelling or mapping by country, but these were excluded from this analysis.

The primary source used to capture the initial model list was the "Cat Risk Tools" repository available through the Oasis Hub.[6] Verification of each model vendor's website was performed to ensure that the model information was accurate and the scope of tools met the criteria. A database in Excel was created that captured the following information:

› Country information
  › Sorted by Continent, Region including ISO3 code
  › V20 Country indicator
› Human Development Index
› Climate Risk Index
› Population (UN statistics)
› Gross national income (GNI) per capita
› World Risk Index
› INFORM Risk Index

The Human Development Index is a useful measure that captures the dimensions of a long and healthy life and overlays knowledge and living standards to compute a score based on the geometric mean of normalised indices for the three dimensions: it can be used to measure the non-physical

6   Cat Risk Tools: https://catrisktools.oasishub.co/records/
     ?page=7&selected_facets=primary_hazard_exact%3AEarthquake

Figure 8

INFORM Risk Index Dimensions

Ranking level	INFORM																
Concept level (Dimensions)	Hazard & Exposure							Vulnerability					Lack of Coping Capacity				
Functional level (Categories)	Natural					Human		Socio-Economic			Vulnerable Groups		Insti-tutional		Infrastructure		
Component level	Earthquake	Tsunami	Flood	Tropical cyclone	Drought	Current Conflict Intensity	Projected Conflict Risk	Development & Deprivation (50 %)	Inequality (25 %)	Aid Dependency (25 %)	Uprooted People	Other Vulnerable Groups	DRR	Governance	Communication	Physical Infrastructure	Access to Health System

aspects of exposure to hazards, giving valuable information on a population's vulnerability. Ultimately, the goal is to measure a country's development based on its people and capacities, rather than just economic performance.

The Climate Risk Index was reviewed to see whether there could be any metrics that might inform the analysis of gaps and opportunities. The index covers the following metrics:

› Fatalities by year
› Fatalities by 100,000 inhabitants
› Losses in US$ in purchasing power parity
› Losses as a % of GDP
› Ranking by country of the various metrics
› Rolling average for the previous 20 years for various metrics
› An overall CRI score based on the weighting of the four main categories

While the data is valuable to capture statistics by year and rolling averages identify trends, it is not designed to reflect the vulnerability of each country. The CRI score is influenced by actual losses over time, not exposure to losses yet to occur. The CRI index was therefore discounted in the overall model gaps analysis.

However, the INFORM Risk Index does provide useful data, as their overall score is determined from the following components:
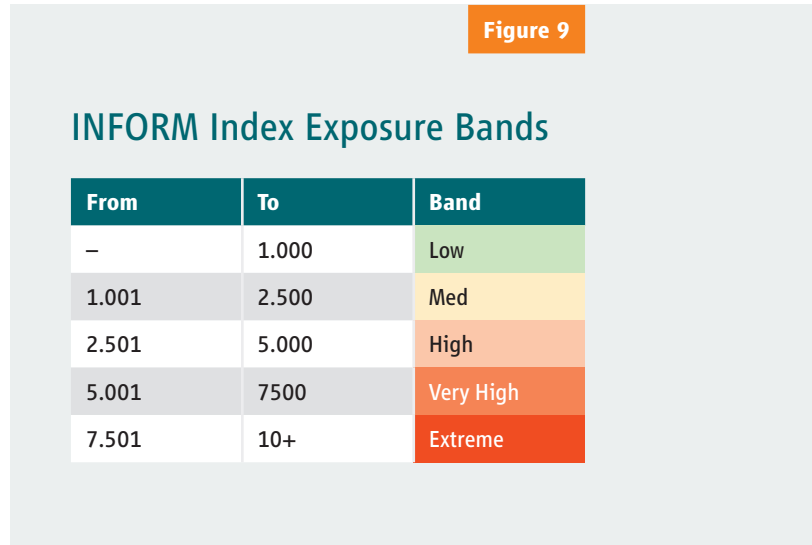
› Hazard and exposure
  › Natural hazards
  › Human hazards
› Vulnerability
  › Socio-economic
  › Vulnerable groups
› Lack of coping capacity
  › Institutional
  › Infrastructure

INFORM's goal is to establish metrics to measure global humanitarian risk. It also provides useful granularity as not only is data available at a country level, but for some countries it also drills down to sub-national or county level. For a future social vulnerability assessment, the INFORM sub-national index could enhance the means of profiling a country, particularly as it includes the coping capacity metric.

To assist with understanding what gaps there might be when compared to the catastrophe models that are available, the following data from INFORM was included in the "Model Gaps" database:

› Earthquake
› Tsunami
› Flood
› Tropical Cyclone
› Drought

Currently there are no specific probabilistic catastrophe models that address the peril of drought, which reflects to an extent how insurance is sold, although the Africa RiskView model, discussed later in the study, does enable some drought cover to be purchased. Catastrophe losses seen from an insurance perspective tend to involve circumstances where the impact can be observed and measured in moments of time. The construction of reinsurance contracts generally

INFORM Index Exposure Bands

From	To	Band
–	1.000	Low
1.001	2.500	Med
2.501	5.000	High
5.001	7500	Very High
7.501	10+	Extreme

defines occurrence of loss in terms of time (hours, days, weeks) rather than trying to define the loss itself. The consequences of drought as a peril for general insurance tend to be limited to claims for subsidence / heave reflecting the impact of long periods of unseasonal dry weather that reduces the water table and causes soil to shrink. Properties built on clay soil with insufficient foundations are prone to subsidence. Subsequent periods of wet weather may cause the soil to expand and cause uplifting of foundations or heave
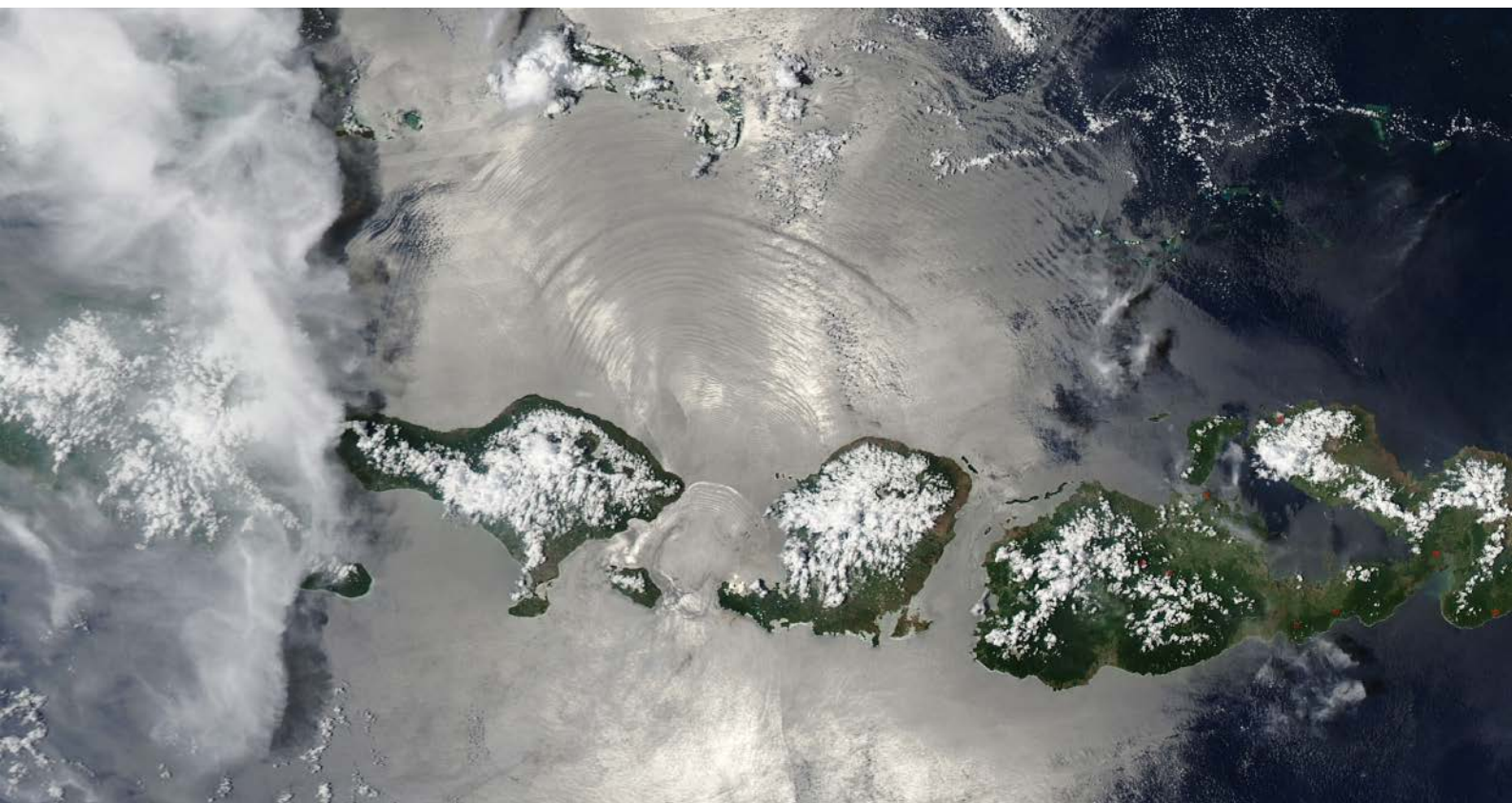
Oceanic Nonlinear Internal Solitary Waves From the Lombok Strait   © Jeff Schmaltz, MODIS Land Rapid Response Team, NASA GSFC

Table 4

INFORM Risk for Selected V20 Countries (as of January 2019)

V20 Country	Population	Tropical Cyclone Risk	Earthquake Risk	Flood Risk	INFORM Risk Index Score
Africa					
Ethiopia	104.96 M	0.00	5.50	5.70	3.80
Kenya	49.70 M	0.00	4.20	5.60	4.90
Madagascar	25.57 M	7.50	0.10	7.30	6.00
Rwanda	12.21 M	0.00	3.90	4.40	3.00
Tanzania	57.31 M	0.80	4.70	5.80	4.70
Ghana	28.83 M	0.00	0.10	4.90	2.60
Americas					
Caribbean	0.46 M	4.65	1.75	0.10	2.30
Barbados	0.29 M	4.60	0.10	0.10	2.60
Saint Lucia	0.18 M	4.70	3.40	0.10	2.00
Central America					
Costa Rica	4.91 M	1.90	9.60	3.30	6.30
Asia					
Philippines	104.92 M	9.60	9.50	7.20	8.50
Timor-Leste	0.23 M	3.70	5.80	1.70	4.00
Viet Nam	95.54 M	7.90	3.10	10.00	7.30
Afghanistan	35.53 M	0.00	9.20	7.20	6.10
Bangladesh	164.67 M	6.90	8.70	10.00	8.20
Bhutan	0.81 M	0.00	7.20	5.40	3.20
Maldives	0.44 M	0.00	0.10	0.10	3.20
Nepal	29.30 M	0.20	9.90	6.80	5.60
Vanuatu	0.28 M	5.10	3.50	0.10	4.60
Kiribati	0.12 M	0.00	0.10	0.10	3.70
Tuvalu	0.01 M	0.10	0.10	0.10	2.80
Total Population	715.79 M	390.98 M	445.32 M	668.31 M	
"No Model" Pop		**190 M**	**140 M**	**620 M**	

claims. Subsidence is therefore a peril captured in additional loss pricing rather than requiring a specific catastrophe model. Some models do exist for bush (wild) fire, mainly for the United States and Australia. In addition, tsunami as an ancillary peril to earthquake shock, has only recently been captured in some models and tsunami following volcano is not captured by any of the models analysed. For the analysis, tsunami and earthquake were grouped together.

The individual INFORM Index scores were then categorized into five bands of exposure from low to extreme.

The table below (Table 7) highlights the V20 countries, showing the population at risk, the risk score from INFORM Risk Index for the perils of tropical cyclone, earthquake and flood, together with the combined natural hazards score for all perils that the index captures.

Scores above 5.0 are highlighted in table 7.

Results were then cross-referenced against existing probabilistic catastrophe models that include a financial loss model (FLM), which is essential for structuring and pricing DRFI solutions, and resulting gaps were determined if the hazard was higher than low.

Four V20 countries have tropical cyclone risks rated high to extreme, for which probabilistic catastrophe models do not exist, although some risk assessments have been done for Madagascar and Vanuatu, and reviews for Bangladesh are ongoing. Combined population at risk in these countries exceed 190 million.

Four V20 countries are exposed to earthquake risk rated high to very high. Although model-based risk assessments have been completed by the World Bank for Afghanistan, Ethiopia and Vanuatu, and the Global Earthquake Model was also recently launched (GEM, 2018), global earthquake hazard and risk maps and models including a FLM are not broadly available. Combined population at risk in these countries is over 140 million.

While risk assessments have been performed for many countries, the biggest gap in the availability of probabilistic catastrophe models is for flood. Thirteen V20 countries have flood risk rated high to extreme. **Combined population at risk in these countries is about 620 million people, or over 8 % of world population. Hazard maps for flood may exist globally, albeit without the resolution required to enable further detailed analysis, but there is a clear gap and consequent opportunity for the Partnership and its Program Alliance as a platform**

of implementing programs to assist with this need, which includes the financial loss models required for structuring DRFI solutions.

It is recommended that the Program Alliance should focus their immediate efforts to improve the availability of tools to assist in the modelling and structuring of peril-based solutions for the poor and vulnerable.

3.6.1 InsuRisk Assessment Tool

Risk assessments based on an indexed approach, such as the INFORM Risk Index, while not as sophisticated as probabilistic models, provide information on all components for measuring disaster risk to be compiled in a simple way. It allows comparison of risk across perils, regions and countries. This is difficult to do with single-risk analysis even where hazard maps are available.

Individual country data from the InsuRisk Assessment Tool is not yet publicly available, but discussions with its developers provided insights on its purpose and how it can inform policy decisions. Answers to the questions shown in Box 1 go beyond those asked in the INFORM Risk Index to assist with helping the Partnership determine where to focus efforts to assist stakeholders looking to use financial solutions to assist with disaster risk reduction strategies.


Box 1

InsuRisk Assessment Tool: Key Questions

› What is the level of vulnerability and climate and disaster risk of a country?
› What is the short-term capacity of a country to cope with hazardous events?
› How high is the remaining residual risk?
› Which long-term preventive strategies exist in a country to tackle future disaster risk?
› What is a country's readiness to accommodate insurance and other risk transfer solutions?

Figure 10

InsuRisk Assessment Tool, showing ARC Risk Pool Members
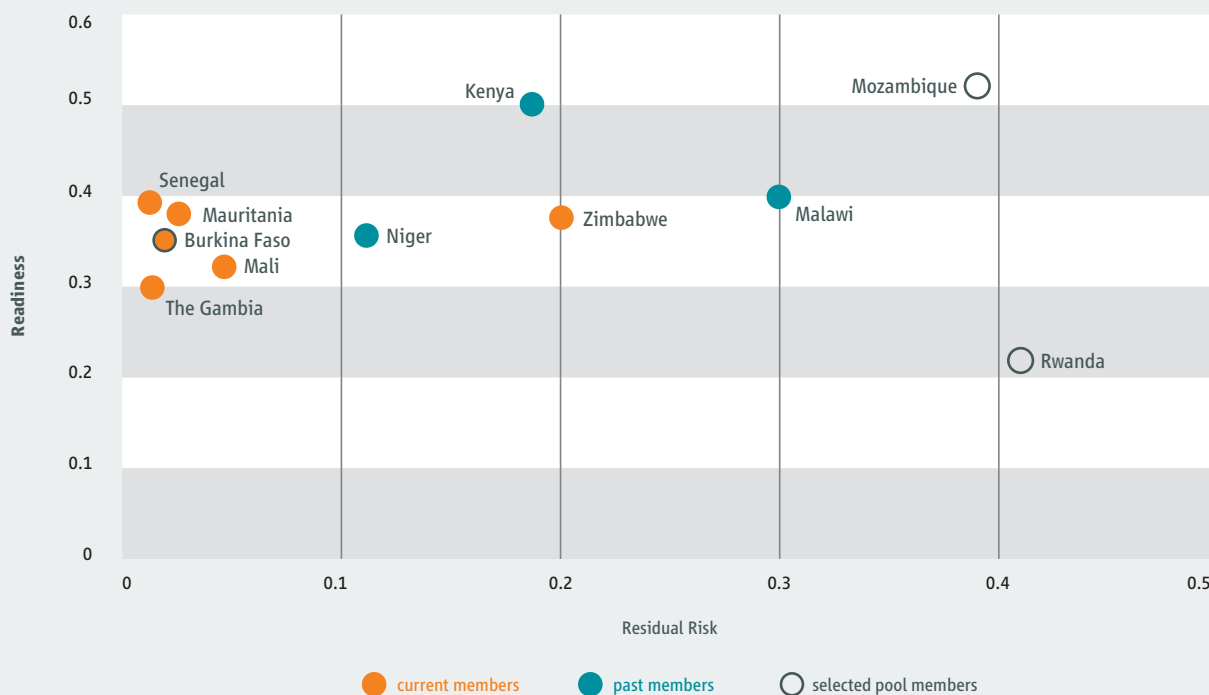
To facilitate those answers, the index calculates "readiness for insurance solutions" in three modules:

› Individual readiness
› How attractive is the political environment to attract insurers for long-term investment?
› How developed is the insurance market in a country?

Like INFORM, the results are index-based, producing two key outputs:

› Readiness for insurance
› Residual risk

High scores for both categories indicate good potential to investigate further. Out of 82 countries in the index, India, Indonesia, Ukraine, Philippines and Morocco (in descending order) score well for insurance readiness, while Philippines and Indonesia have the highest residual risk. Data is highly aggregated, so the real potential value lies in decomposing the data, such as by hazard. Risk profiles may show similar levels of risk in different countries, however the solutions for each country may differ.

Figure 11 shows current members of the African Risk Capacity Risk Pool IV plotted on the InsuRisk Assessment index together with past members. As shown, Mozambique and Zimbabwe (together with Malawi) were heavily impacted by Tropical Cyclone Idai and Rwanda. Interestingly, countries no longer included in the risk pool have higher residual risks yet mostly higher readiness scores.

Many countries have not started their reporting for the Sendai Framework and how they intend to carry this out is still unknown. Because the InsuRisk Assessment Tool looks at the risk of loss, it could assist reporting countries. **Further analysis of this tool, including who is using it, what are they using it for, why they are using it, as well as validating that the data is credible should be next steps.**

4. Mapping Demand-side Needs and Supply-side Stakeholder Innovations

The Geneva Association report on "Stakeholder Landscape" (Golnaraghi and Khalil, 2017) explained how the challenges presented by climate change, disaster risk and sustainable development goals were brought to the forefront of the policy agenda by the United Nations and others over a long period. The breadth of stakeholders involved has moved across international boundaries, impacting regional, national and local stakeholders. Today, the key stakeholders in disaster risk reduction are diverse and multiple. They represent organisations who coordinate, educate and strive for a common goal that includes reducing the burden faced by the poor and vulnerable to disaster risk. The list includes the following groups:International organisations (e.g. United Nations)

› Intergovernmental organisations
  › G7, G20, Africa Union (AU), Asia-Pacific Economic Cooperation (APEC), Association of South-East Asian Nations (ASEAN), Caribbean Community (CARICOM)
› National Governments
› Regional & Local Authorities
› International Development Communities
  › International and Regional Development Banks, including: World Bank, Asian Development Bank (ADB), African Development Bank (AfDB), European Investment Bank (EIB)
  › International Development Agencies / Donors, including: BMZ, KfW, GIZ, DFID, USAID, Insurance Development Forum (IDF)
  › Others such as Organisation for Economic Co-operation and Development (OECD)
› Non-Governmental Organisations (NGOs) & Civil-Society Organisations (CSOs)
› The Scientific Community, Research and Academia
› Private Sector (such as insurers and risk modelling companies)
› Civil Society (including cooperatives, mutual and individuals)
› Youth / Activists (e.g. School Strike for Climate)

Each stakeholder can play a contributory role in disaster risk reduction. For example, a national government is responsible for putting in place sound policies and the framework to provide an enabling environment that allows for better planning and budgeting across the layers and sectors of government. In addition, they have the primary role in addressing and facilitating the collection of reliable disaster risk information including hazard, environmental and socio-economic data. The government is also the key stakeholder in being able to drive strategy both pre- and post-loss through investing in risk reduction and risk transfer opportunities using their networks of PPPs. It is also the government's duty to inform their communities about disaster risk by investing in education and awareness programmes.

Meanwhile, regional and local governments need to be connected both to national government and the community to enable a decentralised approach to the ownership of risk reduction to take place. Local authorities need to be better prepared to face future disasters, but they need the technical and financial support from above in order to do this. Both NGOs and CSOs can support local governments by working closely with communities to help build resilience.

The role of the scientific community and associated research institutions is critical in building the knowledge to understand the many facets of disaster risk as well as developing the technology that allows for better interpretation of how hazards can be modelled, which can assist in increasing the understanding of the impacts of natural catastrophes and the impacts of different risk mitigation techniques. **The challenge for stakeholders is to ensure that research is demand-driven if it is to contribute to the implementation of coordinated risk reduction strategies(United Nations, 2013).** This requires a multi-disciplinary approach to look across the risk landscape as a whole, which is challenging due to the nature of the specialized expertise required to understand the complexities of each diverse risk. Providing a framework that allows for access to risk data that can be shared across stakeholder communities is critical.

Table 5

Mapping Stakeholders

Timeline	Mapping the User Needs: (Increase Resilience) "The Why, for The Who" <Demand-side>	Mapping Available Inputs: (Risk Factors) "The How" <Supply-side>	Mapping Missing Data (Responding to Needs) "The What" <Gaps>
The Present	› What does the user want? › What does the user need?	› Understanding Known Risks: Exposure, Hazard, Vulnerability › Using Known Tools: Models / Platforms	› Finding Gaps in the data › Finding Gaps in the framework › Finding Gaps in the process
The Future	› What might the user want / need in the future? › Which potential future users?	› Discovering Unknown Risks: Emerging Risks / Correlation › Developing New Tools: AI / Big Data	› Creating standards that allow for impacts to be measured by risk type, by location

Perhaps the biggest challenge faced by all these stakeholders is understanding with who is the ultimate "end-user" of disaster risk information and what is needed for stakeholders to take ownership of their role in disaster risk reduction. From here, what is preventing the supply side from responding to these needs? Often, the biggest gap to answering these questions, is down to what data exists to be able to focus a better understanding of these needs into a framework that can collectively channel the right resources into mechanisms that can, over time, increase resilience. Table 8 below describes the various dimensions that this could represent through time (the present and the future) together with questions that the user (any stakeholder on the demand side) might need from a stakeholder on the supply side. There are elements that are known today about disaster risk (but perhaps not the quantum or in sufficient detail), which would represent the inputs to determine the risk factors, such as how frequently a loss might occur and when it does how severe is it going to be. In the same way, there are likely going to be tools, data and mechanisms that may help in the quantification of these risks in the future. Ultimately, the challenge is to review the chain of components to disaster risk and then determine whether or not there is a gap today and if so, is there a way of narrowing that gap sometime in the future.

More concretely, Golnaraghi and Khalil (2017) propose a supply-side landscape of stakeholders engaged with capacity building for disaster and climate risk management. They conceive of four activities in the following groupings:

› Risk knowledge and risk assessment
› Integrated approach to managing disaster and climate risk
› Initiatives and innovations in risk transfer
› Agriculture risk transfer solutions

This framework will be used to discuss the questions of goals and needs, including data needs, from the perspective of supply and demand side stakeholders.

Risk knowledge and risk assessment capabilities at a global level have been driven by the UNDRR and GFDRR as well as organisations like the Intergovernmental Panel on Climate Change (IPCC) and through reports like IPCC SREX (2012), and initiatives like the National Disaster Risk Assessment (UNISDR, 2017), which provides policy guidance for risk assessments and establishing risk systems.

At a regional level, several innovative institutional mechanisms furnish insurance capacity:

› The African Risk Capacity (ARC)
› Caribbean Catastrophe Risk Insurance Facility (CCRIF)
› Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI)
› Turkish Catastrophe Insurance Pool

The PCRAFI, for example, provides Pacific Island Countries (PICs) with disaster risk modelling and assessment tools, leveraging the network of GFDRR, World Bank, Asian Development Bank, the European Union as well as Geoscience Australia, GNS New Zealand, and AIR Worldwide. It builds on these collaborations with the Secretariat of the Pacific Community through its Applied Geoscience& Technology Division (SPC / SOPAC), and produced the GIS tool Pacific Risk Information System (PacRIS). The PacRis tool was used to assemble the following data for hazard modelling:

› Bathymetry maps
› Geodetic and fault data
› Land cover / land use maps
› Satellite imagery
› Surface geology maps
› Surface soil maps
› Topographic maps

Using these inputs, PCRAFI built probabilistic hazard models for all 15 countries included in the scheme to reflect the multi-hazard perils to which they are collectively at risk (tropical cyclone and associated rain and storm surge, earthquake and tsunami). In addition, they were able to capture a historical log of tropical cyclones and earthquakes, which was used to inform the calibration process.

The above entities have, to an extent, been able to fill the protection gap that was discussed in Section 2 and have been able to pool the resources of regional governments and provide investors or reinsurers of these pools some diversification or balance in the portfolios that have been written.

Risk assessment profiles referenced in Section 3.4 help us better understand what organisations are involved. For example, the Rwanda Atlas details the stakeholders who contributed to that project. These included 8 ministries, 10 government institutions, 5 regional organisations as well as 3 international organisations (UNDP, FAO and WFP). The National Technical Advisory Group (NTAG) supported the project.

Providing knowledge on DRR, by bringing together consortiums and collaborations of different organisations has enabled stakeholders to leverage the power of shared and open data. Several organisations and platforms exist that focus their activity from an exposure, hazard and vulnerability perspective. The annex to this report lists organizations and their respective efforts.

Capturing and sharing hazard assessment data, and accessing non-public data (academic or commercial), all presents challenges that could be addressed by the Partnership[7]. Data that was available to access freely may be difficult to process if stored in multiple formats or on data portals that are not easily readable. Also, terminology may vary and technical information (e.g. hazard parameters) requires skilled technicians.

While, there is clearly a crucial role for data and information in mitigating the impacts of disaster risk on vulnerable people, there is still no international consensus regarding best practices for collecting data. According to CRED, variability in definitions, methodologies, tools and sourcing used by the different actors in capturing loss data pose barriers.

For example, GIS and geospatial data and technologies are closely related (See Box 2), but involve distinct approaches and data sets, which can pose barriers to sharing information.

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7   ThinkHazard! *User Guide describing the problem of data sharing*. Available at: http://thinkhazard.org/static/8a92fe492c2bafa5bff7923bb556cd6a/documents/ThinkHazard_briefUserGuide_v2.pdf

Open-source could potentially help make data more transparent and accessible to stakeholders. Many companies are taking advantage of open-source platforms to build tools that assist with DRR. The annex lists tools that map exposure, hazard or vulnerability (EHV) information in geospatial formats and organisations broadly involved with risk assessment (RA) activities, either by hosting portal platforms with information, data or tools used for RA or EHV.

A number of organisations are building platforms that facilitate collation of risk models or are communities fostering the development of open-source DRR tools. In particular, two organisations have been the source framework for other portals. CKAN, for example, is a tool for making open data websites that permits the management or publishing of collections of data (e.g. http://catrisktools.oasishub.co). Its search feature enables browsing data captured within the website, which is used by organisations to build maps, graphs and tables. It is one of a growing

breed of open-source tools leveraging the power of multiple contributors who develop, maintain and enhance its core technology for downstream applications. These initiatives are described further in the annex.

Private companies have built probabilistic catastrophe models, although most of their products require licensing on a commercial basis. These include AIR Worldwide, Risk Management Solutions and others listed in the annex to this report. In addition to these companies, several of the major reinsurance companies (e.g. Munich Re and Swiss Re) and (re)insurance brokers (e.g. Guy Carpenter, Tiger Risk, Willis Towers Watson) offer tools and models that can be licenced by clients to help manage disaster risk. Model output data is proprietary, multi-formatted and requires a license, posing a barrier to expanding access to models, limiting choice and creating inefficiencies for end users.

Open-source is often a matter of degree. To illustrate, GFDRR reviewed over 80 open-source and open-access (non-proprietary) software packages in their 2014 report covering hazard risk models for cyclone (wind), storm surge and tsunami, earthquake, and flood. Open-access tools allow individuals to use the tools, but not necessarily to view the underlying code. Their analysis ranked 30 software packages by attributes (GFDRR, 2014b).

Finally, the InsuResilience "Risk Talk" Tool launched in November 2017 provides an anonymous way of asking questions about climate and disaster risk finance and insurance solutions. The portal enables a community of practice around the subject, rather than users having to search published documents across the web that might not provide such direct answers or interaction with experts.

Box 2

GIS vs. Geospatial

GIS refers to a system where geographic information is stored in layers and integrated with geographic software programs so that spatial information can be created, stored, manipulated, analysed, and visualised (mapped).

Geospatial defines the collective data and associated technology which has a geographic or locational component.

Geospatial Data has a geographic component to it. This means that the records in a dataset have locational information tied to them such as geographic data in the form of coordinates, address, city, or ZIP code. GIS data is a form of geospatial data. Other geospatial data can originate from GPS data, satellite imagery, and geotagging.

Geospatial Technology refers to all of the technology used to acquire, manipulate, and store geographic information. GIS is one form of geospatial technology. GPS, remote sensing, and geofencing are other examples of geospatial technology.

GIS Lounge: https://www.gislounge.com/

4.1 Risk Knowledge and Stakeholder Landscape

Both UNDRR and GFDRR promote an integrated approach to managing disaster and climate risks at a global level. At a regional level, the European Institute of Innovation and Technology supports EIT Climate-KIC to build knowledge and work towards a zero carbon future economy and brings business, non-profit, public institutions and academia together in support of this goal. For example, Deltares focuses on water, principally in deltas with densely populated and vulnerable coastal regions, using open source software to help with infrastructure, environment and adaptive delta planning. Campaigns on Build Back Better and Building Resilient Cities provide frameworks for future cross-stakeholder approaches that recognise that simply repairing

Table 6

37

Build Back Better Stakeholders

Stakeholders involved in Building Back Better	
National government disaster management / civil defence organizations	National, local government agencies involved in long-term disaster recovery, including development planning, finance, environment, education, health, social welfare, public works, transport, housing, development, and agriculture
Members of the National Platform for Disaster Risk Reduction	Banking
Insurance	Public infrastructure, including transport, electricity, water and sanitation
Construction	Logistics
Non-profit and faith-based organizations	Academia and disaster risk management experts
Urban planners, legal, public administration and public policy experts	Government support agencies

damage from disasters will not improve resilience. UNISDR recommends greater integration among stakeholders involved in rebuilding after a disaster (UNISDR, 2017).

Insurance plays a significant role in many areas of climate risk integration, with many individual insurers and reinsurers providing R&D support, communication on the risks of climate change and education on the economics of climate adaptation. Notable initiatives include the work of The Geneva Association, which convenes senior representatives across industry, governments and partners who have the incentive and means to take action, and The Munich Climate Insurance Initiative (MCII). MCII looks for new ways to combine insurance with risk management and DRR adaption strategies. MCII, for example, assisted Ghana to accede to the African Risk Capacity, providing its members access to insurance capacity and enabling a more diversified portfolio of risk for country users.

Resilience was defined by the IPCC SREX (2012, p.5) in the Summary for Policy Makers as "the ability of a system and its component parts **to anticipate, absorb, accommodate, or recover** from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions." For policymakers, climate risk insurance resonates as a key tool to build resilience, not least as it can allow even the poorest and most vulnerable to better understand how to anticipate, absorb and adapt to the risks that they face.

The resilience capacities of insurance uptake, as described by Schaefer and Waters (2016) undertaken by MCII, require anticipation, absorption and adaptation, as further defined in Table 18.

The roles of anticipation, absorption and adaptation in enhancing resilience are further explored in Fernandez and Schaefer (2018) in the context of agriculture and livestock, noting that climate risk insurance has mostly been used in boosting investments aimed at increasing productivity by making agricultural processes more intense (through seeds, fertiliser, more intensive land use). Insurance for livestock enables hedging against climate risk, again with more productivity. Insurance also allowed households to

cope better as the liquidity enabled them not to sell goods or livestock. While these are beneficial, due in part to the lack of data and the short period over which insurance has been available (and lack of major shocks to test the impact of insurance), there is currently **a lack of evidence on the long term impact of insurance on resilience and as a result limited advances in building resilience through insurance.** Few studies have been able to determine whether insurance actually changes risk management by encouraging more diversification or risk preparedness. In addition, **as many of the products sold were designed to help a mostly rural community through agricultural products, it does not yet address the challenge of urbanisation and how insurance can help build resilience there. Ultimately, better monitoring and evaluation systems are required to better measure how insurance is improving resilience.**

Anticipating, absorbing and adapting require a coordinated approach among stakeholders. The Swiss Re "Closing the Gap" report (Swiss Re, 2015) makes two key points. First, greater coordination and thus preparedness enables countries to absorb losses and be less vulnerable. Second, vulnerable countries likely suffer longer recovery times. For example, Haiti enjoyed economic growth of +3.5 % prior to the 2010 earthquake, but suffered -5.1 % growth post-event, costing 120 % of GDP. Haiti has probably not yet fully recovered from the loss.

One of the most innovative schemes for pooling and transferring risk is the Caribbean Catastrophe Risk Insurance Facility (CCRIF), launched in 2007 with 16 countries combining their risks of tropical cyclone, earthquake and excess rainfall into one package. In 2015, the pool became a segregated portfolio company, allowing it to segregate the risks to attract capacity, while maintaining a pooled approach for each country; it has now expanded to 22 countries in 2019. The scheme benefits from scale and diversification that reduces the cost of reinsurance, triggered through parametric indexes, to half that of reinsurance that member countries might pay without the diversification credit. The scheme aims to provide the governments with immediate post-disaster resources within 14 days of a loss being triggered to pay for emergency relief and recovery, not to cover ground up losses. The scheme received additional funding of €15m from KfW as part of the Caribbean Catastrophe Risk Insurance Program (CACCRIP).

One of the key themes in recent years is the recognition that infrastructure investment is critical for increasing resilience. A Centre for Disaster Protection (CDP) and Lloyd's of London (2018) report "Innovative Finance for Resilient Infrastructure" included estimates for the revised impacts of Hurricanes Irma and Maria that caused extensive devastation in the Caribbean in 2017. RMS calculated an 8 % reduction in economic loss were the islands to adopt 2018 building code standards for housing and infrastructure. Enhanced standards would likely avoid most damage for less intense storms, and mitigate damage from more intense storms. Importantly, the initiative hosts capacity building events like its innovation lab that brings industry experts together to innovate products and bring additional capacity to assist DRR, such as:

› Insurance-linked loan package
› Resilience impact bond
› Resilience bond
› Resilience service company

Each of these alternatives represents innovative ways of achieving a similar objective: resilience goals (physical, operational and financial) for improved infrastructure construction are rewarded with payments. Each solution is backed by insurance, which ensures funding is quickly available post-disaster. The CDP / Lloyd's report suggests that the "resilience dividend" has total benefits that could outweigh the costs by a ratio of as much as four to one, however more precision requires further post-event empirical evidence to validate the quantum of benefit. While these alternative risk transfer solutions add weight to the picture of supply-side engagement in DRR, it does not address the data required to assess infrastructure risk from an insurance perspective. Infrastructure risk is largely insured by governments, and for insurance to be a viable option stakeholders must address and capture specific risk attributes and data.

In terms of other risk transfer innovation solutions, the largest non-governmental climate insurance programme was announced in 2018 with the release of the African and Asian Resilience in Disaster Insurance Scheme (ARDIS). ARDIS is an "index" structure triggered once a defined loss arises. ARDIS plans to leverage parametric risk transfer and advanced climate modelling that could benefit up to 4 million people or 1 % of the G7 goal to insure 400 million vulnerable people by 2020. The initial target is to focus on four countries in Africa (Kenya, Malawi, Mali, and Zambia), and two in Asia (Cambodia and Myanmar) leveraging VisionFund's largely female clientele.

Finally, the Program Alliance of the InsuResilience Global Partnership and its members, particularly the Global Risk Financing Facility (GRiF) show how stakeholders can strengthen financial resilience of vulnerable countries through innovation.

4.1.1 Agriculture Risk Transfer Innovations

In the critically important area of agricultural resilience, there have been a variety of initiatives to support the development of agriculture insurance in the developing world aimed at tackling the Penetration Gap, which are described in Schaefer and Waters (2016) as to the challenges in implementing climate risk insurance.

Challenges to expand insurance (including agriculture-focused products) in developing countries include convincing potential customers of the value of the product and finding enough data to build a premium calculation methodology. Currently, traditional indemnity-based insurance is mainly demanded by middle class consumers and large enterprise. A broker network educating clients is essential.

For many, understanding insurance products and the ability to divert scarce funds away from essential spending limits the ability of the poor and vulnerable to access risk mitigation strategies. Networks of cooperatives, NGOs and local associations help communicate with individual farmers or market vendors, who fall into the micro or meso-insurance camp. Beyond this, other structures available are a mixture of meso and macro-level insurance schemes, where pools of cooperatives or broader regional governments can begin to look at pre or post-disaster funding solutions. The key role of the GIIF program in expanding insurance coverage is described in Box 3.

Global Index Insurance Facility

The Global Index Insurance Facility (GIIF) is a dedicated World Bank Group program that facilitates access to finance for smallholder farmers, micro-entrepreneurs, and microfinance institutions through catastrophic risk transfer solutions and index-based insurance in developing countries. Funded by the European Union, the governments of Germany, Japan, and the Netherlands, GIIF has facilitated more than 3 million contracts, covering approximately 15 million people, primarily in Sub-Saharan Africa, Asia, and Latin America and the Caribbean. The facility is part of the World Bank Group's Finance, Competitiveness, and Innovation Global Practice.

All index-based insurance solutions, be they weather-based relying on a network of ground based weather stations or remote-sensing through satellite systems, include basis risk for the buyer, and to an extent the seller. Both offer faster claim settlement than traditional indemnity insurance and normally cost less to administer. However, acquiring data remains expensive and requires expertise to establish structures.

Micro-insurance is the most direct level as the policyholders are individuals such as farmers or market vendors. It is also the hardest to implement as it takes time to educate individuals about the value of the cover, as well as the broader supply chain comprising farmer cooperatives, NGOs, banks and local insurance companies. Typically, premiums are subsidised and renewal rates drop when subsidies fall away.

The Blue Marble Micro Insurance scheme shows how stakeholders are working together to provide coverage for excess rainfall and drought. Working in collaboration with Nestlé Nespresso S.A., a coffee distributor, farmers can buy a product not previously available in the Colombian market.

Meso-level insurance involves risk aggregators such as associations, cooperatives, agribusinesses, as well as more established mutuals, credit unions and NGOs who are then responsible for providing services to individual policyholders.

The Start Network Drought Financing Facility and the African Risk Capacity Replica programme are useful examples of meso-level insurance schemes.

The risk management of these index-schemes involves three key components:

(1) Science-based risk modelling of drought risk
(2) Contingency planning / scenario based response planning
(3) Pre-financed index-based insurance; contingency funds are used for more frequent but relatively minor events, while insurance reacts to only less frequent but severe events.

Other organisations are trying to leverage technology to make food production more resilient to climate variability and increase yields. The World Business Council for Sustainable Development (WBCSD) is launching Data Enabled Climate Solutions (DECS) around the world including one in Ghana and Côte D'Ivoire helping cocoa growers with a plan to install 150 weather stations. DECS give farmers access to better warning systems for pest and extreme weather with location specific data, better use of index insurance.

Similarly, the R4 Rural Resilience Initiative, currently active in Ethiopia, Senegal, Malawi, Zambia and expanding into Kenya and Zimbabwe, leverages the World Food Programme (WFP) network. Farmers can access crop insurance by participating in risk reduction activities. Their research shows that Ethiopian insured farmers saved more than twice as much as those without any insurance; this allowed them to invest more in fertiliser, seeds and equipment. This approach allows farmers to not have to panic and sell their assets when disaster strikes, and this also stimulates faster recovery.

Finally, AgUnity is a company that uses blockchain technology to build trust into the sales system and reduce the waste that causes up to 50 % of the value to disappear between harvest and the point of sale. Many farmers trade through small co-operatives, but they mostly rely on paper-based records, verbal promises, and complicated agreements. There is thus a lack of transparency between the farmer and trader. The company has created a mobile application that records the transactions on the blockchain allowing the farmer to trace his products through the network to market. The challenges of food production tend to go beyond lack of transparency though, with significant amounts of waste being caused by

problems in the supply chain (see, e.g., Omondi, 2018). The Partnership should investigate areas for mutual collaboration with CIAT as they share common goals.

Macro-level insurance is bought by governments, often as part of a regional pool, usually with reinsurance protection backing the scheme. These facilities are designed to provide rapid post-loss financing that help with relief efforts. Many of these schemes are focusing on pre-financing on condition that DRR measures are taken pre-loss.

Ultimately, a mixture of approaches to address different risk appetites and needs, coupled with enhancement of remote sensing technology to even the playing field between risk taker and risk provider can help build trust and increase opportunities for index-based insurance solutions.

4.1.2 Remote Sensing Techniques

The WFP through the Weather Risk Management Facility (WRMF) recommends further scaling up index insurance products based on remote sensing, specifically:

› Further investment should be made in ground data collection protocols, capacity and systems
› Different remote sensing approaches, dedicated mapping tools, and ground level sources of data and information could be combined to improve the quality of index insurance structures
› Future initiatives could focus on developing proper segmentation of the size of the insured area
› Schemes based on remotely sensed data should be carefully planned to mitigating basis risk
› Increase private and public institutional capacity should be leveraged to fill gaps in expertise and ensure sustainability

The value of remote sensing for forecasting and post-event validation of losses should not be under-estimated and should be a high priority for the disaster risk and (re) insurance communities.

5. Gaps between demand and supply-side

Model developers and (re)insurers iteratively revise models to produce results closer to actual losses sustained based on real world experience. Even the most mature models fail to capture unique features of risks when future events produce unexpected results, typically resulting in larger than anticipated losses.

Based on review of the current state of the industry, common "gaps" are listed in Table 19, categorized as natural catastrophe, human-induced losses, and losses due to contract terms and interpretation. To some extent, some of these gaps are due to incomplete modelling, rather than complete gaps.

In addition to the above list, as catastrophe modelling becomes more sophisticated and users become more aware of model limitations, demands for more complex analyses is increasing. Model vendors, working with academics and research organisation, are working on how to incorporate so-called cascading hazards into their models. For example, these could include:

› Earthquake and combined aftershocks, assuming building degradation after first shock
› Earthquake and aftershocks with tsunami, assuming building degradation after first shock
› Earthquake plus landslide, plus heavy rainfall
› Clustering of earthquakes and / or windstorms (available for certain regions currently for windstorm)

Table 7

Known Gaps in Catastrophe Models

Category	Description of specific gaps in catastrophe models
Natural catastrophes and secondary perils	› Inland flooding from tropical cyclones or windstorm driven rainfall (from rivers as well as urban flash floods) › Failure of (man-made or due to landslide) dams, levees or flood defences following earthquakes, causing flooding as a secondary peril › Failure of flood defences in river flood models › Failure of flood defences against storm surge › Earthquake maximum possible magnitude not captured (e.g. Tohoku 9.1Mw) › Tsunami following earthquake not always included › Localised super-catastrophe impacts e.g. contingent Business Interruption › Food spoilage in supermarkets, mould and asbestos removal, building ordinance compliance › Demand surge / post event loss amplification › Contamination and pollution › Hurricane, typhoon, and windstorm antecedent conditions and tree fall › Interior (structural and contents) water damage from rainfall associated with tropical cyclones and consequent losses (e.g. mould)
Human-induced catastrophes	› Drastic post event authority measures (evacuation), new building standards › Civil commotion – looting, fraud › Political / consumer pressure causing coverage expansion (such as lowering deductible) or settling claims up to a certain threshold with little investigation
Coverage and Policy Leakage	› Earthquake sprinkler leakage losses greater than earthquake sprinkler leakage limit. Note: these may be paid under fire policies. › Leakage of earthquake losses into fire policies – given partially burnt structures › Leakage of proportion of the storm surge losses into wind policies › Policy expansion – paid claims are above limits e.g. due to under valuations, waiving deductible) › Undervaluation of sums insured

5.1 Gaps: Modelled vs. Not-Modelled Risks

Catastrophe models do not yet capture all the consequences or subsequent downstream impacts related to a loss. Often this is due to the lack of data capture or granularity at the time of loss that can be related back in sufficient detail to the taxonomy of exposure. Risks from either hard to model perils or those with lengthy return periods require actual loss data to refine the robustness of a model.

A list of natural perils not normally captured in models is shown in Table 20. Loss data from each new event eventually will enable future models to expand the perils modelled as well as the robustness of the results.

5.2 Gaps: Model Uncertainty

Another feature of catastrophe risk models is uncertainty concerning the frequency and severity of events. Perils influenced by climate change involve added complexity as exposure can increase. This could impact all risks from meteorological, hydrological and climatological causes. In addition, as noted in Section 3.2.1, population, socio-economic changes, and urbanisation, can also increase risks of catastrophe loss and contribute to model un-certainty.

Geophysical losses challenge models as major events may not have occurred in the historical record and depend on scientific research to estimate the factors that could contribute to potential losses. For example, the earthquake losses in Christchurch, New Zealand in 2010-11 occurred in a region where no causative active fault was known prior to the loss (Davey, 2011), despite the country having known seismic risks. Risk assessment in the absence of recent data as presented by the New Zealand earthquake case can

be potentially addressed through advances in modelling techniques, further discussed below.

Increases in computational power resulting in in-memory calculations becoming standard have reduced some uncertainty in model output. Prior generation catastrophe models were based on fixed assumptions that included an event set for each peril / region that could be represented by tens of thousands of hypothetical events, each with an annual rate of occurrence and some implied uncertainty. Uncertainty in these models was represented as a standard deviation around a mean loss. Summing the various peril / region event sets produces many millions of rows of data and causes computational challenges to build stable results sets. Judgements must be made on correlation weights and uncertainty distributions, limiting flexibility and risk assumptions. Further, the event-based approach produces results that ignore key information, such as the date during a year when an event actually occurred. As a consequence, modelling of loss occurrence time limitations (such as "hours clauses") or aggregate covers, where small separate events can erode deductibles during the course of a year, could not be modelled. It was also not possible to consider events that are conditional on others occurring as the event rate assumed complete independence from other events. Certain scenarios prone to "clustering" of events, such as extra-tropical cyclones and tropical cyclones, could not be accurately modelled.

Model run times have substantially decreased as tools have become more powerful. Mathematical computations to calculate volatility of loss has evolved to allow simulations using larger data samples and simpler arithmetic. Technological advances have boosted both computational speeds, in memory calculations and storage options allowing for large numbers of "simulation years" to be run in a reasonable timeframe and that allow the missing pieces of "per event" models to be overcome. Models now allow a sampling

Table 8

Gaps: Modelled vs. Not-Modelled / Limited Capability

Modelled Peril	Modelled Perils Analysed	Not-modelled or limited modelling
Natural perils	Earthquake; hurricane; tropical & extra-tropical cyclone, storm surge; rain; inland flood; tornado; hail; winter freeze	Volcanic eruption; tsunami; avalanche; landslide; mudslide; bush / wild fire (outside of specific areas), drought

approach of events and their losses over these simulation years. By calculating a random number – or loss quantile – for the event's loss distribution, each time the event itself appears in the simulation, the new model is able to capture uncertainty in a different way to prior models. Uncertainty is only considered once using this quantile approach, which allows for simplification through arithmetic. Complex mathematics is no longer required. Further, employing simulation for ground up losses eliminates reliance on complex financial calculations. This enables financial model results to be more transparent and easier to understand.

Another benefit of improved computational performance is the ability to perform multiple analyses in a realistic timeframe, which previously was not possible. Demands from users will soon see the adoption of automated Global Sensitivity Analysis through tools like the Sensitivity Analysis for Everybody (SAFE) Toolbox. SAFE, currently under development, will soon be integrated into model workflows, enabling greater ability to test the output sensitivity of various inputs, like RMax for tropical cyclones.

5.3   Data Gaps

This report has highlighted areas where data is lacking but where new techniques can help fill those gaps. For example, in the critically important agricultural sector, which has benefitted from application of these techniques, remote-sensing and new technology associated with local weather stations is improving data connectivity at the farm level. In turn, connectivity supports the further development of agricultural insurance products and increases the ability of communities to prepare for both human-induced hazards, such as pestilence, and natural hazards. Multiple organisations are involved in profiling risks from the farm to market, enabling new sets of data to be captured to fill gaps related to vulnerability. Box 4 summarizes the OpenDRI Field Guide's rules for data management during NDRA work. Following these rules will gradually lead to fewer gaps when stakeholders need data.

The impacts of sustained population growth in urban regions combined with de-population of rural areas are creating potential disaster scenarios, particularly for regions at risk from climate change. Exposure and vulnerability data surrounding these cities must be captured in more detail and updated more frequently than before in order to capture the changing extent, population density and characteristics of the urban environment. OpenDRI suggests a collaborative approach for the collection and sharing of data using open-source GIS tools. Providing more tools for crowdsourcing the

Data Management for Risk Assessments

To serve decision makers across a society, data needs to be fully open, both legally and technically. This means that data must be:

(1) Technically open: Many government datasets are locked in data formats that can only be read by proprietary software (and sometimes hardware, like obsolete magnetic tape backup drives). The data must be released in ways that allow any device or software to read them.
(2) Legally open: The licence under which the data are released must permit redistribution and reuse.
(3) Accessible: The data must be available at a public internet address (URL).
(4) Interoperable: The data must follow open standards.
(5) Reusable: The data can be redistributed and reused in ways that were not necessarily anticipated by the curator of the original data.

Source: Crowley (2014)

collection process is useful, provided consistent standards are adopted to allow the information to be collated and shared.

WorldPop, whose open-source databases help build the exposure profile of populations at risk and are widely used for disaster risk management, provided a strong critique on the gaps in data:

"Relevant data are either lacking or are of poor quality. Scarcity of mapping resources, lack of reliable validation data and difficulty in obtaining high resolution contemporary census statistics remain major obstacles to settlement and population mapping across the low income regions of the world." – WorldPop (2020)

EM-DAT also voiced concern over the lack of international consensus regarding best practices for collecting disaster data. "Together with the complexity of collecting reliable information, there remains huge variability in definitions, methodologies, tools and sourcing."

5.3.1 Examples Addressing Data Gaps

The devastating tropical cyclone that hit Madagascar in 2017 disrupted its economy and production of vanilla of which the country produced approximately one third of global supplies (GFDRR, 2018c). An example of extreme vulnerability and lack of risk mitigation, three organisations have provided combined modelling capability that will enable future risk management measures. AIR Worldwide deployed an existing catastrophe risk model that had been developed for prior regional analysis to model the impact of tropical cyclone on buildings and infrastructure, while the African Risk Capacity tool and D-RAS from the World Bank modelled the impacts of economic and agricultural losses, respectively. This demonstrates the fast modelling response that can be achieved where a model already exists.

In the space of twelve months, the combined efforts of the companies captured the necessary information, processed it and provided enough output to assist the government in accessing post-disaster contingent financing as well as developing diversified strategies for farmers.

Machine learning opens further opportunities for insights gained from disasters in one country to model the potential outcome in another country (GFDRR, 2018b). For example, modelling of vulnerability to hurricane losses has been tested in St Lucia, based on neighbouring country Dominica's experiencing CAT 5 winds following Hurricane Maria in September 2017. Using similar building characteristics (roof material, shape and size) and using a number of inputs from drone images, street view imagery and point-cloud elevation data, comparable damage ratios were calculated using machine learning algorithms.

A similar exercise was performed in Guatemala, looking to understand building vulnerability to earthquake. It was not practical to perform a ground survey by foot; however, by capturing images and evaluating these images using deep learning algorithm techniques, it was possible to quickly identify vulnerable buildings. The process caught 85 % of buildings that were flagged as vulnerable, saving time and cost.

The most exciting developments are happening in the InsurTech space, where companies are entering the crop insurance space and using mobile data networks. Many users already use their phones for mobile payments following Vodafone's successful launch of M-Pesa (meaning Mobile + Money in Swahili) in 2007. Start-up companies leverage existing mobile infrastructure and distribution networks to generate new streams of revenue by combining their customer base with users who want value-added services from their mobile. Mobile app designers leverage Unstructured Supplementary Service Data (USSD) or "Quick Codes" to communicate information through GSM networks that can be analyzed over a broad set of users to generate risk and loss data. This allows for real-time connection (compared to SMS data) and enables two-way communication between the user and the operator. At the same time, Application Programming Interfaces (APIs) enable others to securely access the data.

One company demonstrating this interplay between a crop index-insurance provider and mobile operator is OKO, which designed tools using Quick Codes data for implementing its insurance program in Mali and Fiji. For example, OKO worked with the Fijian government and Fiji Sugar Corporation to offer a subsidised insurance premium contract to protect farmers from drought, floods and hurricanes. Automated claim payments are received by users in their mobile app, and the index can use the GSM location to capture ultra-localised weather data.

Combining the benefits of wider ownership of "smart" mobile phones, API connectivity, blockchain technology, open-data and crowd-sourcing (whether deliberate or harvested) provides intriguing opportunities for collecting risk and loss data, providing early warning, and making insurance accessible in developing markets.

5.3.2 Data transparency for users

The Understanding Risk report (GFDRR, 2014a) highlighted lessons learned about how data was used for policy-makers following case studies in Bangladesh and Nepal. Governments must not only be included but must be seen to own projects. Early engagement should ensure that correct resources are made available, and that data can be accessed across departments in an open and understandable manner.

Resources like OpenDRI's Design for Impact Framework report provides guiding principles to effectively use risk data. Extensive outreach across the full community of stakeholders is essential to assess data needs across the supply chain: from farmer to market and downstream from government, to local government, NGO and those operating with cooperatives and mutual companies. Even if models, hazard maps and data exist, opportunities to enhance understanding as to how these tools can help with disaster risk management are certain to exist.

The Lloyd's report on Innovative Finance for Resilient Infrastructure highlighted that policy-makers need to understand risks and invest in good risk data. According to the report, "Risk information is the basis for planning and decision making in many areas of disaster risk management, including resilient infrastructure, pre-disaster planning and purchasing insurance" (Lloyd's, 2018).

To fully understand the needs of stakeholders and determine where gaps remain, a review process creating a hierarchy of questions posed to the hierarchy of users for each hazard will help establish the true gap between what is currently available and where more work is required. Risk assessment to be implemented under the Sendai Framework for Reporting provides new opportunities to assess remaining gaps.

To understand the gaps to improve resilience requires a better understanding of user needs. Frequently the key hazards are human-induced perils and secondly from perils not covered by insurance; both of these are outside of the current scope of the Partnership's focus. The Partnership should therefore examine what would be required to expand current insurance offerings to meet these needs.

As stakeholders capture loss data and organisations like INFORM compile sub-national and local data for their vulnerability and exposure analyses, more consistency in defining the data standards will support creating a better record of historical losses. Sharing these standards will enable the community at large to adopt a common approach and thereby leverage open-source data for the common good. Open-source data comes with several clear advantages, including:

› Low or no barriers to entry
› Easier collaboration with stakeholders
› Data becomes reusable for multiple applications, across borders

5.4   Solving the gaps

The GDFRR (2016) "Solving the Puzzle" report made a number of recommendations that are now being adopted to promote the use of risk assessments in developing countries. These include the HEV-E initiative and current work by the IDF on interoperability. The recommendations highlight both the complexity and breadth of the work that must be done, as reflected in the table below.

Much has been accomplished by the various stakeholders to develop suites of reference hazard events. Open exposure – along with open-source tools – are gaining traction. Building better risk model interoperability is a key part of addressing gaps. We know there are gaps in the data for all risk components, but the largest gaps occur where there is little current insurance or model capability, such as infrastructure, or areas where the Partnership is currently not looking to focus, such as social vulnerability to risks from human-induced hazards.

Table 9

"Solving the Puzzle" Recommendations

Category	Recommendation
Reference Data	Support development of open, high resolution DEMs for developing countries
Hazard	Develop a suite of reference hazard events that provide examples of historical and hypothetical events for impact analyses in developing countries
Exposure	Support enhancement of open exposure dataset with structural data and building valuation
Vulnerability	Develop open databases of vulnerability functions for a variety of exposures (e.g. structural damage and social vulnerability), spatial resolutions, and hazards
Disaster Loss	Develop open database of site-specific loss data that includes standards for data collection
Platforms	Support an effort to develop standards to support risk model interoperability
Capacity	Develop training modules for the interpretation and use of risk assessment results
Communication	Formalize a community of practice for open-source disaster risk assessment

Source: GDFRR (2016) "Solving the Puzzle" Report.

6. Changing landscape for data and insurance

6.1 Challenges and Opportunities

According to Golnaraghi et al. (2018), seven key factors for catastrophe models include:

› Methodology and assumptions
› Data requirements on hazard, vulnerability and exposure
› Standards and interoperability
› Open framework and open source versus restricted framework
› Model validation and uncertainty
› Resource requirements
› Regulatory issues

Changes in **methodology and assumptions** potentially provide opportunities to improve models where data is currently non-existent or poor quality. Advances in computational capacity, simulation and numerical techniques are changing the way models are calibrated. Historically, statistical methods extrapolated known observations into event sets used in the models. As discussed in the previous chapter on model uncertainty, greater computation power is disrupting older practices, contributing to advances in the state of the art. For example, hydro-meteorological perils can now be evaluated across timescales running physical climate models under different conditions to represent either natural climate states like El Nino or changes in near-term hurricane frequency.

The continuing challenge of lack of hazard data to develop and calibrate models is due in part to developing countries' continuing reliance on paper records. Some publicly funded initiatives addressing this gap leverage the open-source Oasis Loss Modelling Platform, such as for example the H2020 project. Meanwhile, lack of common standards and **interoperability of models** have constrained transparency and thus advances in modelling. Coupled with the drive towards open-source models, these factors are changing the market. The Insurance Development Forum (IDF) through their Risk Modelling Steering Group host two work streams aimed at improving modelling infrastructure and models and data availability by looking at both interoperability and open platforms and standards (IDF, 2018).

The nascent Icebreaker One project (https://icebreakerone. org), backed by Climate-KIC, seeks to promote rigour in developing common standards and bridge the data gaps between finance, policy and climate change. Icebreaker One presents significant opportunities for the insurance industry if new standards are developed and adopted. The aims of this initiative include:

› Develop an open standard for sharing environmental risk modelling information
› Generate sufficient momentum to achieve engagement and adoption
› Enable a step-change in economic, social and environmental outcomes that unlock the multi-trillion-dollar market opportunity in the use and application of risk information.

Icebreaker One presents opportunities to address infrastructure as an asset class in relation to increasing resilience.

Designing models for developing regions that currently lack them would greatly benefit local governments in conducting risk assessments, and accessing risk finance and insurance instruments that address their specific climate and disaster risks effectively. The resulting increased transparency would also benefit the public and private sectors within the international community, ultimately potentially expanding insurance solutions.

Integration of maps and agricultural insurance products, particularly where crops change frequently and maps are not updated to reflect the change in land use, remains a gap for remote sensing. Basis risk remains a concern due to differentials between losses incurred and insurance pay-outs. As with other index insurance products, consumer education is essential. Mobile applications potentially offer buyers more understandable ways to purchase insurance animation-based engagement.

6.2 Potential conflicts of interest

Not all interests will align at all times. Although open-source data, platforms and models are widely recognized as important, commercial modelling companies compete for a shrinking market due to mergers of prospective insurance clients, exerting pressure on revenues while the costs to develop enhanced models in regions where data is lacking remain high. Rating agency and insurance supervisors / regulators also exert pressure on (re)insurance companies to better understand how models work, requiring private model vendors to be significantly more open about how their tools have been calibrated. Openness has myriad competitive implications. For a private company to spend time, effort and considerable cost to capture and record data and then build tools to represent hazard and model scenarios, they must earn a market return.

6.3 Climate Adaptation

Many agencies, including those like CIAT, operating in Africa, Asia and Latin America, are working with demand-side stakeholders through the key value stages from farm, through harvest, storage and product marketing to tackle environmental degradation, food insecurity and malnutrition, and the impacts of climate change. Risk profiling is key to this work. For example, in Kenya climate risk profiles have been completed in 31 of 45 counties over several years, however the initiative could eventually build up a digital information profile that is farmer specific. This Climate-Smart Agriculture (CSA) approach seeks to help with crop suitability under climate change by determining how crops will evolve and help farmers in targeting risk. In turn, this helps farmers in developing countries by making them more competitive, more profitable, and ultimately more resilient through the use of more sustainable natural resource management.

From an insurance perspective, agriculture risk management approaches enable partner institutions to improve insurance products, for example, by bundling credit for climate-smart agriculture with index-based insurance products to de-risk the investment to farmers.

From an economic perspective, CIAT and other organisations employ tools to assess the impact of climate adaptation. Ultimately a range of measures could be taken, mostly from a local or national government perspective, which could build resilience and assist with disaster risk reduction. Available measures fall into various mitigation categories, such as behavioural, engineering, green infrastructure and finally risk transfer.

Climate Adaptation Measures

Category	Sample Measures catered for in Climada tool
Behavioural	› Awareness campaign › Early warning system › Emergency response › Evacuation of vulnerable people and valuables › Limit developments in high risk areas › Relocation of people › Urban planning
Engineering	› Backup generators › Enforce building code › Modification of infrastructure
Financing	› Cash reserve › Contingent capital › Risk transfer, insurance
Green Infrastructure	› Vegetation management

Open-source probabilistic models offer potential to help calculate the impact of adaptation measures, and can support training, education and communicating what inputs are required to perform a risk assessment and ultimately identifying gaps in data availability.

Examples of open-source software tools include a GQIS plugin called InaSAFE, which allows users to model the impact of natural hazard scenarios and test vulnerability to allow for better planning and preparedness, and climada, which is available on GitHub. Climada is a probabilistic tool that enables advanced users to test the present value cost of applying measures for each of the adaptation categories and determine the impact on cities, regions and at a country level. The tool does not yet cover all perils, but for the principle risks of tropical cyclones (plus associated storm surge) and earthquake, it can overlay various adaptation measures and apply damage functions to exposures (people, buildings, public infrastructure). It provides 90 measures that could be used, some of which are peril specific. A sample of the measures that could be modelled in Climada for all tropical cyclone, flood and quake perils is shown in the table below.

7. Key Findings

7.1 Insurance Solutions

In the developed world, insurance is still a valuable product, as the transfer of risk from an economic perspective is significant; elsewhere we have seen that more than 80 % of economic losses are not insured, so more needs to be done to find better solutions for the developing markets.

For the developing world, it is not a given that insurance represents a solution. The most vulnerable are still not always catered by insurance and the policies must be carefully designed to ensure that disaster risk reduction investments are properly incentivised (Weingärtner et al., 2017). This would help improve renewal rates, especially among sovereign levels.

By contrast, Sibiko and Oaim (2017) show there is evidence to support how insurance uptake benefits farmers, causing resilience behavioural changes, for example by increasing the use of fertilisers and genetically modified drought / pest resistant seeds to achieve higher yields. Without insurance, a common alternative reaction would be to sell assets: livestock or anything that could pay for food. This might offset some of the pain of a poor year, but overall it is associated with continuing low average yield and income.

Yet, under the same report, indemnity-based insurance has not been successful due to poor data, wrongly priced products and poor communication between buyer and seller. Insurers are generally reticent about entering new markets or placing capacity in an initiative where interests are not clearly aligned. Consumers must be convinced of the benefits and properly value the long-term security that insurance offers.

Index-based solutions appear best suited for developing markets, but still require incentives to persuade buyers due to lack of understanding of how products work, and their benefits following a disaster. More data would reduce basis-risk for the buyer and encourage sellers to expand coverage.

7.2 Risk Assessments

Many countries have already embarked on profiling their disaster risk, beyond the work of development banks and international DRFI projects to manage risk. Examples of these efforts include Uganda, Rwanda and Ethiopia, as well as work carried out by PCRAFI for Pacific Island Countries. Thus, there is already data and skilled professionals to advance these efforts. In Rwanda, for example, the National Risk Atlas assesses hazards by peril, exposure by overlaying the hazards using GIS techniques, and vulnerability using specific assessments by peril. The Atlas shows social vulnerability clearly, identifying the number of people at risk by peril, and providing methodologies to estimate likely physical vulnerability and economic costs of disasters. Approximately 30 groups participated in its development, demonstrating that cooperation can be effective.

The impact of risk assessments once completed is less clear. Although assessment information is clearly useful furnishing a baseline understanding of their exposure to natural hazards, and the exercise may influence countries whether to join or continue with risk pooling institutions, like the African Risk Capacity mechanism, they do not fully assess stakeholders' needs. To baseline needs, stakeholders should conduct a needs review for various outputs (exposure: people and infrastructure; vulnerability: financial capacity and DRR plans; readiness for insurance: financial literacy) and vulnerability indicators (e.g. Table 3) for each category of risk. By comparing data availability by country, risk transfer providers can baseline needs for future work. Still more work will be needed to support community-based risk assessments that do not enable quantification and pricing on the basis of long-term averages. Deep data analysis and feedback on results of concrete decisions will inform future approaches and tools.

Those working (e.g. INFORM and InsuRisk) to capture and report country and sub-national hazard and exposure, vulnerability data are providing valuable data points to guide policy decisions on disaster risk management and help with the allocation of funding. Country reports enable a better understanding of what inputs are available, how these are used to measure disaster risk and create hazard maps. These risk assessments provide benchmarks for other countries. Impressively, as of March 2019, the OpenDRI database for tracking resilience contained 826 datasets covering 54 countries, of which around 25 % were open data and 33 % were closed.

Yet, 159 countries have yet to start reporting for the SFM for the year 2017. Many countries struggle to report data. Using the InsuRisk Assessment Tool to evaluate the reasons and conduct case studies on individual countries (perhaps linked to ongoing work in Bangladesh, Philippines and Nepal) could be valuable.

CIAT explained that they are working hard with demand-side stakeholders from the farmer, through harvesting, storage and product marketing to tackle environmental degradation, food insecurity and malnutrition and the impacts of climate change. Kenya's loss of US$1.5 billion of harvested food, forcing the country to import 6 million additional bags of maize, illustrates the magnitude of the problem and the value of solutions (Omondi, 2018). CIAT's profiling work is vital to implement Climate-Smart Agriculture (CSA) to promote crop suitability under climate change by determining how crops will evolve and helping farmers in target risk areas. They project that future profiling work will be increasingly granular enabling a digital information profile that is farmer specific. Combined with Agricultural Risk Management, CSA will help expand insurance as farmers become more competitive and prosperous.

Better social-vulnerability data, specifically, hazard dependent and independent indicators, are needed as well as more modular and flexible systems. Where data is only captured at a country level, more granularity of data at a sub-national level is also required. However, risk assessment is not an end in itself. It should enable the identification of options, delivering potential synergies, trust and local buy-in to target outcomes.

7.3 Tools for Education and Climate Adaption

Stakeholders expect that provision of funding will be conditioned on resilience measures being tracked and instigated. Building back better and more resilient infrastructure are examples of measures that can address both natural and human-induced risks, such as urban population growth. Tracking the impact of measures and presenting results as an educational tool would help address gaps in understanding disaster risk data.

The Climada tool as described in Section 6.3, which estimates the net present value of climate adaptation measures, provides a tangible way for local governments to understand which DRR measures make sense. Further, it supports decision makers in selecting a course of action, weighing both social and environmental factors. The complexity of these tools, however, limits their use to those who possess both skills and data required to operate them, combined with the lack of the required data inputs to run them. However, without appropriate tools to evaluate the impact, it limits the potential for testing the value of DRR measures and ultimately impedes the take-up of insurance.

Historically, private vendors of models to gauge insurance risk commit the human and financial resources to develop a tool to measure risks once insurance penetration has achieved a certain level and demand is sufficient to ensure a return on investment. However, without either insurance or a catastrophe loss model available to assess and price the risk, the market stagnates. As we have seen, risk models developed by GFDRR and others (e.g. PCRAFI) eventually have led to DRFI solutions. The IDF RMSG Strategy Paper (2018) suggests supporting the development of risk models for those countries where they are currently lacking. A combination of leveraging open-source tools like Climada and open-source platforms like the Oasis Loss Modelling Framework for meetings gaps in models and education can help create a robust risk transfer market, especially for infrastructure risks not covered by major insurance products.

New peril models in an open-source format that captured all required components might provide the incentive for new entrants to enter a market to extend product offerings beyond the current focus on agriculture insurance. While current models cater to tropical cyclone and earthquake, coverage for flood and drought are missing in areas where the poor and vulnerable are concentrated.

7.4 Ownership

Recent adoption of crowd-sourcing for mapping exposures and the opening of data repositories is necessary building for local acceptance of results and outcomes. Ownership and commitment must start at the highest level of authority within a country. It is then the responsibility of all ministries and departments to ensure that all available data that could inform DRR is shared across departments.

Being able to access and use models locally is essential to build local knowledge. The OpenDRI Field Guide (Crowley, 2014) helps train end users and explains how resilience can be enhanced using open data. Beyond government ownership, it is essential to build trust in the data through building partnerships, including local universities, and providing access to imagery as widely as possible. Finally, the process requires a long-term commitment and sustained engagement from all stakeholders to achieve success.

7.5 Communication

Communication among local and global stakeholders is critical. The Joint Research Council Report on Science for disaster risk management produced a number of recommendations around the three pillars of partnership, knowledge and innovation. The report emphasized that communication was key to effectively integrate the layers of knowledge and improve preparedness.

Both message management and breaking down silos within departments are part of the solution. For the former, certain tools, data or maps might not be the best method of explaining risk to the target audience. The message should be tailored to the subject's education, knowledge of the subject, and problem to be solved. Providing the output of a stochastic model on flood hazard, for example, should be managed carefully to ensure that it is digestible. Those who can instigate plans for disaster risk reduction at a community or local government level would be a better audience to understand how to prioritise measures and the cost/benefit of doing so. Helping the general public begin to adopt behavioural changes, which might include insurance solutions, is a continuing challenge, which needs to be continually reinforced, perhaps with the right incentives, especially as new people become involved in the process. This is especially true for hazards with a long return period of reoccurrence.

The InsuResilience "Risk Talk" Tool promotes education for those seeking risk financing by providing an open forum for users to find answers to specific questions from experts, rather than relying on generic sources.

8. Recommendations for the InsuResilience Global Partnership

Based on literature review and interviews with key stakeholders, this paper assessed the needs of demand-side stakeholders against available products in order to identify supply-side gaps to inform Partnership priorities to improve data production, application of climate and disaster risk management solutions, and access to risk financing. Some of the challenges for those involved in DRR activities are listed in Box 5.

Recognizing there are gaps in data across the spectrum of inputs that demand-side users need, the supply-side is gradually building tools to deliver the data required, but not necessarily in an organised way that leverages the combined knowledge and skills of the entire framework. The Global Risk Assessment Framework (GRAF) promises to bring together organisations and coordinate efforts.

Certain gaps will resolve over time as computational and algorithmic enhancements, combined with machine learning, build capacity and refine models. Other gaps require intervention, particularly where their lack of activity or focus. For example, although many models assess and forecast drought conditions, we lack actual catastrophe/financial loss models for drought. Similarly, combined models to capture pestilence, drought and potentially extremely contagious diseases (e.g. Ebola) do not exist yet would help manage the full spectrum of social vulnerability risk populations face.

Recording data in a format that can be accessed widely, if not freely, using open-source tools will likely bring immediate value and should be prioritised. CIAT and others have observed that data existing only on paper or PDF files is a barrier to downstream users exploiting these resources.

Existing system of monitoring risk concentrate on national and sub-national tools, such as those provided by INFORM, to provide details of hazards (natural and man-made) and coping capacity by country. More local risk profiles are needed to supply data to capture the key ingredients of social vulnerability of populations and physical vulnerability of buildings and infrastructure.

Capturing accurate historical loss data is a major gap, which will also inform vulnerability calculations and help improve transparency. Greater transparency reduces uncertainty and the costs of DRR and building resilience. In turn, this encourages insurers to invest resources into developing insurance products; further reducing the cost of risk transfer products. Reducing the cost of insurance will encourage consumers to consider these tools to manage their risk, however the very poor and vulnerable may remain unable to afford these products.

The following sections detail specific recommendations for the Partnership to consider.

8.1 Users and their needs

For poor and vulnerable countries with an economic foundation based on rain-fed agriculture, limited knowledge base to forecast and respond to natural catastrophes – it is essential better data to capture risk and tools for risk assessments, needs specification, and risk modelling.

User needs were established through a hierarchy of questions such as "will it rain, will it flood, should seeds be planted and if so, what type?" with each one becoming more complex. Moreover, questions that were developed and discussed using the example perspective of a farmer, up through the stakeholder chain to local cooperatives, to local government, to regional and national government, in order to answer the questions: Each answer leads to more questions, in turn revealing more data requirements. Each level of user in the hierarchy of stakeholders may not be aware of what is currently available or what is possible and without these insights they may not yet know what they want, what they need or what the next step is. As a result, the hierarchy of questions quickly becomes a hierarchy of gaps both in terms of what data is required and what might be performed on as yet unknown tasks, and then what gaps in the data exist to be able to perform these new tasks.
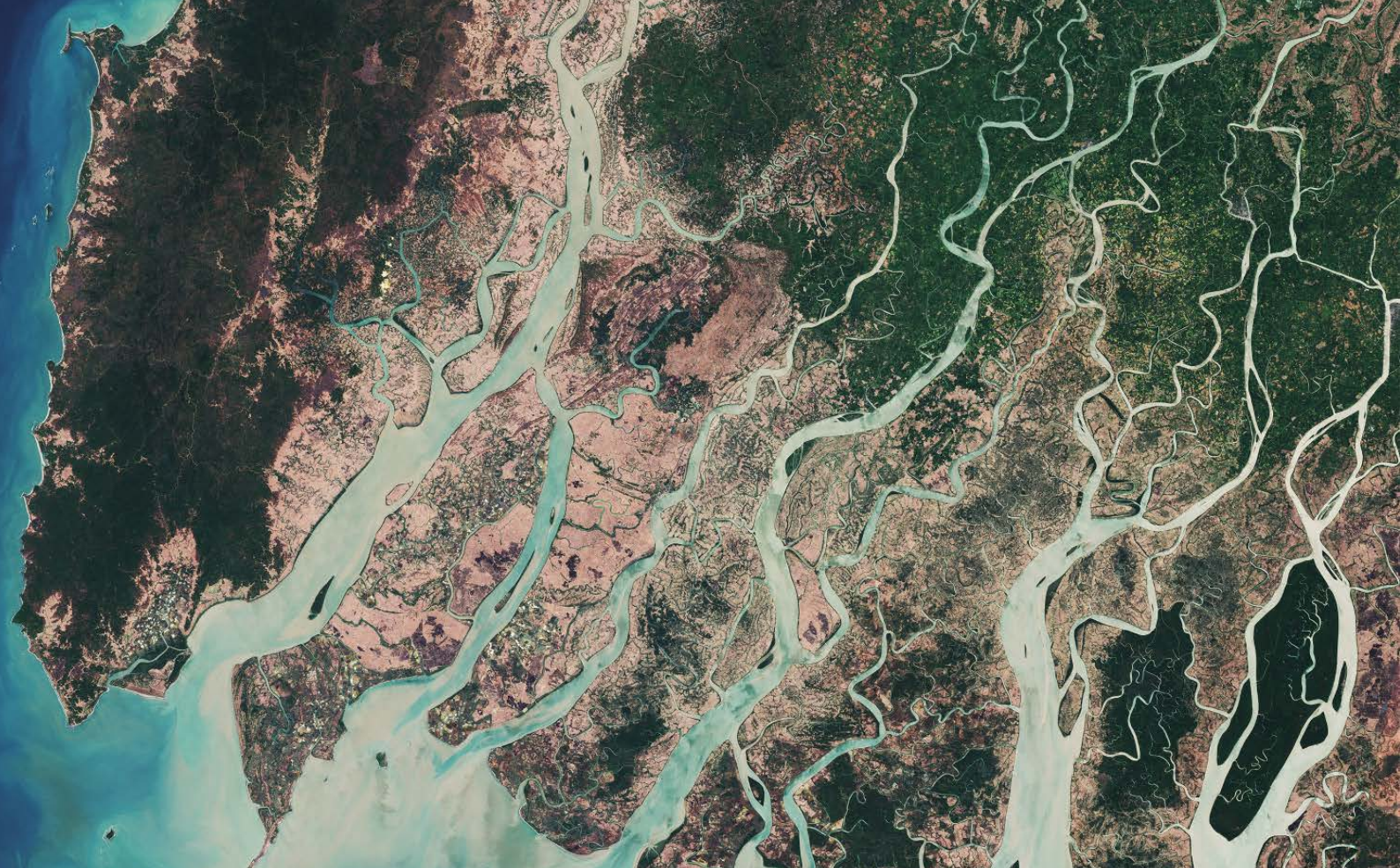
Irrawaddy Delta, Myanmar

The Rwanda National Risk Atlas study can be used as a proxy for user needs, identifying the following gaps or items for follow up:

› Use population and vulnerability profiles to estimate impacts from drought, earthquake, landslide and windstorm by district
› Build or enhance early-warning systems for districts exposed to flood and windstorm
› Use profiles for resource mobilisation to support diverse projects aimed at DRR, addressing vulnerability and building resilience
› Increase education at a sub-district level on disaster risk
› Use drought risk profiles to support development of comprehensive disaster risk financing strategies, including risk retention and risk transfer mechanisms, such as agricultural insurance schemes

These requirement that Rwandan government agencies follow up on these items, combined with its commitment to update the Risk Atlas every five years, align well with reporting commitments to the SFM.

While these follow-ups or gaps could probably be used as a benchmark to measure the progress of DRR goals in most developing countries, **the Partnership should monitor progress of these requirements and assess whether findings would be for similar countries at the same stage of DRR reporting. This would create benchmarks and potentially assist those countries yet to embark on risk assessments or struggling to report the Sendai Framework Monitoring requirements.**

8.2   InsuRisk Assessment Tool Action Plan

The InsuRisk Assessment Tool currently lacks a user front-end to query data. The underlying data should be maintained and towards this end it would be advantageous to share the raw data with the IDF and interested members of the Program Alliance. Additionally, graphics showing "readiness vs. risk" in easy to understand format would be helpful to end users. **The Partnership should aim to achieve a number of goals in next steps presented below, not least the validation of the tool itself.**

In relation to the InsuRisk tool, the INFORM Risk Index offers potential synergies. INFORM is presently under review for its utility to determine if and how stakeholders use the data, and if not, why is the data not useful. INFORM seeks to capture granular data below sub-national level. As a tool to measure and compare risk across districts, regions, and countries, it offers more information than otherwise available in other tools.

› **Data validation of InsuRisk Assessment Tool**
  › Compare the InsuRisk Assessment Tool residual risk outputs with that of INFORM Risk Index
    › Do the residual risk scores for each country align?
    › Are there additional data elements from either tool that could enhance the other?
    › Does INFORM's greater granularity affect scores to assess residual risk in InsuRisk?
  › Compare the readiness for insurance scores against those countries who have joined (and / or left) regional schemes (for example ARC, CCRIF, PCRAFI, R4)
    › How do countries with stated requirements to investigate DRFI compare with readiness scores (for example Ethiopia, Rwanda and Uganda)?
    › Does INFORM's greater granularity imply different sub-national potential for insurance solutions?

› **Target future engagement**
  › Review (in conjunction with UNDRR) which countries are struggling to report according to the Sendai Framework Monitoring and compare these against the INFORM and InsuRisk index results; those that score well for the Partnership goals should be evaluated to cross-reference what risk models are available, prioritising those with the highest residual risk
  › In collaboration with the IDF and Program Alliance, consolidate tool outputs to better understand what could be done to enhance the readiness for insurance score for those countries targeted by the Partnership
    › Review the reasons why Kenya, Malawi and others exited schemes, role of data / pricing, and whether enhancing trust could encourage more economical pricing and more engagement from nations

The InsuRisk Assessment Tool could enhance its usefulness, especially in prioritising the Partnership towards countries genuinely seeking alternative solutions to increasing resilience; starting with data validation.

Challenges to address

› Building trust so that data and information is shared and results used at the local level
› Extending collaboration and networks
› Create cohesion globally so that local outcomes are more prevalent, systematic and sustainable

8.3 Urbanisation and Infrastructure Resilience

Two key threats to developing countries are rapid urbanisation and how inadequate infrastructure increases disaster risk. Cyclone Idai that hit Mozambique in March 2019 cruelly reminded us of the challenge of post-disaster aid, where roads became impassable and bridges were washed away, restricting the ability to distribute essential supplies. DRFI initiatives can help encourage building back better and improving existing infrastructure resilience in rapidly expanding cities.

Attracting capital to the market requires transparency of risk. Enhanced data and open environment with shared standards can facilitate transparency. Tools to calculate the cost and benefit of climate adaptation measures, including improvements to infrastructure, would further enhance transparency. The climada tool and the Icebreaker One project could support a focus on infrastructure where open standards could be established. Infrastructure development is fast becoming a targeted asset-class for investors and insurers must develop alternative products to remain relevant. **InsuResilience Global Partnership and the Program Alliance should investigate how they might contribute to leveraging the outcomes of these three related projects. It is rare for infrastructure projects to be modelled for catastrophe risk, providing an opportunity to support innovation in this area.**

8.4 Climate-Smart Agriculture and Technology

Agriculture plays a crucial role for Africa and other developing nations, who are critically dependent on rain at the right times and in the right amounts to survive on subsistence farming. Climate change will reduce the productivity of crops traditionally grown in specific areas putting livelihoods at greater risk. Climate-Smart Agriculture, as discussed in Section 6.3, will increase resilience and improve productivity and should present opportunities for further exploration by the Partnership and the insurance sector as a whole.

The Partnership should continue to work closely with organisations such as WBCSD, with their launch of Data Enabled Climate Solutions, and CIAT, in support of their Agriculture Risk Management approaches, where "digital agriculture" at the level of individual farmers on specific plots of land is becoming a reality.

Solutions include bundling credit for CSA with index-based insurance products to de-risk the investment for farmers. The further development of comprehensive disaster risk financing strategies, including risk retention and risk transfer mechanisms such as agricultural insurance schemes leveraging new techniques in remote sensing, should increase the confidence of buyers and sellers that products will function as intended.

In the same way that mobile networks in Africa are disintermediating banks through money apps such as M-Pesa, the insurance industry could be disrupted by an insurance product wrapped with a phone data package. In time, Big Data companies like Google, Amazon and IBM may attempt to leverage their knowledge of social media and real-time data to challenge existing insurance players using very different data and new strategies. Although some insurance carriers like Allianz have partnered with OKO in Mali to offer new product offerings through technology, insurers should do more to innovate in this space. **Building partnerships with mobile network operators and mobile application developers to study opportunities for innovation is highly recommended.**

8.5 Open-data / Interoperability

Open-source data should be seen as an opportunity rather than a threat, enabling new tools to build capacity for DRR efforts. The cost of accessing proprietary data is becoming prohibitively expensive, raising barriers to entry. Open-source formats could therefore encourage a new breed of model developers to innovate in this space. Sharing data automatically increases the return on investment of generating the data. However, problems of model interoperability and the steep learning curve required to begin to access and use those models must also be addressed.

The Partnership should continue supporting and contributing to existing interoperability initiatives, through collaboration with the IDF / RMSG and GFDRR, who have shared goals in this area. Adapting and enhancing tools that are already open and providing simpler paths for adoption through better training, education and communication will expand the user base and ultimately lead to more creative solutions from local developers. The Partnership and Program Alliance should lead collaborations. The Understanding Risk 2018 Forum recognizes these themes as well as the need for standards to measure the key components of risk, and improving communication of risks (GFDRR, 2018a). Developing effective tools for communicating risk will also lead to building trust between both providers and users of risk information.

8.6 Support Risk Model / Tool Development

The role of disaster risk finance and insurance to build financial resilience is foundational for managing climate and disaster risk. Being able to offer and price risk transfer products requires the development of catastrophe risk models, many of which do not currently capture the risk faced by V20 countries.

As part of a strategy with the IDF / RMSG to expand the availability of probabilistic models, **the Partnership should support relevant projects identified by the IDF**, provided that open-source principles are followed in the development of these tools. This aligns with The World Bank, UNDRR and Program Alliance objectives to assess disaster risk in all countries. It is also linked with the goals of the Sendai Framework, which individual countries have committed to reporting the Sendai Goals.

The Partnership and Program Alliance should focus on insurable climate risks for poor and vulnerable people, specifically **to support the development of probabilistic catastrophe models targeting the perils of riverine flood and storm surge from tropical cyclones and agricultural drought risk in Africa and Asia, with the addition of earthquake where appropriate.**

Many human-induced risks feature prominently in risk assessment analyses performed in Africa, and **these stakeholder needs should also be addressed**. Ultimately, this requires development of data for risk measurement to support pricing and demonstrate the value of potential index-based insurance products.

The vulnerability component of risk lacks solid data. Building a vulnerability database to reflect critical infrastructure and risks from different types of event pre-loss, would significantly help planning DRR efforts. Both the INFORM Risk Index and the InsuRisk Assessment Tool capture data on vulnerability. **Once the InsuRisk Assessment Tool has been validated, it should be further developed, and its granularity enhanced. Data for critical infrastructure and social-vulnerability risks should be developed to reduce residual risk.**

The exposure component of risk remains the key piece of the puzzle as it describes the location of people and infrastructure in hazard-prone areas. It is essential to accurately capture and model vulnerability to various hazards with precision. Various initiatives seek to build open-source databases that follow standards to allow third-party integration (inputs, outputs and visualisation). **The Partnership should continue to support initiatives to develop open-source exposure data.**

8.7   Leverage GRAF/MGA WG Survey

The Mapping and Gap Analysis Working Group of the GRAF surveyed stakeholders (comprising UNDRR's mailing list) to assess gaps in their framework as well as the data needed to manage disaster risk. Initial survey feedback suggests more and better data, more and better models, training on how to use models and access to a network of peer users are priorities. **The Partnership should review survey outcomes with UNDRR to respond to needs expressed by respondents. One area of immediate need is training, which the InsuResilience Risk Talk tool can meet if it is more widely used. The Partnership should continue to publicise it and engage more experts to respond to users.**

8.8   Solutions for the very poor & vulnerable

The Partnership should consider the difficult realities raised by the ODI "Triple Dividend" report (Weingärtner et al., 2017). These include a better understanding of adverse effects of insurance on the extremely poor. Ultimately, **better monitoring and evaluation systems are required to measure whether and how insurance improves resilience. The Partnership should consider how monitoring is reflected in DRFI project proposals.**

Identifying significant basis risk and how to minimise it for index-based insurance by improving local data through mobile data or networks of weather stations should be a priority as per Recommendation 8.4. To protect the poorest in society, countries must commit to comprehensively improving resilience measures, likely requiring allocating government budget to do so.

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Annex

Table 11: DRR Platforms / Communities

Tool Name	Sponsor	Type	E, H, V	Peril / Scope
GeoPortal	European Space Agency	DRR Platform	E,H	All
ReliefWeb	UN office for the Coordination of Humanitarian Affairs (OCHA)	DRR Platform	V	Humanitarian Aid
Understanding Risk	GFDRR	DRR Community	E, H, V	All

E = Exposure, H = Hazard, V = Vulnerability

The organizations listed below build knowledge of natural hazards and develop tools to share data. Some focus on one peril. Some use open-source data; others provide intellectual property on a proprietary basis.

Table 12: Hazard Assessment, Modelling & Tracking

Tool Name	Sponsor	Type	E, H, V	Peril / Scope
GAR Risk Data Platform	UNDRR	Hazard Assessment	E, H, V	TC , EQ
Global Earthquake Model	GEM Foundation	Hazard Assessment	H	Earthquake
Global Landslide Hazard Assessment Model	NASA	Hazard Assessment	H	Landslide
Global Tsunami Model	European Union – COST Action	Hazard Assessment	H	Tsunami
Global Volcano Model	Natural Environmental Research Council (NERC)	Hazard Assessment	H	Volcano
HEV-E Platform	GFDRR	Hazard Assessment	E, H, V	Multiple
InaSAFE	Indonesian Government-BNPB, the Australian Government, the World Bank-GFDRR	Hazard Assessment	E, H, V	Multiple
ThinkHazard!	GFDRR	Hazard Assessment	H	Multiple
Global Flood Partnership	European Union – JRC	Hazard Modelling	H	Flood
Kinetic Analysis Corporation (Kinanco)	Private	Hazard Modelling	H	Wind
Dartmouth Flood Observatory	Dartmouth University	Hazard Tracking	V	Flood
Global Flood Awareness System	European Union – ECMWF	Hazard Tracking	H, V	Flood
Global Tropical Cyclone Tracks	Private	Hazard Tracking	H	Wind

Organisation that are enhancing knowledge of disaster information are listed in:

Table 13: Loss Databases

Tool Name	Sponsor	Type	E, H, V	Peril / Scope
CatDAT	CEDIM / KIT	Loss Database	H, V	All
DesInventar	UNDRR / LA RED	Loss Database	H, V	All
Emergency Events Database (EM-DAT)	CRED	Loss Database	H, V	All
Global Identifier Number	Asian Disaster Reduction Centre (ADRC) / UNDRR	Loss Database	H, V	All

These tools are mostly involved with mapping exposure, hazard or vulnerability (EHV) information in geospatial formats.

Table 14: Mapping Tools

Tool Name	Sponsor	Type	E, H, V	Peril / Scope
ArcGIS	ESRI	Mapping	E	GIS
DIVA-GIS	Private	Mapping	E, H, V	Biodiversity
GeoFabrik	Private	Mapping	E, H, V	GIS
Natural Earth	Private	Mapping	E	GIS
Office for National Statistics	UK Government	Mapping	E	All
OpenStreetMap	OpenStreetMap Foundation	Mapping	E	GIS
QGIS	Community foundation	Mapping	E, H, V	GIS
Spatial Key	Private	Mapping	E	GIS
WorldPop	University of Southampton	Mapping	E	Population

The following selection of organisations are broadly involved with risk assessment (RA) activities, either by hosting portal platforms with information, data or tools used for RA or EHV.

Table 15: Risk Assessment / Index

Tool Name	Sponsor	Type	E, H, V	Peril / Scope
CAPRA	Private	Risk Assessment	E, H, V	All
GAR Atlas	UNISDR	Risk Assessment	E, H, V	All
Global Assessment Report	UNISDR	Risk Assessment	E, H, V	All
INFORM (Index for Risk Management)	Inter-Agency Standing Committee (IASC) European Union	Risk Assessment Index	E, H, V	All
Insurdata	Private	Risk Assessment	E	All
InsuRisk Assessment Tool	InsuResilience Global Partnership	Risk Assessment Index	E, H, V	All
Open Data for Resilience Index	GFDRR	Risk Assessment Index	E, H, V	All
Riskscape	GNS Science NZ	Risk Assessment	E, H, V	Geoscience

The following table includes organisations building platforms that facilitate collation of risk models or are communities fostering the development of open-source DRR tools.

Table 16: DRR & Modelling Communities

Tool Name	Sponsor	Type	E, H, V	Peril / Scope
CatRiskTools	IDF	Risk Model Database	E, H, V	All
Delft-FIAT	Deltares	Risk Model	H	Flood
METEOR	UK Space Agency	Exposure Modelling	E	All
Oasis Hub	Private	Data Catalogue	E, H, V	All
Oasis Loss Modelling Framework	Private	Modelling Platform	E, H, V	All
Open Data for Resilience Initiative	GFDRR	DRR Community	E, H, V	All
RASOR	CIMA Foundation	DRR Mitigation	E	All

This table lists two organisations that have been the source framework for other portals.

Table 17: Risk and Data Aggregation tools

Tool Name	Sponsor	Type	E, H, V	Peril/Scope
CKAN	Private	Content Management	N/A	Data browser
GeoNode	Private	Geospatial Data Management	E, H, V	All

The final table in the Risk Knowledge category lists private companies that have built probabilistic catastrophe models. Almost all of their products require licensing on a commercial basis.

Table 18: Catastrophe Model Companies

Catastrophe Modelling Companies	
AIR Worldwide	JBA Risk
Ambiental Risk Analytics	Karen Clark & Co
CatRisk Solutions Ltd	KatRisk
COMBUS	Risk Frontiers
CoreLogic	Risk Management Solutions
ERN	RMSI
Impact Forecasting	