Operationalizing Resilience against Natural Disaster Risk: Opportunities, Barriers, and a Way Forward

Zurich Flood Resilience Alliance

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Acknowledgements

The authors wish to thank the following sponsors for their support in conducting this research: Zurich Insurance Group.

Citation

This report should be cited as:

Keating, A., Campbell, K., Mechler, R., Michel-Kerjan, E., Mochizuki, J., Kunreuther, H., Bayer, J., Hanger, S., McCallum, I., See, L., Williges, K., Atreya, A., Botzen, W., Collier, B., Czajkowski, J., Hochrainer, S., Egan, C. (2014) Operationalizing Resilience against Natural Disaster Risk: Opportunities, Barriers, and a Way Forward. Zurich Flood Resilience Alliance

Design/layout and printing: IIASA Communications, Library and Media Department

Cover image: Adapted from Shutterstock

Cooperation between Zurich Insurance, IIASA and Wharton

This white paper is one of the first outputs of the *academic cooperation with Wharton and IIASA to empower the global flood resilience program.*

An increase in severe flooding around the world has focused greater attention on finding practical ways to address flood risk management. Therefore, Zurich Insurance Group launched a global flood resilience program in 2013. The program aims to advance knowledge, develop robust expertise and design strategies that can be implemented to help communities in developed and developing countries strengthen their resilience to flood risk. To achieve these objectives, Zurich has entered into a multi-year alliance with the International Federation of Red Cross and Red Crescent Societies, the International Institute for Applied Systems Analysis (IIASA) in Austria, the Wharton Risk Management and Decision Processes Center (Wharton) in the USA and the international development non-governmental organization Practical Action.

The cooperation builds on the complementary strengths of these institutions. It brings an interdisciplinary approach to flood research, community based programs and risk expertise to generate a comprehensive framework to how community flood resilience can be improved. It seeks to improve the public dialogue around flood resilience, while measuring the success of our efforts and demonstrating the benefits of pre-event risk reduction, as opposed to post-event disaster relief.

The research program will focus on:

- Identifying and addressing research gaps
- Developing a methodological framework based on systems analysis
- Demonstrating the benefits of ex ante disaster risk reduction and preparedness
- Addressing behavioral, economic and policy obstacles to effective community flood resilience
- Conducting case studies with communities in OECD and developing countries together with the other partners of the flood resilience program
- Fostering flood risk management in OECD and developing countries
- Improving public dialogue around flood resilience

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Executive Summary

The risks from floods have been rising globally due to increasing population, urbanization, and economic development in hazard-prone areas. The number of flood disasters throughout the world nearly doubled in the decade from 2000-2009 compared to the previous decade. There have been more flood disasters in the last four years (2010-2013) than in the whole decade of the 1980s. Evidence indicates that climate change-induced sea level rise, storm surge, and more intense flooding will reinforce this trend unless risk management measures are undertaken immediately to manage future losses well and make communities more resilient to flooding.

It is widely recognized that there is a mutually reinforcing relationship between disaster risk and development: disasters impact development and development impacts disasters. Evidence shows that repeated disasters undermine long-term socioeconomic objectives. This is particularly evident in low income countries where disasters can impede the development process. The extensive time required to recover from damage, the loss of capacity with which to rebuild, and systemic risk negatively affect livelihoods, in extreme cases trapping people in poverty. In developed countries, recent floods triggered massive economic losses and undermined long-term competitiveness. The impact of disasters is felt most acutely by households and communities. In both developing and developed countries alike, local-level studies strongly indicate that the poor suffer disproportionately due to the lack of (1) financial and social safety nets and (2) institutional representation.

Development can affect disaster risk via three main channels: by (1) increasing the physical assets and people exposed to the risk, (2) increasing the capacity to reduce, respond to, and recover from the risk, and (3) increasing or decreasing the vulnerability based on specific development strategies chosen. We identify this interaction as a key research gap; taking account of disaster risk and balancing it with development opportunities will require a paradigm shift in the way we think about and do both development and disaster risk management.

We identify a number of challenges to disaster theory and Disaster Risk Management (DRM) practice which must be addressed if increasing risk is to avoid undermining long-term development. (1) Decades of coordinated efforts to manage and investigate disaster risk have led to increasing awareness of the need for better management and financing of disasters, organized around a holistic understanding of people's capacities, vulnerabilities, and wellbeing. Yet this holistic understanding is rarely operationalized. Without such a holistic perspective of communities, the full costs and benefits of appropriate disaster preparedness, risk reduction, and risk financing strategies may not be taken into account in development, investment, and growth planning. (2) DRM strategies that are too hazard-focused (i.e., do not adequately consider the "human element") may miss opportunities for development that would improve lives and wellbeing. (3) Behavioral drivers are leading to an emphasis on response and recovery to the neglect of risk reduction and preparedness. These behavioral drivers, including the cognitive biases affecting risk perception, must be incorporated into DRM theory and practice. (4) Increasing uncertainty in future sociodemographic and climatic conditions is changing the decision space for disasters. Unfortunately, decision making under this sort of uncertainty is not well understood. Overall, there is a need for comprehensive and inclusive approaches for tackling disaster risks; this is being recognized by both development policy and practice, the private sector, the academic community, the Organisation for Economic Co-operation and Development (OECD) and developing economies, international donors, and an increasing number of businesses and global forums (e.g., World Economic Forum).

This review identifies the concept of resilience as a useful entry point for a holistic understanding of DRM. Resilience has a long history, and different disciplines have provided a variety of perspectives. Throughout the 20th century the term was adopted in the fields of engineering to design fail-safe production systems; psychology in regard to recovery from adversity or trauma; ecological systems theory on the persistence of the bio-ecosystem following a disturbance; and economics regarding the efficiency of resource allocation and input mobility during a shock, and how quickly the economy can return to efficiency after the shock. The central theme that unites the various perspectives on resilience is that of response and recovery from shocks, and thus it seems a natural extension that the concept be applied in disaster research and practice.

A range of definitions and conceptualizations of disaster resilience have been put forward by academia, key multilateral organizations, development agencies and nongovernmental organizations (NGOs), and the private sector. Many of these perspectives have important overlap in terms of stressing the "ability" or "capacity" of a system or community to withstand and recover from disaster. Additionally, several analysts point to a dynamic aspect, for example, "adapting more successfully to," highlighting that learning from the event is central to resilience. A key aspect taken up by the disaster resilience discourse is to emphasize the need to embed resilience in a development perspective and focus on the interconnectedness and interdependency between natural and social systems.

We find that there is both scope and need to advance the discourse in order to provide guidance on conceptualizing and operationalizing community-level disaster resilience. Building on the established disaster resilience discourse, we propose a broader framework and a definition of disaster resilience focusing specifically on community flood resilience that (1) more explicitly emphasizes development opportunity, as this is arguably the reason resilience is desirable for a community, (2) sees community resilience embedded in complex adaptive systems, and (3) identifies resilience as being able to cope with (flood) events, thrive in the face of uncertain flood events, and continue to strive toward new opportunities in the face of changing flood risks. These elements of a more holistic framework appear tacitly in a number of the definitions mentioned above. Bringing these out more explicitly, we suggest a broad-based working conceptualization of disaster resilience.

Conceptualizing disaster resilience

Disaster resilience is the ability of a system, community, or society to pursue its social, ecological, and economic development and growth objectives, while managing its disaster risk over time in a mutually reinforcing way.

This conceptualization has important implications for a community perspective on disaster resilience and the work of the Alliance. First, it stresses that managing disaster risk well (identifying, mitigating, preparing for, and responding to the risk) is an important component of building resilience in practice. At the same time, if we understand communities as complex adaptive systems, we can study their ability to learn, change, and operate in an environment that is changing. As risks are dynamic due to an environment that is changing, the community's wellbeing and development opportunities will likely change over time. To continuously grow and develop in the face of risk implies the need for a risk management process that considers learning, innovation, and transformation.

We propose a systems-based perspective of resilience that goes beyond the conceptual phase and offers a structured way to operationalize and measure community disaster resilience. It is built on the key community assets – social, human, physical, financial, and natural. These assets are viewed as interdependent capacities that holistically make up the community system. This integrates widely utilized community capacity frameworks with systems thinking frameworks, which are the dominant conceptual frameworks used in resilience literature to date.

Community capacity frameworks focus attention on developing the underlying resources and capacities needed to escape poverty, and to develop and manage risk on a sustainable basis. They depict the critical mass of assets needed to cope with stresses and shocks, and to maintain and enhance capabilities now and in the future.

We also highlight principles that can provide simple "rules" for managing complex systems such as a community. The systems thinking literature has identified four main properties for complex dynamic systems to be resilient: robustness, redundancy, resourcefulness, and rapidity. These properties provide one potential framing that will be investigated by work within the Zurich Flood Resilience Alliance to better understand how to generalize resilience strategies. For example, in the context of community disaster resilience, we can think of access to credit, which has been found to be critical for small businesses during normal times, and even more so during disasters, as creating redundancy in the system (slack liquidity) and therefore contributing to a source of resilience. As credit access has not historically been a focus of DRM, we are able to systematically investigate a wider array of resilience options within this framework.

Finally, we suggest embedding this thinking and the rules in an iterative and adaptive community-based process. Iterative Risk Management (IRM) is an approach to risk management that links expert risk analysis together with stakeholder participation. It is an approach that is adaptive and provides feedback for learning to iterate and further adapt or transform. IRM approaches are being recognized as a useful way forward, as they can address issues such as lack of robust data, long time scales, uncertainty in future conditions, and operationalization and quantification which are commonly acknowledged problems in risk management. This process prioritizes ex ante risk reduction action. However, because it is embedded in the system, it is only one process that aids the overall goal of the system and thus must balance risk reduction options with development opportunities.

What does this imply concretely for the analysis of community resilience? A community using the IRM approach would (1) monitor the performance measures – how well the system is functioning at balancing opportunity and risk exposure. It would do this within (2) a process for identifying and then assessing the risks to the community's performance. Next (3), it would seek solutions to reduce the risks by looking at solutions in terms of the "four Rs" of resilient systems (i.e., how does the solution contribute to building robustness, creating flexibility (redundancy), enabling greater resourcefulness, or promoting rapidity (learning and smarter recovery). It would finally (4) implement them effectively (and perhaps innovatively) by taking into account multi-attribute analysis of costs and benefits and behavioral economic considerations.

We contend, however, that building and enhancing flood resilience critically rests on the ability to measure impacts of interventions and track progress. We identify this as the major research gap. Metrics are needed in order to evaluate the effective sources of resilience and monitor resilient outcomes in the community. These metrics can be both quantitative and qualitative. While many resilience metrics and methodologies have been proposed in the literature, we are not aware of any that have been implemented across different countries and monitored over time. Further, we know of none that matches up sources of resilience with a set of pre-event determined resilient outcomes to track and test the sources and thereby learn which are most effective.

To drive an evidence-based understanding of flood resilience we propose the development of a comprehensive set of metrics grounded axiomatically in properties of a resilient system to help guide the exploration of potential sources of resilience and test their effect on outcomes. Using the five capitals framework, potential resilient indicators might include: (1) Physical capital – the number of access roads and bridges (source) and the number of households with uninterrupted access to utility services post flood (outcome); (2) Social capital – the number (or percentage) of stakeholder groups represented on a planning board discussing ways to reduce losses from future disasters; the amount of times they meet (source) and the number of community members engaged in aiding others in recovery (outcome); (3) Human capital – diversity of skills/training in the community (source) and the number of days children are displaced from schooling (outcome); (4) Financial capital – the average household savings in the community (source) and the amount of days of lost income (outcome); and (5) Natural capital – the degree of soil absorption (or ability for natural run-off) (source) and the percentage of protective barriers eroded (outcome).

In summary, this white paper suggests that a better appreciation, understanding, and measurement of resilience is needed to address the major challenges in relation to disaster risk globally. This will help balance disaster risk and the opportunity for community socioeconomic development. This paper synthesizes the research and shows the following: (1) resilience can be defined by distinct properties; (2) it can be operationalized through an IRM process; and (3) it can be measured at a certain point in time and over time. Our review has laid out a methodological approach within a systems framework that can be taken to communities in a series of case studies within the Zurich Flood Resilience Alliance program. By systematically collecting data and through the co-generation of knowledge and action with the communities and testing within this framework, we will be able to build up an evidence-based measure of the characteristics of disaster resilience in communities.

1 Introduction

Zurich Insurance Group has launched a multi-year flood resilience program to help strengthen the resilience of communities against floods and to develop and disseminate knowledge and expertise on flood resilience. To achieve these objectives, Zurich has entered a multi-year alliance with the International Institute for Applied Systems Analysis (IIASA, Austria), the Wharton Risk Management and Decision Processes Center (Wharton Business School, University of Pennsylvania, USA), the International Federation of Red Cross and Red Crescent Societies (Switzerland) and the international development NGO Practical Action (UK). This cooperation builds upon the complementary strengths of these institutions. It brings a truly interdisciplinary approach to the task, broadening the scope of the research while at the same time benefiting from synergies between all groups.

This white paper on disaster resilience is one of the foundational pieces of this research collaboration. It identifies key challenges and research gaps on risk, risk management, and resilience, as well as entry-points for tackling these gaps. Finally, it sets the stage for in-depth and participatory research on risk and resilience.

The review identifies the salient ongoing and emerging challenges and opportunities confronting the management of flood risk. It examines the significance of the surge of interest around resilience as a concept in the disasters field, which holds many gaps and challenges. We present an approach that identifies and builds on the strengths in the current thinking on disaster resilience and brings these out explicitly.

We suggest there is need and opportunity to go beyond current approaches to resilience by taking a perspective that is centered on wellbeing. While there may be many ways to operationalize resilience concepts, we set out a broad framework for operationalizing resilience against flooding at the community level. This framework and associated methodology will inform work in a number of case locations studied by the Zurich Flood Resilience Alliance program (henceforth "the program") over the coming years via a participatory process, and move the discourse forward via testing, refining, empirical validation, and synthesis of key lessons learned.

A way forward: Bolstering community wellbeing via a holistic resilience-based approach

Disasters affect a community's resources – human, social, physical, financial, and natural. These resources provide the means not only for livelihoods and wellbeing but also for Disaster Risk Reduction (DRR), preparedness, risk finance, response, and recovery. A better appreciation and understanding of the dynamic link between managing disaster risk and community development is needed. In this paper we will argue that a more holistic approach to managing risk by focusing on resilience building can better harness the community's resources to provide for growing and sustainable wellbeing, which implies reducing disaster risk and coping well when disasters do occur.

At times "resilience" has been at risk of becoming an empty buzz-word that offers little tangible improvement over the current approach to Disaster Risk Management (DRM). We argue that resilience is not simply "DRM done well" and instead outline the case for a systems perspective of resilience focused on the community's livelihood and wellbeing goals. We focus on the social, human, natural, financial, and physical assets available to communities because this provides a lens to understanding a community's wellbeing and development opportunities. Critically, we take account of the interdependencies of these capacities and the flood hazards that put them at risk. Within this framework, we lay out a broad research methodology for the remainder of this partnership that will ultimately identify effective sources of resilience, interventions, and practices by testing against pre-flood identified resilient outcomes (objectives) within communities. This systematic analysis will lead to a grounded theory understanding of community flood resilience and an ability to benchmark and build flood resilience in communities.

The research approach and agenda

We extend the established research beyond the conceptual phase by proposing a structured way to operationalize and measure resilience at community level. First, our working definition of resilience recognizes that a community is a complex socioeconomic system. A systems-based perspective of resilience views community resources – Social, Human, Physical, Financial, and Natural – as capacities that lead to disaster exposure and vulnerability as well as resilience. This integrates the community capacity frameworks and the systems thinking frameworks, the two dominant conceptual frameworks used in the resilience literature to date. Systems thinking also implies that the system (e.g., a community) is dynamic, namely, that it is changing and capable of changing.

We lay out our arguments as follows: in section 2 we outline the burdens imposed by flood risk and present evidence regarding the deep interconnection between disasters and development. Section 3 explores the current approaches and challenges in the field of DRM. In section 4 we summarize the many and varied perspectives on resilience relevant to disasters. In section 5 we go beyond established work to propose a systems-oriented and development-based framework of disaster resilience, including a working conceptualization. We explore the properties of a resilient system and identify Iterative Risk Management (IRM), a type of risk-based analysis and adaptive learning, as a potential way to begin to operationalize resilience in communities. In section 6 we explore issues relating to measuring resilience and identify elements of a measurement framework from our systems perspective before section 7 concludes with an outlook regarding operationalizing resilience overall and for the work of the Zurich Flood Resilience Alliance.

2 The Need for Resilience: Managing Disasters and Development

It is widely recognized that there is a dynamic and mutually reinforcing relationship between disasters and development: disasters impact development and development impacts disasters. Disaster risk, particularly with regard to flooding, is on the rise; hence, understanding the nuances of this relationship is critical. A better understanding of this relationship is required for identifying entry-points for resilience-based interventions.

2.1 Flood risk is increasing

The world is facing increasing risks as globalization connects people, economies, and ecosystems. This interconnectedness and interdependency makes resilience a particularly relevant concept in DRM due to the inability to predict all potential direct and indirect impacts of systemic risks (Adger et al., 2005).

Risk is a combination of the size of the loss and the likelihood of a loss. Thus, a driver of increasing risk is increasing development that exposes more value to hazards (both in terms of exposed people and physical assets). Another driver of increased risk is changes in hazards due to changing climate conditions. Increased risk is leading to an increase in the severity and frequency of disasters.[1]

People and assets located in disaster-prone areas around the world are growing in number, and this trend will continue in the coming years. This holds particularly true for flooding; Figure 1 exhibits the geographic centers of the more than 3,700 large floods observed globally over the last 25 years, many of which hit key loci of socioeconomic development.

Globally, the number of people exposed to floods each year is increasing at a higher rate than population growth. More than 90% of these exposed people live in South Asia, East Asia, and the Pacific. Economic opportunity is one of the factors drawing people to flood plains (UNISDR, 2011). Low- and lower-middle-income countries have a larger proportion of exposed population, and their exposure is growing faster. Since 1990 global vulnerability has been decreasing or stable with some exceptions, noticeably in South Asia.

1 Disaster is defined as "a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources" (UNISDR, 2009).

However, while development increases the potential losses (value at risk), it can also drive the reduction in vulnerability via increased DRM capabilities.

Anthropogenic climate change is an example of the need for integrated development, DRM, and climate change mitigation and adaptation (IPCC, 2012). Climate change is modifying the intensity and frequency of heavy precipitation episodes, which will also affect flood risk (Jongman et al., 2014). Climate change could also trigger large-scale, system-level regime shifts and alter climatic and socioeconomic conditions. A dieback of the Amazon rainforest, decay of the Greenland ice sheet, and changes in the Indian summer monsoon are some of the plausible risks with global ramifications for flood risk. At the community level, alterations to systems could include environmental shifts such as freshwater eutrophication and woody encroachment of savannahs which impact flood hydrology. The abruptness and persistence of such socio-ecological system changes, coupled with near or absolute irreversibility, has driven the impetus for applying the concept of resilience to disasters (Davoudi, 2012; O'Brien et al., 2012).

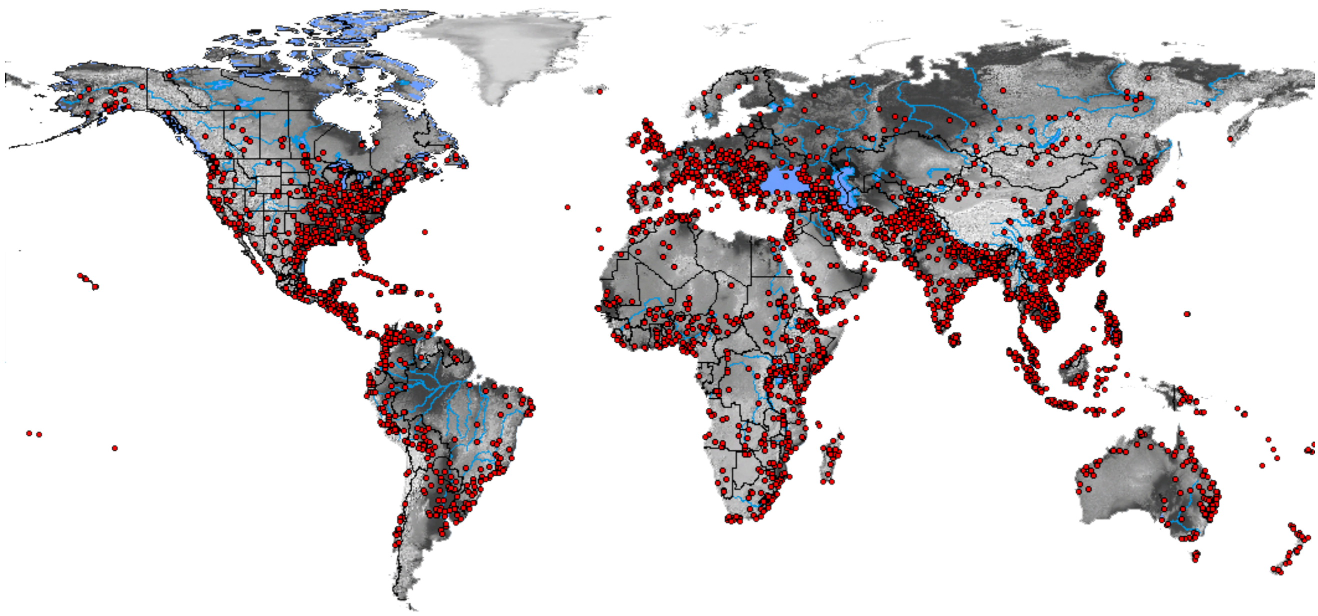


Figure 1. Geographic centers of large floods over the period 1985-2010
Source: Dartmouth Flood Observatory archive as in Kundzewicz et al. (2014)

2.2 Disasters impact development

The Global Assessment Report (GAR) on Disaster Risk Reduction (UNISDR, 2013), a key report based on global analysis, finds that the impact of disasters on development and business performance is deep and far-reaching. Disasters undermine long-term competitiveness and sustainability, which can then impede development. This is particularly devastating in developing countries, where it is the poorest of the poor who tend to bear the brunt of disaster impacts (UNISDR, 2013), particularly in pockets where repeated disasters erode the capacity to recover, trapping households or communities in a vicious cycle of poverty.

At the national level, the impacts of disasters on aggregate economic performance and human development indicators have been examined in several studies over the last four decades through empirical and statistical analysis as well as modeling exercises. While the earlier studies addressed predominantly developed economies and focused on sectorial and distributional impacts of disasters, in recent years there has been more emphasis on developing countries (Handmer et al., 2012). Studies generally find very limited aggregate macroeconomic impacts in developed countries, but important regional economic and distributional effects (Okuyama, 2003). In developing countries, disasters have been found to lead to important adverse macroeconomic and developmental impacts and to affect the pace and nature of socioeconomic development (Mechler, 2004; Otero and Marti, 1995; Benson and Clay, 2004; ECLAC, 2003; Charveriat, 2000; Raddatz, 2007; Kellenberg and Mobarak, 2008; Hochrainer, 2009; Noy, 2009; Cavallo and Noy, 2009; Handmer et al., 2012).

The impact, though, of disasters is felt most acutely by the affected households, businesses, and communities rather than the country itself. Whether, and to what extent, an individual, household, firm, or country suffers or even gets stuck in a poverty cycle due to disaster depends on many factors such as their levels of preparedness, the availability of, and access to, external assistance, and choices of coping strategies. In addition, institutional factors, such as the quality of disaster management authorities and policies, as well as economic factors, such as the prevailing business climate and access to credit markets, all affect individual prospects for recovery.

Table 1. Erosive and non-erosive strategies for coping with disasters

Erosive	Non-erosive
Selling productive livestock	Selling excess animals
Reducing food consumption	Consuming less expensive or less preferred food, or gathering wild foods
Selling agricultural or fishing equipment	Drawing on kinship transfers of food or money, or reciprocal labor exchange
Mortgaging or selling land	Migration and remittances
Borrowing money at very high interest rates	Casual local work or temporary migration
Over-exploiting natural resources	Drawing on existing savings

Source: Heltberg et al. (2012)

Where quantification exists, local-level studies strongly indicate that disasters have long-term impacts on businesses, households, and individuals, that vary across groups. More often than not, the poor suffer disproportionately due to the lack of financial and social safety nets and institutional representation (Morris et al., 2002; Cutter et al., 2006; Anttila-Hughes and Hsiang, 2013).

As micro-enterprises and SMEs (small and medium-sized enterprises) form the basis of much local-level livelihood in developing countries, Sardana and Dasanayaka (2013) surveyed 50 of these in the Galle district of Sri Lanka. The authors found that six years after the Indian Ocean tsunami of 2004, those enterprises recovered on average only around 62% (in terms of sales revenue) and 58% (in terms of capital employed). The extent of their recovery depended on many factors including their own sources of savings, access to credit and other external sources of support, and the general economic environment. Only a handful of firms were insured, but most of those insured did not receive sufficient compensation, as tsunami damage was not included in their coverage. The delivery of external assistance was complicated further by convoluted procedural requirements, hindering efforts toward a swift and equitable recovery.

As with firms, household recovery from disasters also depends on a number of distinct factors. Investigating agricultural production and asset rebuilding following the 2010 flood in Pakistan, Kurosaki and Khan (2011) surveyed 10 rural villages in Khyber Pakhtunkhwa. They concluded that factors such as household size (which affects the availability of labor), educational level of household heads, and initial levels of asset endowment (such as livestock level), were all significantly related to self-reported levels of disaster recovery. Receipt of government emergency aid also had a significant and positive relation to land and crop recovery.

The lack of formal safety nets such as property and crop insurance is a common feature found in developing countries due primarily to prohibitive transaction costs, affordability issues, and lack of an insurance culture. In the absence of formal insurance, households and firms turn to "informal" insurance such as kinship exchange of food and money. The availability of these informal arrangements, and their effectiveness, are strongly tied to resource endowments. Nevertheless, informal risk sharing at the community level is of limited effectiveness for managing disasters because when an event occurs, the whole community can be affected (Fafchamps and Lund, 2003; Townsend, 1994). These resources, combined with individual actions taken pre- and post-disaster, determine how well an individual, household, firm, or community responds to, copes with, and adapts to risks over time. One aspect of building resilience over time must therefore be to create an environment conducive to non-erosive strategies, while also reducing risk and strengthening wellbeing.

Table 1 (above) summarizes different ways people can cope with a disaster. Strategies are called "erosive" when they lead to medium- and long-term negative impacts on development and wellbeing. This happens when the way disaster losses are accommodated for leads to a decline in, or "erodes," social, human, natural, financial, or physical assets.

Some examples of erosive coping strategies include:

- Selling productive assets which may allow for consumption smoothing in the period immediately following the disaster, but reduces livelihood opportunities in the long term.
- Removing children from school, which may ease financial burdens and/or provide extra labor, but ultimately reduces human and social capital in the household.
- Taking on debt, particularly at high interest rates, which creates a debt burden that reduces long-term financial capital.
- Over-exploitation of natural resources, which may result in short-term flows but erodes the natural resource base in the long term.

The adoption of erosive coping strategies is largely driven by poverty and vulnerability, where people have no option but to utilize the only savings they have to meet their immediate needs following a disaster (World Bank, 2013). Helgeson et al. (2013) find social and cultural factors at play, where education level is inversely correlated with the tendency to remove children from school following a disaster. In the worst-case scenario, the impacts of a disaster coupled with erosive coping strategies (or the unavailability of non-erosive coping strategies) can lead to poverty traps (discussed below). Disasters, however, can have a positive impact on development in a couple of ways: (1) when old capital stocks are replaced with new, more productive capital (Crespo Cuaresma et al., 2008) and (2) when there is learning that creates new innovations for better managing risk (Skidmore and Toya, 2002).

Poverty traps: the vicious cycle of disasters and poor development

A "poverty trap" is defined as a livelihood that is at too low a level to permit escape. At the household or community level, a poverty trap is an extreme example of the negative interaction between disaster and development. For example, a poverty trap can be characterized by a large loss of productive assets, coupled with an accumulation of debt due to the need to borrow post-disaster for consumption purposes at high interest rates (see Figure 2). The threat of becoming stuck in a poverty trap comes from both the macro- and micro-economic impacts described above. Disturbances and shocks such as natural disasters are increasingly seen as a critical factor affecting the prospect of long-term poverty alleviation. Above, we have outlined some of the key ways in which disasters can undermine development, and below, we show that development can impact disaster risk both positively and negatively. These impacts occur at the local and national level, when persistent risk and poor planning in communities that are already economically marginal continue to destroy the asset bases that are necessary to invest in risk reduction.

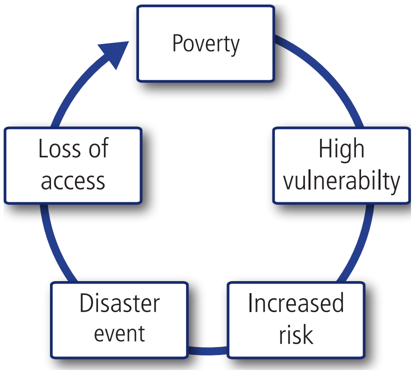


Figure 2. The disaster and poverty cycle

The literature documents evidence of persistent poverty traps and their debilitating effects on wellbeing (e.g., Berhanu, 2011; Carter, et al., 2007; Jakobsen, 2012). Surveying pastoral communities in Southern Ethiopia, Berhanu (2011) found that the likelihood of a household falling below the poverty trap threshold was significantly related to how often households have been affected by recurrent shocks such as droughts. Furthermore, as pastoralists experienced repeated disturbances over time, their reliance on external assistance increased, which in turn weakened their indigenous social support system founded on the use of livestock assets. Box 1 explores the use of cattle for consumption smoothing in Zimbabwe.

Carter et al. (2007) also found evidence of these dynamics and poverty trap thresholds by examining asset regrowth paths after a rapid-onset event (Hurricane Mitch in Honduras in 1998) and slow-onset event (drought in Ethiopia from 1998-2000). Following Mitch, households with asset levels below $250 were found to move toward a lower growth equilibrium, while those above this threshold recovered their wealth toward a higher equilibrium. Recent studies have begun to emphasize that many low-income-country households are neither poor nor non-poor all the time; their levels of earning and assets fluctuate, and hence they are prone to being in and out of poverty (Giesbert & Schindler, 2009). Given the precarious status of such households, the availability of asset buffers and their ability to withstand or cope with shocks such as natural disasters are especially important and for any developmental policies that are targeted toward them (see, for example, Bui et al., 2014; see also Box 1).

2.3 The impact of development on disaster risk

Development can affect disaster risk via three main channels: by (1) increasing the physical assets and people exposed to the risk, (2) increasing the capacity to reduce the risk, respond to the event, and recover from the event, and (3) increasing or decreasing the vulnerability based on specific development strategies chosen.

Rich countries record higher gross economic losses because of their higher-value infrastructure and economies. The relative impact on GDP, however, is much higher for poorer and middle-income countries, particularly where GDP is low and governance is weak. Poorer countries also experience higher mortality from disasters (UNISDR, 2011). Thus, as development increases in both developed and developing countries, there is greater value at risk both in lives and physical assets. However, the capacity to protect this value may be where more of the impact of development on disasters is evident. The link between development, governance, and disaster impacts is fundamental to risk; where GDP is low and governance is weak, poorer countries also experience increasing mortality (UNISDR, 2011).

Particularly in developing countries, regions that have been the most successful at attracting investment and experiencing rapid economic growth are doing so in areas exposed to hazards (UNISDR, 2013). Hallegatte (2011) points out that hazardous sites often provide comparative advantage for investment; for example, sites close to ports – which are critical for export – can be highly exposed to storm surge. The United Nation Office for Disaster Risk Reduction (UNISDR, 2013) reports that the "number of export oriented Special Economic Zones has expanded

Box 1: Capital accumulation in the face of risk for a Zimbabwean cattle-farming household

Source: Foresight (2012)

Disasters can cause direct impacts (often called losses) and indirect effects. Generally, direct losses of assets are quantitatively estimated, while indirect effects on livelihoods and wellbeing are more difficult to quantify, yet can be large; accounting for the latter either qualitatively or quantitatively is important. Even without a specific event occurring, the anticipation of potential losses to be suffered may lead to disincentives to invest and to aspire to higher and more stable livelihoods. The assets of lower-income households in disaster-exposed regions, generally used for smoothing income variations, are at high risk. In particular, livestock is a key asset for smallholders that may be lost during a disaster or become sick/injured. As a consequence, households will tend to save less and underinvest in productive assets, leading to a long-term shortfall of livelihoods compared to a situation with safer assets.

A recent study (Foresight, 2012) of rural livelihoods in Zimbabwe finds large adverse effects in terms of chronic, persistent poverty in the face of risk, when cattle are used as an income-smoothing strategy. The simulation shows that over a time period of five decades households are only able to accumulate on average about half of the assets (the orange line in Figure 3) as compared to a situation without risk or with full elimination of risk (e.g., through risk sharing arrangements) (the upper red line).

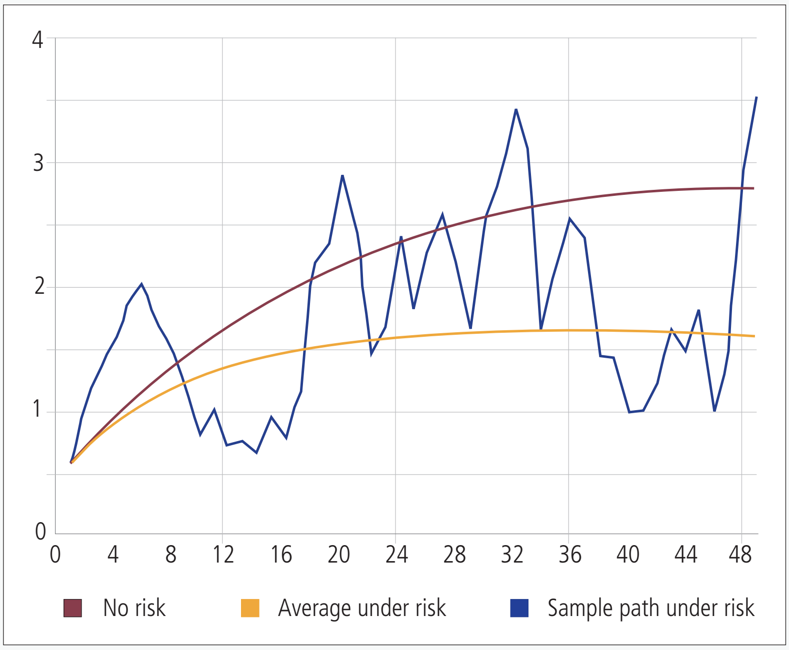


Figure 3. Long-run risk of capital when cattle used to smooth consumption in the event of disaster

Source: Foresight (2012)

from 176 zones in 47 countries in 1986 to 3,500 zones in 130 countries in 2006." Many of these zones of high economic growth are located in hazardous areas, such as coastal areas which provide access to ports that are important for their success. Here we see how "successful" development can inadvertently increase disaster risk. In Box 2, Practical Action (2012) shows how dynamic development processes are increasing disaster risk and require integrated and holistic responses.

Noy (2009) examines the characteristics of an economy to determine what factors influence economic productivity after a severe event, examining 428 natural disasters occurring between 1970 and 2003 in 109 countries. He focuses on short-term growth, real GDP growth for the year in which the disaster occurs, and explores specific aspects of development to determine which of these contribute to the economic consequences of disasters. Economic recovery is improved by human capital (as measured by literacy rates), institutional strength, trade openness, government size, and per capita income. Recovery is also positively affected by the size of local credit markets but unaffected by stock markets, suggesting that financing for households and small and medium firms may be particularly important to facilitating reinvestment after an event.

von Peter et al. (2012) generally confirm the results of Noy (2009) showing that economic development reduces the macroeconomic consequences of disasters. While Noy shows that, on average, "natural" disasters have a positive effect on economic growth in developed countries, the results of von Peter et al. (2012) find that a positive effect is only present for insured events. A consistent theme between the results of von Peter et al. (2012) and Noy (2009) is that timely access to finance for reconstruction, whether from credit, insurance payments, or government agencies, is fundamental to reducing the economic consequences of a disaster.

Empirical evidence of the household-level drivers of disaster loss and recovery is not prolific. The evidence available suggests that initial asset level (wealth) is correlated with increased speed and completeness of recovery (Berhanu, 2011; Carter et al., 2007; Naqvi, 2012; Silbert and Useche, 2012). However, with respect to disaster loss (as opposed to recovery), the correlation with initial asset level is unclear, with some finding that being wealthier increases losses, others finding that it reduces losses, and some resulting in insignificant conclusions (Berhanu, 2011; Morris et al., 2002; Jakobsen, 2012). This inconsistency reflects the complex nature of the interaction between disaster risk and development.

At the household level, empirical studies show much evidence for the positive effect that diversification of livelihoods has on reducing losses from disasters (Carter et al., 2007; Wong and Brown, 2011; Mueller and Osgood, 2009) and aiding recovery (Carter et al., 2007; van den Berg, 2010; Little et al., 2006; Mueller and Osgood, 2009). This is an important conclusion that we will pick up again in section 5 when we discuss the properties of a resilient system. Another household-level study, using country-year panel data, suggests that there is a hump-shaped relationship between development and disaster risk. Kellenberg and Mobarak (2008) found that as income rises, choices at the household level, like developing nearer to coastal areas, tend to increase disaster risk. However, after a certain threshold of higher income is reached, the effects of higher income on DRR dominate and disaster risks decrease.

Unfortunately, isolating and quantifying the impacts of various development indicators (e.g., education level or environmental regulation) on disasters is methodologically very difficult. Data availability coupled with deep co-correlation makes statistical analysis controversial. A review of the literature finds scattered empirical evidence for the impact of various underlying factors on disaster loss and recovery. Apart from wealth and diversification, described above, the following factors have been found to reduce disaster loss and improve recovery at the household level: access to credit (Carter et al., 2007; di Nicola, 2011; Jakobsen, 2012), access to insurance (di Nicola, 2011; Janzen and Carter, 2013), education (Wong and Brown, 2011), social capital (Carter et al., 2007; Carter and Castillo, 2005; Jakobsen, 2012), and technology and innovation investment (di Nicola, 2011).

Box 2: Development at risk in Nepal

Text Source: Practical Action (2012)

People in Nepal are being exposed to more frequent and severe hazards. There is a high risk of floods in the plains and landslides in the hills. While hazards are increasing in frequency and severity, their impacts are exacerbated by a series of dynamic development processes including population growth, increasing poverty and marginalization, environmental degradation and the impacts of climate change. Low levels of awareness of disaster preparedness and management, lack of efficient mechanisms and capacity to deal with these natural disasters has had severe impacts on the lives of the people, property and economy at large.

Practical Action, a UK-based international development NGO, has led interventions over the last few years to tackle the complex and interacting factors shaping risks. Livelihood preparedness, gathering community perceptions of changing hazards and risks and strengthening community organization have all been used in an integrated and holistic way. Each strategy works to reinforce the others, and has resulted in outcomes of increased food security as well as better access to governance systems, decision making, and resources.

3 Current Approaches to Disaster Risk Management

The traditional view of disaster was one of an "Act of God" – a random and devastating hazardous event that wreaked havoc on humans (Quarantelli, 2000). The mainstay of this traditional approach is emergency response. While the field has moved on profoundly in terms of understanding disaster risk as essentially "unnatural," this perception remains common today in practice and policy, reinforced by behavioral biases, resource constraints, and political factors.

Under the traditional risk framework there are two main approaches to reducing disaster risk: reducing the hazard or reducing exposure to the hazard. A hazards-centered approach to DRM aims to avoid or lessen the hazardous event. Hard infrastructure projects such as a dyke or seawall physically contribute to reducing the human exposure to hazard. In this way the risk from the extreme weather event is lessened because the probability of a loss event has decreased. Disaster theory and practice has moved from a disaster focus to an appreciation of the human dimension of disasters. An extreme weather event is only a disaster because human interests (Quarantelli, 2000) are exposed.[1] The characteristics of the people exposed to disasters determine the quantity and quality of disaster impacts: poor people are more likely to live in hazardous areas; women are more likely to be killed in a disaster than men; farming communities who lose their only source of income cannot recover. "Vulnerability"[2] became the buzzword in DRM (Kuhlicke et al., 2011) and was included as a fundamental driver of risk (Figure 4).

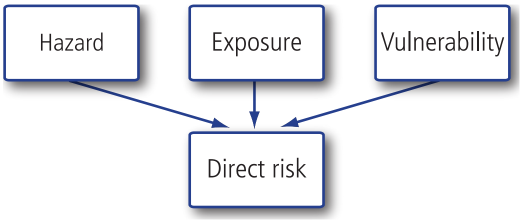


Figure 4. Hazard, exposure, and vulnerability drive direct risk

Figure 4 shows the contemporary understanding that (direct) risk is a function of hazard, exposure, and vulnerability. Typically "direct" is not explicit in discussions on the underlying drivers of risk; however, we have included it here because we consider the distinction between direct risk and indirect risk to be important and pick up on this below. Direct risk is the likelihood of direct losses, which are the immediate impact of the disaster, such as physical damage caused by flood waters. Indirect risk relates to indirect losses, which are the consequences that flow from the direct loss, such as the inability to continue production for some time or permanently due to loss of assets (Mechler, 2004).

Coupled with the shift in perspective that recognized vulnerability as a key risk driver, was recognition that preventing disasters is probably more desirable and effective than emergency response.

From the contemporary understanding of disaster risk we identify research gaps, challenges, and opportunities in the DRM field and beyond. In this section we identify three central challenges for DRM, which are driving the surge in resilience thinking. These aspects, when taken together, establish the case for a holistic, systems-based approach to resilience that considers both risk and wellbeing dynamically over time, which we outline in section 5.

1. An emphasis on response and recovery rather than risk reduction and preparedness, where cognitive biases are driving a focus on ex post over ex ante action.
2. Uncertainty in future socio-demographic, economic, and climatic conditions that are not sufficiently acknowledged by or incorporated into decision making.
3. The increasing awareness of the systemic interdependence of the often-ignored human, social, environmental, and even economic drivers and incentives that influence risk and wellbeing.

3.1 Challenge: Behavioral drivers leading to an emphasis on response and recovery rather than risk reduction and preparedness

Despite almost universal acceptance that disasters are unnatural and can thus be mitigated by human actions, very little money is actually spent on reducing risk before an event strikes (Benson and Twigg, 2004; Hoff et al., 2003; Kellett and Caravani, 2013). This is in stark contrast to the demonstrated cost-effectiveness of ex ante actions to reduce risk and prepare for events, outlined below.

Empirical studies of the effectiveness of flood damage mitigation measures implemented by households show that such measures can substantially reduce flood damage (Kreibich et al., 2005; Kreibich and Thieken, 2007; Bubeck et al., 2012). Kreibich et al. (2005) interviewed households affected by the severe River Elbe flood in 2002 in Germany to assess their level of preparedness for flooding and to estimate the effectiveness of damage mitigation measures that households implemented before and during the flood. They found that household-level flood preparedness reduced damage significantly. Flood-adapted building use reduced damage to buildings and contents by, respectively, 46% and 48%, while flood-adapted interior fittings saved damage to both buildings and contents by 53%. Placing utility and electrical installations on higher floors reduced flood damage by 36%.

These results of the effectiveness of flood mitigation measures in Germany have been confirmed by Kreibich and Thieken (2007) who conducted a similar survey, after floods in 2005 and 2006, in the city of Dresden. The results of this survey

1 Exposure is defined as: "People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses" (UNISDR, 2009).

2 Vulnerability is defined as: "The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard" (UNISDR, 2009).

indicate that household preparedness improved before the 2005/2006 floods, compared with the 2002 Elbe flood and that this improved preparedness resulted in significantly less flood damage. Similar findings have been observed by Bubeck et al. (2012) who collected data on flood preparedness and flood experience of 750 households along the German Rhine River. Their results show that these households suffered less damage during a flood in 1995 compared with a 1993 flood event, which can be attributed to improved flood preparedness by households.

Foresight (2012) finds that the benefits of investment in DRM outweigh costs, in terms of damages avoided and losses reduced, by an average factor of four to one across a number of interventions and hazards. Figure 5 summarizes results found for flood risk prevention. The chart shows that for many such interventions around the globe benefits exceeded costs (identified as the straight line at a B:C ratio of 1).

Despite evidence on the cost-effectiveness of flood risk prevention, policy is yet to catch up. As shown in Figure 6, disaster aid is heavily dominated by emergency response. Over the last two decades, of about $107 billion spent on disasters, approximately 87% went into emergency response, reconstruction, and rehabilitation, whereas only 13% ($13.5 billion) was used for reducing and managing the

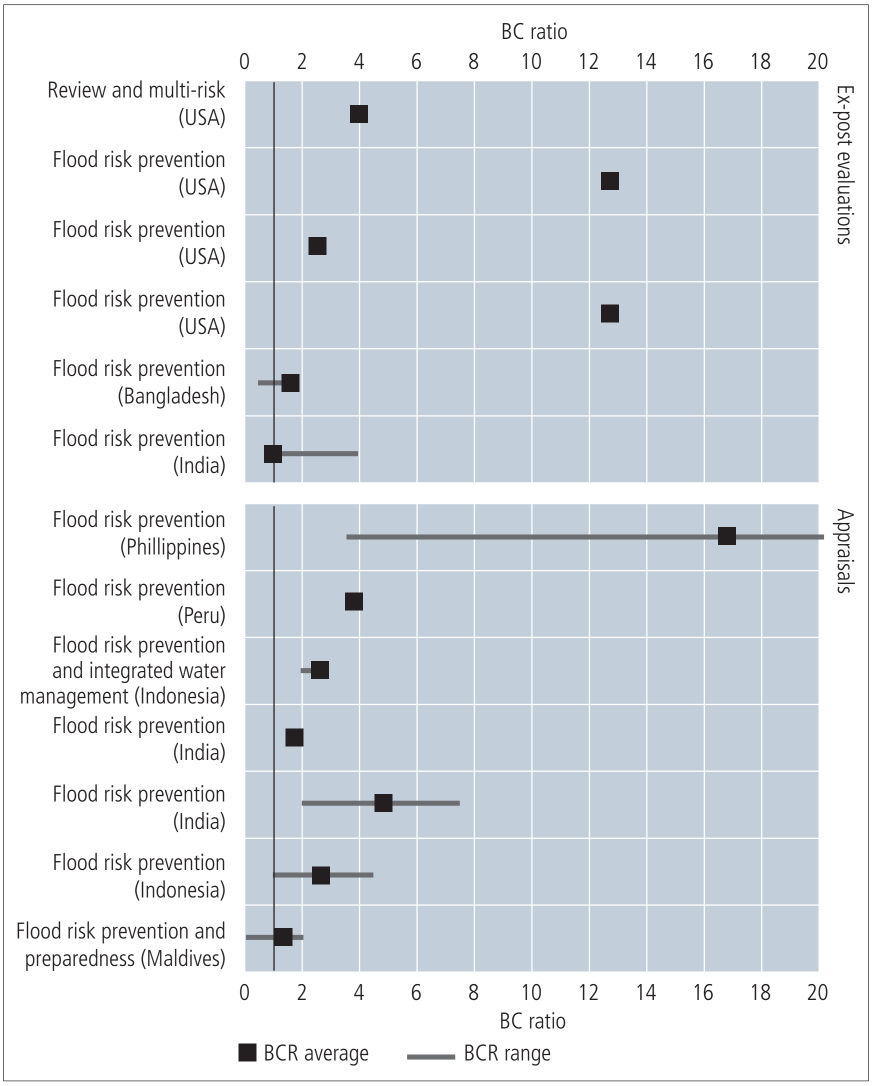


Figure 5. Cost-benefit ratios of flood risk prevention
Source: Foresight (2012), based on Mechler (2012)

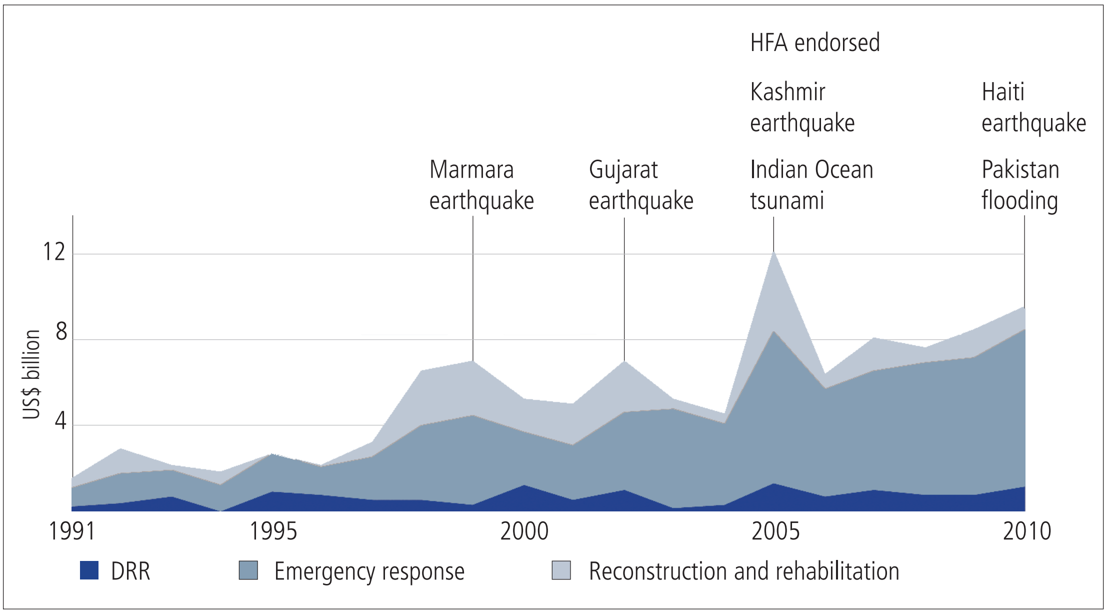


Figure 6. Disaster-related financing, 1991-2010
Source: Kellet and Caravani (2013)

risks before they manifested themselves as disasters. In relation to international development assistance, this has meant that "for every $100 spent on development aid, just 40 cents has been invested in defending that aid from the impact of disaster" (Kellett and Caravani, 2013).

There are many explanations for this focus on ex post relief and reconstruction over ex ante risk management. From households to national and international bodies, people across the globe are notoriously biased when it comes to reducing risk. Research has identified some broad drivers of ex post versus ex ante action. These are: (1) perceptions of the risk; (2) cognitive biases when it comes to dealing with low-probability and/or uncertain events; and (3) budget and affordability concerns (Kunreuther et al., 2013; for more details see Box 3.)

At the level of government and international assistance, several perverse incentives exist that contribute to the majority of resources going to ex post response and recovery. First, there is a continued perception of disasters as "Acts of God" among some politicians, planners, and populations. Second, it is difficult to estimate and politically justify the expense of scarce resources for prevention for something perceived to be a rare occurrence. This makes the benefits of prevention largely invisible because they are what did not happen in a disaster (the unseen); response and relief on the other hand are politically positive because they are visible and demanded by people. With respect to international aid, populations in donor countries like to see concrete outcomes from their aid dollars (Kellet and Caravani, 2013) and, as such, response and recovery is far more attractive (for similar visible versus invisible reasons).

At the individual level an illustrative example of cognitive biases hindering ex ante actions can be found in the risk-reducing activities undertaken, or not undertaken, by residents prior to the onset of Hurricane Irene in the United States in 2011. A survey of nearly 800 residents in coastal counties revealed that less than half of storm shutter owners in the state of New York actually installed them to protect their windows before the hurricane struck. The reason given was that it would have "taken too long." This is an interesting example of risk reduction measures being purchased but

Box 3: Cognitive biases affecting risk perceptions

A number of cognitive biases are to be reckoned with respect to understanding and perceiving risk.

Under-weighting the future: A fundamental feature of human cognition is that we are influenced more by cues that are concrete and immediate than abstract and delayed (Marx et al., 2007). Human temporal discounting tends to be hyperbolic, so that distant events are disproportionately discounted relative to immediate ones (Loewenstein and Prelec, 1992; Laibson, 1997). Hyperbolic discounting implies that the upfront costs of risk reduction and adaptation measures with respect to a property loom disproportionately large relative to their delayed expected benefits during the overall life of that property.

An extreme form of hyperbolic discounting is myopic behavior where the decision maker only focuses on the potential benefits of an investment over the next T periods. Suppose there are significant expected benefits from the adaptation or risk reduction measures 10 or 20 years in the future. If a decision maker's time horizon is only two years, then she will not consider these potential returns, which she should, in fact, do if she is undertaking deliberative thinking.

Lack of concern: Individuals may not consider undertaking measures to reduce risk if they view the likelihood of the disaster to be below their threshold level of concern. There is empirical evidence that people tend to ignore risks whose subjective odds are seen as falling below some threshold. In a laboratory experiment on purchasing insurance, many individuals bid zero for coverage, apparently viewing the probability of a loss as being sufficiently small that they are not interested in protecting themselves against it (McClelland et al., 1993).

Box 4: Intuitive and deliberative thinking

Daniel Kahneman in his Nobel address (2003) and book, Thinking, Fast and Slow (2011) characterizes two modes of thinking as "System 1" and "System 2" by building on a large body of cognitive psychology and behavioral decision research. The intuitive System 1 operates automatically and quickly with little or no effort and no sense of voluntary control. It uses simple associations (including emotional reactions) that have been acquired by personal experience with events and their consequences. The deliberative System 2 initiates and executes effortful and intentional mental operations as needed, including simple or complex computations or formal logic.

Many of the simplified decision processes and rules that characterize human judgment and choice under uncertainty use the intuitive capabilities collectively referred to as System 1. Often, decisions made by less effortful System 1 processes lead to reasonable outcomes while requiring much less time and effort than a more exhaustive analysis of the expected utility of different options. Decisions using simple heuristics and System 1 processes are, however, least effective for choices that require one to focus on outcomes that are far in the future and highly uncertain, because people lack associations, including emotional reactions, and personal experience with such events. Decisions that involve reducing risks to extreme events such as floods fall into this category.

A lack of experience or expertise can lead to cognitive biases, particularly when relying on System 1 thinking. These are key barriers to risk reduction activities that need to occur prior to a disaster event occurring.

One of the key challenges in designing risk management measures to reduce losses from natural disasters is to recognize the limitations of public and private decision makers in dealing with risk and uncertainty. Another is to design tools and incentives that help them make more informed and efficient choices.

not utilized (Baker et al., 2012). Thus, preparedness measures incentivized by insurance companies or other authorities that do not properly account for the "user costs" (e.g., know-how, degree of difficulty, etc.) will not be implemented. This insight might be called the "shutter effect." Box 4 outlines some of the reasons why decision-making processes that work fairly well in normal times can be problematic when applied to risk-based decisions.

One reason for this lack of interest in protective measures is that residents feel that a future disaster will not happen to them. Burby (2006) provides compelling evidence that actions taken by the federal government, such as building levees, may make residents feel completely safe, when in fact they are still at risk for catastrophes should the levee be breached or overtopped. Gilbert White (1945) pointed out that when these projects are constructed, there is increased development in these "protected" areas. Should a catastrophic disaster occur so that residents of the area are flooded, the damage is likely to be considerably greater than before the flood-control project was initiated. This behavior and the resulting problems are exacerbated by non-enforcement of building codes and zoning restrictions. The perception of protection observed among the population can be assumed to extend to public officials and hence to the level of the government.

The most basic explanation as to why individuals and governments fail to invest in adaptation and risk reduction measures in the face of transparent risks is affordability. A budget constraint may also extend to higher-income individuals if they set up separate mental accounts for different expenditures (Thaler, 1999). Under such a heuristic, a homeowner might simply compare the price of the measure to what is typically paid for comparable home improvements. The family may then decide that flood-proofing exceeds what they had budgeted in this account. Similarly, lack of political will may result in disaster authorities with limited budgets. A key opportunity then exists to find innovations in affordable solutions; for example, through new financing mechanisms, securities, and adaptations that may achieve the goal of risk reduction.

3.2 Challenge: Uncertain future conditions

The trends in hazard frequency and severity, exposure, and vulnerability outlined in the introduction and section 2 point to a changing face of risk. Future trends in population, investment, technology, and wealth accumulation are often expected to match observations of past behavior, despite the fact that these may not apply in the future (World Bank, 2010). Coupled with this is uncertainty regarding future greenhouse gas emissions and resulting impacts, that may produce feedback loops and/or tipping points that are not currently understood. Determining the probabilistic likelihood of catastrophic and/or irreversible impacts in a changing climate is fraught with massive problems (Jotzo, 2010).

With socioeconomic and climate change occurring, challenges appear regarding reliance on past experience of disaster risk to inform future actions. This is problematic because traditional risk management, particularly for floods, is built around the assumption that we can know the relative frequency of severe weather events and their associated impacts (World Bank, 2010). The problems associated with using past socioeconomic trends and hazard frequencies to predict future conditions are exacerbated the further into the future these projections are made.

The issue of uncertainty in and of itself does not render analysis useless, of course. Several publications (ECA, 2009; IPCC, 2012) have found that decisions about risk under uncertain future conditions can still be made in the presence of large uncertainties. Sensitivity analysis is essential in the context of expert analysis. However, the presence of deep uncertainty gives extra weight to "soft" options that increase the flexibility of a system and enhance its adaptive capacity, also known as "low-regret strategies" (Fankhauser et al., 1999; IPCC, 2012).

3.3 Challenge: A holistic understanding of risk and wellbeing

Human societies are complex social-ecological systems with multiple dynamic aspects. Within these systems, people interact, act, and respond to circumstances in ways that create interdependencies. These interdependencies call for a need to understand these relationships and interconnections rather than the individual parts, in order to achieve desired community outcomes. A hazard-focused tradition coupled with modern institutional arrangements that silo "disaster risk" within a narrow government authority, have led to a narrow understanding of risk and wellbeing.

The incorporation of vulnerability into DRM (described above) was in line with sustainable development practice, and it advances local as opposed to central decision making. Thus, vulnerability naturally aligned with development and in particular with sustainable development. The dynamic interaction between development and disasters described in the first two sections has resulted in increasing calls for "mainstreaming" DRR and climate change adaptation into development, as well as mainstreaming DRR into climate change adaptation. Mainstreaming refers to the integration of disaster risk and climate change adaptation considerations across government and civic investments or initiatives. This has widened the scope of responsibility for emergency response agencies (Schipper and Pelling, 2006). However, the converse, mainstreaming of DRM in development decision making, still remains weak.

Despite the recognition of vulnerability as a central driver of risk, DRM practice and supporting research are still characterized by a number of gaps in their approach to human, social, and ecological drivers of risk and wellbeing. In particular, we identify the omission of: (1) the "human element" for individual and community-based approaches; (2) the "intangible" environmental impacts of disasters and contribution to risk; and (3) the "soft" economic instruments to effectively incentivize individual and community DRM.

The focus on command and control options often neglects community participation in DRM. Below we outline a way to operationalize community flood resilience, largely by harnessing the participation and collective knowledge of the community. For DRM to fully appreciate the impact of disasters and DRM activities on wellbeing, the people whose wellbeing is impacted ought to be central decision makers. An incorporation of human and social capital aspects is a notion central to modern development theory and practice, as well as natural resource management (Mostert et al., 2007). Pearce (2003) finds that disaster preparedness initiatives fail when they have insufficient community involvement. A more genuine incorporation of individual and community motivations and incentives may help avoid the "shutter effect" mentioned above, where risk reduction measures fail because they ignore the perspective of the people themselves.

Unfortunately, many examples exist of failed DRM, often owing to a lack of community participation. One recent example was the lack of an adequate and effective disaster-response communication system during Hurricane Katrina in the United States. Effective communication is vital between emergency managers and local residents for execution of evacuation plans, and between residents to help each other avoid risks in a self-organized manner (Li and Goodchild, 2010). Communication channels are a fundamental linkage between parts of a community system and linkages between them and other systems. Understanding how communities give and receive information is key to effecting better outcomes.

Building these lines of communication is in fact an ex ante action that needs to be firmly established before a disaster strikes. A notable success story was the recent Cyclone Phailin which struck eastern India. The government there was praised for the level of preparedness and the resulting low number of casualties. Advanced warnings and evacuations may have been what saved hundreds of thousands of lives (World Bank, 2013). Similarly, Turner et al. (2014) empirically investigated the connection between early warnings and taking mitigation action after the 2010 floods in Pakistan. They found that receiving an early warning significantly increased the likelihood of taking mitigation measures and empirically connected this with lower household losses.

Our review has also identified that intangible (non-market) values are largely ignored at the institutional level when considering impact and risk, due to the fact that they are not readily quantifiable (Barkmann et al., 2008). Intangible impacts are defined as those not measurable in monetary terms because they deal with "assets" not traded in the market place (Markantonis et al., 2012). Intangible impacts make up a significant proportion of disaster losses but are frequently ignored in disaster impact assessment and are not well integrated into risk decision making.

The impact of environmental degradation and land use on flood risk is well documented (Yin and Li, 2001; Bradshaw et al., 2007; Ward et al., 2008; Wheater and Evans, 2009; Meyfroidt and Lambin, 2011; de la Paix et al., 2013). Important examples include the impact of upstream land clearing on downstream flood levels (Ward et al., 2008; de la Paix et al., 2013), and the impact of tillage practices on flood water behavior (Schmidt et al., 2001; Holland, 2004; Nowak, 2009). Research has demonstrated the cost-effectiveness of relatively simple environment-based interventions for reducing flood risk. Linnerooth-Bayer et al. (2013) found that conservation tillage practices could be particularly cost-effective at reducing annual runoff compared to other physical measures such as constructing large reservoirs, ponds, or shelterbelt. Despite this evidence environmental interventions are only beginning to be seriously considered as viable flood risk measures. Environmental measures can have significant co-benefits for livelihoods and environmental health, rather than undermining these.

Considering the full suite of DRM interventions in regard to certain "soft" economic instruments can also be hindered. The potential for instruments such as insurance to incentivize risk reduction is frequently cited in the literature. In theory measures such as insurance provide key information and incentives for risk reduction. However, in practice, risk financing and risk reduction are not well interlinked (Kull et al., 2013), and there are numerous difficulties associated with implementing risk-based pricing.

Lastly, it should be noted that even the best-designed DRM interventions will fail if they are implemented within a system with weak institutional capacity. Institutions provide the rules and enforcement of the rules (the rule for breaking the rule) that govern the relationships between all other parts of the community system. The quality of official (government-driven) DRM depends on the latent institutional capacity in the area in question. More research on this critical aspect of risk and wellbeing is needed.

Smart and soft interventions

The narrow perspective that neglects key components of the community system (human, social, environmental factors) stifles innovative solutions that a community might have or develop to reduce and manage risk, that are affordable and appropriate for them. DRM interventions that are focused on individual and community behavioral incentives are sometimes called "smart and soft," in contrast to "hard" infrastructure. Smart and soft interventions can also be thought of as "low-regrets" measures (see IPCC, 2012). Low-regrets measures include:

- Soft (environmental) infrastructure
- "Space for the river" type interventions
- Warning systems
- Land-use planning
- Subsidies and taxes
- Water markets
- Public-Private Partnerships
- Risk financing (see Box 5)

These non-structural interventions have been shown to be cost-effective, yet are often neglected (UNISDR, 2011; Kull et al., 2013). The implementation and success of these types of intervention is predicated on a holistic understanding of the community's assets – human, social, natural, and financial, as well as physical.

We now turn to a concrete example of the results of smart and soft interventions carried out in India within a participatory framework.

Assessing smart and soft interventions: An example from India

The benefits of smart and soft approaches to dynamic risk reduction and response are key to building resilience. This example from India shows the nature of outcomes achieved when a joint expert-community participatory approach is coupled with a holistic understanding of risk and development opportunity. This example shows how holistic and inclusive interventions can address long-term risk from riverine flooding.

The Rohini River is part of the Gangetic Basin, located primarily in the Gorakhpur and Maharaganj Districts of Uttar Pradesh State, India. Starting in Nepal, the river

Box 5: Risk financing as a smart and soft intervention

Because of the potential of insurance and other risk-financing instruments, it is prudent to ask how public/private catastrophe insurance systems in developed countries, for example, those operating in France, Japan, the USA, and many other countries, have fared with regard to increasing community resilience. There is recent empirical evidence that countries with high insurance penetration have less long-term economic disruption from disaster and thus less disaster-related development setbacks. There is more limited evidence on the linkage between private and publicly backed national insurance systems and the reduction of risks, for example, by encouraging public infrastructure development and private preventive measures. A study carried out in Switzerland, where there is a mixture of fully private and fully public systems depending on the canton, showed that public monopoly insurers have been more successful in reducing losses of flood events (Schwarze et al., 2011). Thieken et al. (2006) reached a similar result in the case of Germany. Because of the limited evidence, more research is needed to appraise the record of public-private insurance systems in reducing flood disaster risk.

This does not mean that all households, farms, and firms in vulnerable communities should be insured, or that insurance will, on the whole, increase community resilience. Private insurance is expensive, and will take funding away from other important household expenditures like education or investing in family businesses. Moreover, insurance can be unaffordable for highly exposed poor communities, and other coping strategies, such as relying on savings, family, remittances, and post-disaster loans, may be less costly. However, for high-level risks in which whole regions are affected, these strategies are often insufficient. Consequently, donor support for insurance and other pre-disaster financing activities (like financial institution development for receiving remittances) can be more effective than post-disaster aid.

Development organizations have given a great deal of recent attention to piloting micro-insurance projects, many of which are index-based, operating throughout the developing world. There is only mixed evidence on whether donor-backed micro-insurance can scale up to provide safety nets to vulnerable households and farms. The systems are often plagued by basic risk and lack of regulating institutions. Insurers that operate in developing countries have high start-up and transaction expenses, which can greatly limit affordability and constrain insurance penetration. Moreover, because disasters can affect whole communities or regions (co-variant risks), insurers must be prepared for meeting large claims all at once. Their cost of requisite backup capital, diversification, or re-insurance to cover co-variant claims can add greatly to the business expenses and raise the premium far above the client's expected losses. Yet, as satellite monitoring technology and regulatory institutions develop, the potential for public-private insurance across the developing world appears hopeful (see Linnerooth-Bayer and Mechler, 2007).

Keeping in mind the benefits and limitations of risk financing instruments with regard to community flood resilience, insurance can play an important role in many contexts. By spreading stochastic losses temporally and geographically, and assuring timely liquidity for the recovery and reconstruction process (which can itself save lives and livelihoods), insurance is beneficial to those in the risk pool. Moreover, it provides the pre-disaster security essential for productive risk taking. These benefits, however, come at a cost that can be unaffordable for poor communities. Providing donor support to the emerging financial risk-management opportunities for the developing world, while not a panacea for enhancing community resilience, has potential for reducing the effects of disasters on national economies and providing security for investments as an important precondition to escape poverty. Many donor governments and bodies, including the World Bank and European Commission, are in this way moving away from post-disaster assistance toward supporting pre-disaster financial instruments.

flows approximately north to south, ending at its junction with the Rapti River near Gorakhpur City. Like all of eastern India, the Rohini is prone to floods during the monsoon. There is always some annual flooding, with major floods occurring most recently in 1998, 2001, and 2007. The primary flood risk management strategy in the Rohini Basin, begun in the 1970s, is to reduce the hazard through the construction of embankments. These fail frequently, often due to insufficient maintenance, while sometimes their designs are simply exceeded.

The focus on (poorly maintained) embankments was clearly a limited approach. When the embankments failed due to poor maintenance or overtopping, communities had few avenues for protection and/or recovery. The processes in place only focused on one aspect of resilience – robustness, and even this was limited. This intervention did not have any co-benefits in relation to development.

As an alternative, the research team, in close contact with stakeholders, developed a decentralized "people-centered" approach to identifying a portfolio of interventions. Table 2 shows the interventions and the types of flood losses they were assumed to reduce. In section 5.2 we revisit this example and explore how these smart and soft approaches can enhance resilience.

Where poverty is a major concern, as in this case, the benefits from investments in DRM tend to accrue to dominant sections of society and not to women, children, the poor, or other socially excluded groups. This is particularly important with regard to major infrastructural projects, but may also be of concern in respect of other interventions. In the case of embankments in the Rohini Basin, the largest beneficiaries tend to be wealthy individuals living in towns, while the most vulnerable groups live either between the river and the embankments, just outside embankments, or in other locations with a concentrated flow. These people bear many of the negative consequences. Interventions such as fodder and food banks through self-help groups, as identified in the Rohini people-centered strategy, are of particular benefit to the poor and also can have extremely high returns in terms of avoided livelihood impacts.

Table 2. Interventions and their loss reduction areas for the people-centered flood risk management strategy

Interventions	Flood losses reduced										
	Housing	Assets	Crops	Seeds	Livestock	Fodder	Debt servicing	Wages	Health/medical	Food & grain	Infrastructure
Individual level											
Raise house plinth	X	X			X	X				X	
Raise fodder storage unit					X	X					
WatScan package							X		X		
Community level											
Early warning		X									
Elev. handpumps & toilets					X				X		
Flood shelters		X			X				X	X	
Community grain bank							X				
Community seed bank							X				
Maintain key drainage points	X	X	X	X	X	X	X	X	X	X	X
Self-help groups							X				
Purchase community boat								X			
Societal level											
Flood-adapted agriculture			X								
Strengthen overall healthcare							X	X	X		

Source: Kull et al. (2008)

Better information needed

We have identified information access as a critical first step toward addressing the issues outlined in this section. Sufficient community involvement depends upon timely access to good information. However, flows of information are traditionally very top-down and face barriers such as data rights issues, restrictions, and prohibitive costs, all of which limit knowledge transfer.

An example of the more traditional top-down approach is the European Floods Awareness System (EFAS), an early flood warning system complementary to national and regional systems. It provides the national institutes and the European Commission with information on possible river flooding to occur within the next 3 or more days. Since flood warning is a member state responsibility, only archived flood warnings can be made publicly available. The real-time warnings are made available to the national partner institutes only. While there are multiple reasons for this, such restricted access to data essentially inhibits community participation.

In a complex adaptive system it is the interconnections and relationships that are critical for outcomes. These channel the flow of information and resources to meet goals. Access to information that is relevant and manageable is critical for effective humanitarian assistance and as a critical lifeline for local self-help operations. In fact, information is just as important as access to food, water, or shelter, for without information there is no guarantee people will know where the nearest shelter is, or whether the water is safe to drink. This highlights the importance of prioritizing two-way communication with disaster-affected communities. The major consequences of the information revolution are the rise of self-help actions directed by and for disaster-affected communities, and the unparalleled volume of real-time crisis information generated following a disaster (World Bank, 2012). Technology is decentralizing information and provides opportunities to learn how to better utilize this for DRM.

Box 6 outlines an initiative of this project that will generate crowd-sourced information on risk.

An example of a more bottom-up approach is being developed by the global disaster alert and coordination system (GDACS, n.d.). iGDACS is a mobile app that allows people to get the latest GDACS alerts and key statistics on a mobile device. In addition, it allows users to provide feedback on GDACS events, which is - after moderation - communicated to the GDACS community. Such efforts build on human and social capital, and are changing the role of communities and encouraging community participation. Regional examples also exist in various stages of development, tackling issues from early warning to flood alerts. However, they tend to be top-down, in terms of providing information but not requesting it.

Social media feeds are rapidly emerging as another novel avenue for the contribution and dissemination of information that is often geographic. Their content often includes references to events occurring at, or affecting, specific locations. Recent findings support the notion that people act as sensors to give results that are comparable, and sometimes superior, to traditional methods, in a timely manner. They may also complement other sources of data to enhance situational awareness and improve understanding and response to disaster events (Crooks et al., 2013).

Box 6: Generating useful information in the field: Geo-Wiki and crowd-sourcing

Data scarcity on risk, vulnerability, and options, combined with the fact that the majority of information flows are top-down, are key issues hindering risk reduction, preparedness, and response. This issue affects many stakeholders including planners, insurers, communities, and individuals. Furthermore, there is a key gap between traditional, bottom-up knowledge and technology. This is a problem because on-the-ground information is essential for land use planning (risk reduction), warning systems (preparedness), and response operations. It is also critical in the medium term during impact assessment and adaptations, as these have profound impacts on livelihoods. The receipt of accessible information, as well as contributions to the wider body of knowledge, is one of the critical aspects of participatory DRM and development.

Within the framework, "monitoring," or more broadly, "awareness," is essential for the functioning of resilience-building processes. We propose exploration of a shift to include a bottom-up system of data exchange. The use of technologies such as mobile devices, internet, and social media all hold potential for two-way information exchange that warrants investigation. These types of intervention could provide incentives to reduce risk, for example, by documenting assets and taking risk reducing action, finally leading to reduced premiums. Monitoring could include remote sensing, but crowd-sourcing is likely more effective in the framework of IRM. The crowd could consist of a bounded crowd, made up of local experts, NGOs, Zurich personnel, etc.

4 The Struggle to Define Resilience

We have identified resilience as a useful entry point for holistic DRM. We now ask where is the discourse on resilience overall? Resilience has a long history and different disciplines have provided a variety of perspectives. Throughout the 20th century the term was adopted in the fields of engineering to design fail-safe production systems; in psychology with regard to recovery from adversity or trauma; in ecological systems theory on the persistence of the bio-ecosystem following a disturbance; and in economics regarding both the efficiency of resource allocation and input mobility during a shock and how quickly the economy can return to efficiency after the shock. Below we describe these various perspectives on resilience, many of which have informed popular, academic, and practitioners' understanding and use in relation to disasters, which will be the focus of the second part of the chapter.

4.1 The emergence of resilience thinking in various disciplines

Engineering

The dictionary definition and popular understanding of resilience comes from the engineering field. Engineering resilience has traditionally referred to the resistance of a system to disturbance and the speed at which the system returns to equilibrium (Davoudi, 2012). The faster it bounces back, the more resilient it is. Holling (1996, p. 33) states that engineering resilience "focuses on persistence, change, and unpredictability – all attributes at the core of engineers' desires for fail-safe design." Resilience in flood engineering circles is aligned with this view. As one important example, the UK Institution of Civil Engineers (ICE, 2008) argues that "resilience" can be achieved by improving embankment works and maintenance. At the same time, the ICE (2008) acknowledges that a totally fail-safe design for embankments is unfeasible in contexts characterized by change, particularly under climate change.

Ecology and social-ecological systems

Holling (1973) is widely held to be the father of the concept of ecological resilience. In his seminal work he defines resilience as "a measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" (Holling, 1973, p. 14). He contrasts this description of resilience with that of stability, defined as "the ability of a system to return to an equilibrium state after a temporary disturbance; the more rapidly it returns and the less it fluctuates, the more stable it would be" (Holling, 1973, p. 17), which is close to the engineering perspective of resilience. Holling argues that when stability is high, resilience is generally low; as the variables within the system become increasingly interconnected, the system itself becomes vulnerable to a shock that can trigger a system-wide collapse. When stability is low, however, the system can fluctuate in response to external stimuli, which is a property of high resilience.

Holling's work on ecological resilience formed part of the foundation for the development of the concept of social-ecological system resilience, coined by the Stockholm Resilience Centre (2007):

> Resilience is the capacity of a system, be it an individual, a forest, a city, or an economy, to deal with change and continue to develop. It is about the capacity to use shocks and disturbances like a financial crisis or climate change to spur renewal and innovative thinking.

This social-ecological system perspective sees human societies and the biosphere as intimately interconnected. This perspective sees resilience thinking as an important part of the solution to sustainable development because it strives to build flexibility and adaptive capacity in the longer term. This transcends a short-term focus on optimal production and considerations of economic gains.

Psychology

The concept of resilience developed in psychology concurrently with ecology, with little overlap. The concept of "psychosocial" resilience in psychology came from both epidemiology and child development theory. This perspective is centered on the individual's ability to recover from trauma. It is concerned with the ability of an individual to maintain physical and psychological health in the face of continuing adversity. The US Army applied this concept in their Comprehensive Soldier Fitness program and saw resilience as a skill that can be learned to create "resilient" soldiers who can operate under significant uncertainty. More recently this has been expanded to the concept of community resilience, which looks at the collective ability of individuals situated in a community to cooperate and thrive in an unpredictable environment (Welsh, 2013; Berks and Ross, 2013).

Economics

In economics, resilience is generally related to how markets behave during and following a shock. It is concerned with the efficiency of resource allocation and input mobility during a shock, and how quickly the economy can return to pre-shock output levels following the shock. Business continuity services, which revolve around sourcing essential services to minimize losses during a shock, are a component here (Rose, 2009). Economic resilience is generally thought to be achieved by a stable macroeconomic environment and microeconomic market efficiency. A stable and effective institutional environment (governance) is also required, along with social development (Rose, 2007). Recently, alternative economic theories have also started to draw from the ecology field and emphasize resilience as a property that allows for adaptive change and transformation over time (Simmie and Martin, 2010; Briguglio et al., 2005).

4.2 Disasters and resilience: Toward a development-focused conceptualization of disaster resilience

As the central theme that unites the various perspectives on resilience is that of response and recovery from shocks, it seems a natural extension for the concept to be applied in disaster research and practice. Resilience thinking in DRM has become pervasive over the last few years. It initially drew on the psychology field, where the ideal of individual resilience to shocks was applied to community resilience (Berkes and Ross, 2013). This was intuitive for emergency responders and the NGO community who are on the front lines with individuals and communities after an event. The concept was soon broadened and supported by academic research to incorporate the ecological perspective espoused by Holling, which drew in fundamental ideas about linked social-ecological systems. This complemented thinking on the human dimension of natural disasters. The concept has been further extended to the national and regional levels, as resilience enters the global arena (for example, National Research Council, 2012). Theory and experience in sustainable community development have also contributed to the debate to identify what attributes of communities enhance their resilience, such as social networks, communications, social capital, leadership, and culture (Berkes and Ross, 2012).

Many studies have grappled with the understanding and definitions of disaster resilience. A central critique of resilience thinking is that it is a normative approach that accepts the system(s) as a given and works within it, crowding out space for questioning the underlying problems. Berkes and Ross (2012) identify lack of attention to power and agency as key critiques of resilience in DRM. That is, by focusing on existing community capacities, resilience thinking might miss important institutional arrangements that are limiting community capacity. Further to this is the critique that resilience is attractive to the "small government" discourse and is being used to justify shifting risk from government on to citizens (Welsh, 2012). Our approach to resilience, outlined below, starts with the current system before connecting with development and vulnerability theory to put people at the center of decisions regarding their risk and wellbeing.

As the concept of resilience took hold in the disaster literature and practice, efforts to define it in order to better understand and operationalize it became a priority. In Table 3 we list a range of definitions put forward by academia, key multilateral organizations, development agencies and NGOs, and the private sector, many of which have important overlap. We highlight in bold the key recurring concepts in the various definitions.

All definitions listed in Table 3 refer to the "ability" or "capacity" to withstand and recover (UNISDR, 2011; ESCAP, 2013; ADB, 2013; DFID, 2011; IFRC, 2012; Pasteur, 2011; IPCC, 2012; NRC, 2012; Twigg, 2009; Cutter et al., 2008). Additionally, several definitions point to a dynamic aspect, for example, "more successfully adapt to" (NRC, 2013), highlighting that learning from the event is an aspect of resilience. There is a distinction between definitions that tend to assume that the current level of development is acceptable and those that assume development to be on an upward trajectory. As an example of the latter, DFID (2011) includes "by maintain or transforming living standards," thereby suggesting that a key component of resilience is ensuring that disasters do not reverse positive trends in development objectives.

The definitions have many common elements and reflect much of the thinking outlined in this paper. The bolded words in Table 3 also show that many of the definitions include a full understanding of DRM, in particular including aspects of risk reduction shown in the use of the words "plan"; "anticipate," and "adapt to." Many also finish with a statement that reflects the importance of development opportunities in thinking about disaster risk. For instance, the definition by the Asian Development Bank (ADB, 2013), states that disaster resilience is "the ability of countries, communities, businesses, and individual households to resist, absorb, recover from, and reorganize in response to natural hazard events, *without jeopardizing their sustained socio-economic advancement and development* ". Similarly, at the end of their definitions, DFID (2011) and IFRC (2012) mention "without compromising their long-term prospects"; Practical Action (2012) ends with the phrase "without enduring detriment to food security or wellbeing." These definitions all allude to the fact that disasters can impede development or wellbeing over time.

The importance of the long-term interconnection between development – which drives wellbeing (the central goal of the community) and DRM is secondary in most, if not all, definitions of disaster resilience. There is a distinct emphasis on emergency response and "bouncing back." Where definitions go beyond this they tend to remain focused on traditional risk management, which sees resilience as the ability to essentially do "good" risk management, which does not capture the complexity of the interplay between development, direct and indirect disaster impacts, and DRM activities.

Taking the definitions and current thinking forward, we propose a broader framework and a definition of flood resilience that (1) more explicitly emphasizes development opportunity, as this is arguably the reason resilience is desirable for a community, (2) sees community resilience embedded in complex adaptive systems, and (3) identifies resilience as being able to survive (flood) events, thrive in the face of uncertain flood events, and continue to strive toward new opportunities in the face of changing flood risks. These elements of a more holistic framework appear in a number of the definitions mentioned above. Bringing these out more explicitly, we suggest that a broad-based working conceptualization of disaster resilience would be:

Disaster resilience: The ability of a system, community, or society to pursue its social, ecological, and economic development and growth objectives, while managing its disaster risk over time, in a mutually reinforcing way.

What does this mean for a community perspective on resilience? If we understand communities as complex adaptive systems, this means they are able to learn and change and operate in an environment that is changing. It also means that the community faces risks and that totally eliminating these risks is neither possible nor desirable. As they are dynamic and the environment is changing, the community's wellbeing and development opportunities will likely change over time. To continuously grow and develop in the face of risk implies the need for a risk management process (identifying, mitigating, preparing for, and responding to the risk). That is, communities that are always pursuing development opportunities must do so in a way that balances the risks, if they hope to continue to pursue their objectives and thrive. Thus, we do not define resilience as doing the steps of DRM, it is in fact more. But doing DRM well, we argue below, is an important component for building resilience in practice.

In the following sections we discuss why a complex adaptive systems approach provides a useful way to explore, identify, and test resilience-building strategies. We then sketch out the framework for measuring this definition of resilience and finally provide a way to operationalize it in general and describe what the approach looks like when implemented in practice.

Table 3. Definitions of disaster resilience

Source	Report/paper title	Disaster Resilience definition (emphasis added)
Multilaterals		
United Nations International Strategy for Disaster Reduction (UNISDR) (2011)	Global Assessment Report (2011)	The ability of a system, community or society exposed to hazards to **resist, absorb, accommodate to, and recover** from the effects of a hazard in a timely and efficient manner.
Economic and Social Commission for Asia and the Pacific (ESCAP) (2013)	Building Resilience to Natural Disasters and Major Economic Crises	The capacity of countries to **withstand, adapt to, and recover** from national disasters and major economic crises – so that their people **can continue to lead the kind of life they value**.
Asian Development Bank (ADB) (2013)	Investing in Resilience: Ensuring a Disaster-Resistant Future	The ability of countries, communities, businesses, and individual households to **resist, absorb, recover from, and reorganize** in response to natural hazard events, without **jeopardizing their sustained socioeconomic advancement** and development.
Development agencies and NGOs		
Department for International Development (UK) (DFID) (2011)	Defining Disaster Resilience: A DFID Approach Paper	The ability of countries, communities and households to **manage change, by maintaining or transforming living standards** in the face of shocks or stresses – such as earthquakes, drought or violent conflict – **without compromising their long-term prospects**.
The International Federation of Red Cross and Red Crescent Societies (IFRC) (2012)	The road to resilience: Bridging relief and development for a more sustainable future	The ability of individuals, communities, organizations, or countries exposed to disasters and crises and underlying vulnerabilities to **anticipate, reduce the impact of, cope with, and recover** from the effects of adversity **without compromising their long-term prospects**.
Pasteur (2011) (Practical Action)	From Vulnerability to Resilience	The ability of a system, community, or society to **resist, absorb, cope with, and recover** from the effects of hazards and to adapt to longer-term changes in a timely and efficient manner **without enduring detriment to food security or wellbeing**.
Academia		
International Panel on Climate Change (IPCC) 2012	Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation	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.
National Research Council (NRC) (2012)	Disaster Resilience: A National Imperative	The ability to **prepare and plan for, absorb, recover from, and more successfully adapt** to adverse events.
Twigg (2009)	Characteristics of a Disaster Resilient Community	System or community resilience can be understood as the capacity to: • **anticipate, minimize, and absorb** potential stresses or destructive forces through adaptation or resistance; • **manage or maintain certain basic functions** and structures during disastrous events; • **recover or "bounce back"** after an event
Cutter et al. (2008)	A place-based model for understanding community resilience to natural disasters	Resilience is the ability of a social system to **respond and recover** from disasters and includes those inherent conditions that allow the system to **absorb impacts and cope** with an event, as well as post-event adaptive processes that facilitate the ability of the social system to **reorganize, change, and learn** in response to a threat.

5 A Systems Approach to Disaster Resilience

The introduction highlighted how the interdependencies among people, communities, and countries are increasingly appreciated as the indirect impacts of events are being felt in far-reaching areas. A systems perspective is a way to conceptualize and analyze the dynamic interconnections that produce the overall outcomes for a community. We now show how this perspective has the potential to address the operational challenges outlined in section 3 by allowing for a systems-based and more holistic understanding of the community. Whereas complicated linear mechanisms can be analyzed by looking at individual component parts and understanding the cause and effect of forces acting upon objects, complex adaptive systems cannot be understood by its parts. Instead the patterns that emerge are based on the relationships between the parts and the way they act and react to the actions of others.

5.1 A development-based framework of disaster resilience: Integrating asset-flow relationships

In section 2 we reviewed research on the dynamic interaction between disasters and development, and established the need for a resilience perspective that places the development and wellbeing goals of the community at the center. A community is a complex and dynamic coupled socioeconomic-ecological system. One succinct definition states that complex adaptive systems are characterized by strong interdependencies and non-linearity due to, among others, "dispersed interaction, cross-cutting interaction, continual adaptation, and far-from equilibrium dynamics." (Arthur, 1994).This makes systems thinking an appropriate framework for exploring the complex multi-scale aspects of community flood resilience.

A key to systems thinking is looking at relationships and connections between the parts in the system. As discussed in the sections above, much of response and recovery after a disaster depends on the timely flow of information and resources. From a systems perspective, then, a better understanding of these channels and the relationships that govern them has the potential to provide insight into effective "buffer zones," "control points," and other flow control measures that can greatly enhance the sources of resilience ex ante, which effect ex post resilient outcomes.

A systems perspective is not only multiscale and multivariable but looks at the interactions between these subsystems. Rather than focusing on the outcome alone, it identifies and considers the processes of a community that interact to achieve the outcome. Managing the risks to the system, then, can become a natural part of the process that provides monitoring, mitigating, and preparing for potential disruptions to the system. When a disruption occurs, it enacts processes to respond and recover efficiently.

A systems perspective is also useful because it helps to keep focus on how policies that affect one function may interact with the others, which would then affect the overall functioning of the community. For example, a policy that is meant to enhance resilience by increasing the number of evacuation routes could encroach on the marshlands that provide natural drainage systems.

The systems perspective of resilience is cyclical and dynamic, encompassing the feedback loops and interconnections demonstrated in Figure 7. The figure shows a complex system linking development/wellbeing, risk (direct and indirect), and three key sites where disaster resilience comes into play. Starting with the accepted understanding of direct risk (or loss) we show that it is driven by hazard, exposure, and vulnerability. Exposure and vulnerability are influenced by socioeconomic drivers; these socioeconomic conditions are one key aspect of resilience which are themselves driven by development/wellbeing. Direct risk influences development process via, for example, direct damage to productive assets. The ability to respond to/cope with direct impacts is a key aspect of resilience which is influenced by the level of development. Indirect risk (the impact on development) is a combined consequence of direct risk and coping capacity. How well one recovers from indirect risk is a further aspect of resilience (itself a function of development) which in turn influences the prospects for longer-term development. Over time the dynamic interaction between initial levels of risk, resilience, and

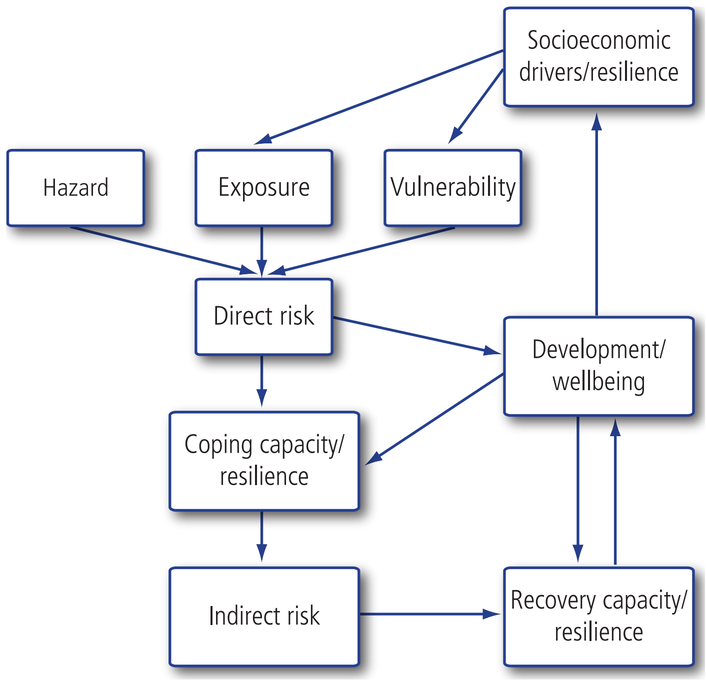


Figure 7. Charting the development-risk-resilience system
Source: Adapted and expanded from IIASA CATSIM model (Mechler et al., 2006)

development drives longer-term impacts on risk and wellbeing.

The systems approach is also valuable for understanding unmitigated or increasing risk that a community has the capacity to address. For example, poorly designed insurance or credit products or government relief can create moral hazard, motivating households and firms to take risk at the expense of insurers and lenders and governments, respectively. Outdated building codes and hazard maps may inadequately capture and address disaster vulnerability and so fail to encourage risk reduction. Markets may price the amenities of coastal living without the risks when proper signals of the risk are not transmitted (e.g., through risk-based pricing of insurance on the coastal property). Such outcomes reduce wellbeing, and the systems approach explains their perpetuation through recognition of competing incentives among decision makers and/or the aggregation of cognitive biases in the interactions among agents in the system.

In the sections below we sketch out our framework for understanding and pursuing resilience measures. We start with a focus on the community as a system with an overall function (purpose) to provide wellbeing and development opportunities for its members. By establishing a baseline profile and tracking wellbeing over time one can observe how the system is performing. One can further observe the impacts of a disaster on the ex post performance of the community and also the impacts of a DRM intervention on broader wellbeing. Ideally, we would like to know if the system will continue to function – and in what capacity – prior to an event actually occurring.

The overarching objective of both development and DRM is to promote the wellbeing of people. In sections 2 and 3 we presented evidence that an integrated approach is required if twin goals of DRM and development are to mutually reinforce wellbeing rather than undermine each other. Despite increasing acknowledgement, both the DRM and development communities of practice are yet to operationalize this well. A narrow conceptualization of wellbeing, for example, one that focuses only on easily quantifiable economic assets, adds to this dilemma as key determinants are neglected, particularly in contemporary DRM.

To address these shortcomings, the usefulness of asset or capacity building models has been increasingly recognized. Such models focus attention on developing the underlying resources and capacities needed to escape poverty and manage risk on a sustainable basis. They depict the critical mass of assets needed to cope with stresses and shocks, and to maintain and enhance capabilities now and in the future. This framing recognizes that everyone has assets on which to build and with which to support both individuals and families to achieve long-term wellbeing. They may focus on a more limited (e.g., specifically economic) or a wider set of assets (e.g., personal, cultural, social, and political).

One example is from Turnbull et al. (2013) who identify a large number of assets that help with understanding risk and building resilience, as shown in Figure 8.

The Sustainable Livelihoods (SL) framework is another such model that can be used to map and analyze wellbeing in the presence of shocks, and has been widely used in international development as a conceptual device (Knutsson and Ostwalk, 2006). The SL framework is an asset-based framework that represents wellbeing holistically by encompassing five types of capital. It is applicable for developing and developed countries and ties in with notions of sustainable development and poverty reduction. The SL framework is also applicable at multiple scales, qualitatively and quantitatively.

The SL framework considers five types of capital assets (human, social, natural, financial, physical), which leads to an understanding of livelihood outcomes and risk. Closest to the people are the resources and livelihood assets they have access to and utilize (see Figure 9). Additionally, in debates regarding sustainability-oriented macroeconomic accounting systems, which aim to go beyond GDP as the key indicator, asset-based approaches embrace basically the same set of assets (see UNU-IHDP and UNEP, 2012).

These five capital classes broadly capture the core capacities (or asset base) that enables the overall community system to

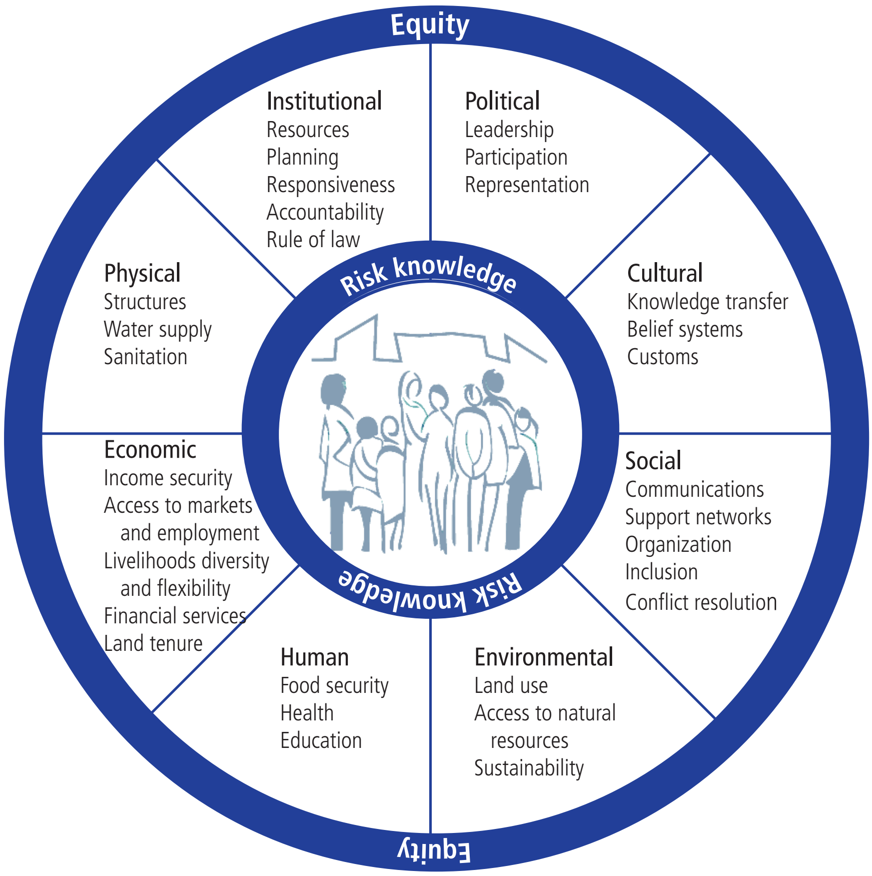


Figure 8. Key factors influencing resilience
Source: Turnbull et al. (2013)

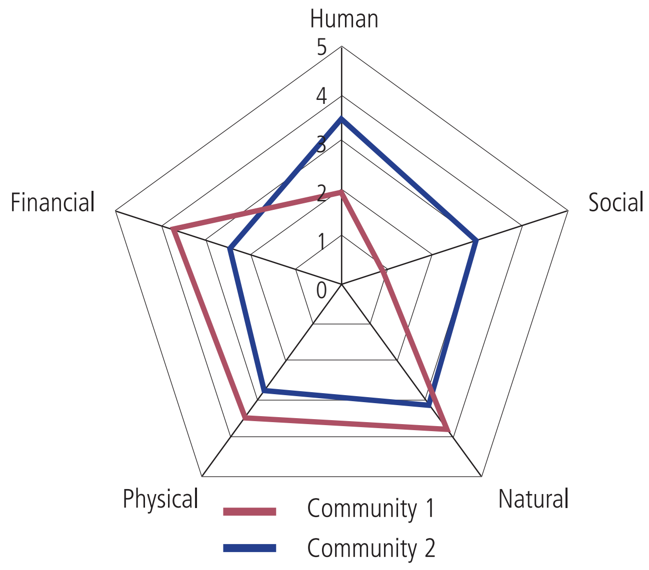


Figure 9. Mapping capital in the Sustainable Livelihoods Framework
Source: Nelson et al. (2007)

provide wellbeing, opportunity, and risk management. They are:

- *Human capital:* the education, skills, and health of household members;
- *Social capital:* reciprocal claims on others by virtue of social relationships and networks, the close social bonds that aid cooperative action and the social bridging, and linking via which ideas and resources are accessed;
- *Natural capital:* the natural resource base (e.g., productivity of land) and actions to sustain productivity, as well as the water and biological resources from which livelihoods are derived;
- *Physical capital:* capital items produced by economic activity from other types of capital that can include infrastructure, equipment, and improvements in genetic resources (e.g., crops, livestock);
- *Financial capital:* the level, variability, and diversity of income sources, and access to other financial resources (credit, savings, cattle) that together contribute to wealth (Nelson et al., 2007).

Figure 9 is a "spidergram" based on Nelson et al. (2007); it shows the asset profiles of two hypothetical communities. As discussed above, a community profile based on these five capitals has far more analytical richness than a single metric such as average income. Communities can be tracked through time to reveal how the capitals, which are all essential to wellbeing, are responding and interacting.

5.2 Identifying properties of a resilient system

The SL framework outlined above looks at how resources (or capitals) can grow or shrink depending on investments made or losses incurred. Resilience is closely linked to the five capitals themselves – the community utilizes these capitals to manage disaster risk and development opportunities, and these assets are in turn impacted by disasters and development. However, capital levels and combinations in and of themselves do not tell us explicitly how well a community may perform in the face of the uncertain risks and opportunities. As a hypothetical example, we can imagine that two communities are endowed with identical levels of each capital. One community is devastated by the disaster, yet another fares well due to a combination of planning, response, coping, and recovery strategies that ultimately support wellbeing rather than undermine it. In other words, it is possible to have a community with low capital levels and high resilience, or a community with high capital levels and low resilience. Further, a temporal dimension also adds difficulties; a resilient system today may be subject to changes both within and outside the system, possibly leading to future loss of resilience (Holling, 2001). Carpenter et al. (2001) and van Apeldoorn et al (2011) add to the complexity by asserting that short-term resilience may reduce longer-term resilience, and systems with shorter-term deficiencies may be more resilient over a longer time scale.

With regards to household level resilience, the main body of literature focuses on highly agrarian developing regions, where disasters have the potential to exacerbate poverty. The quantity and type of assets appear to be significant in determining the amount of loss and the duration of the recovery period, with a higher concentration of productive assets being the most effective asset portfolio (Berhanu, 2011; Little et al., 2006). There is agreement on the importance of a diversification of livelihoods, specifically access to off-farm labor, as a way to reduce risk and build resilience. Evidence suggests the availability and access to credit acts as a means to both reduce the downside risk of investment ex ante, and recover from the negative effects of a disaster ex-post (di Nicola, 2011; Gitter and Barham 2007; Carter et al., 2007; van den Berg, 2009). Education and Social capital, such as community altruism and trust, also appear to be correlated with faster recovery (Carter et al., 2007; Wong and Brown, 2011).

This leads to the question of whether we can identify some general properties or principles to look for in communities that would enhance resilience over time and in various contexts. We know that resilience of a system is latent, only emerging once a system is subject to shock or stress (Engle, 2011). The extremely scale-, place-, and system-specific nature of capital stocks also creates difficulties when attempting to generalize a set of key factors that enhance resilience (Tol and Yohe, 2007; Vincent, 2007).

This is particularly where thinking of communities as complex adaptive systems proves useful. The systems thinking literature has found some generalized properties that contribute to system resilience. Four main system properties that enhance resilience have been identified thus far (Cimellaro et al., 2010):

1. Robustness: is strength, or the ability of elements, systems, and other measures of analysis to withstand a given level of stress or demand, without suffering degradation or loss of function.
2. Redundancy: is the extent to which alternative elements, systems, or other measures exist, that are substitutable

(i.e., capable of satisfying functional requirements in the event of disruption, degradation or loss of functionality).

3. Resourcefulness: is the capacity to identify problems, establish priorities, and mobilize alternative external resources when conditions exist that threaten to disrupt some element, system, or other measure. Resourcefulness can be further conceptualized as consisting of the ability to apply material (i.e., monetary, physical, technological, and informational) and human resources in the process of recovery to meet established priorities and achieve goals.
4. Rapidity: is the capacity to meet priorities and achieve goals in a timely manner in order to contain losses, recover functionality, and avoid future disruption.

Rapidity takes account of the learning and recovering in a more resilient way, which may involve a transformation. While rapidity is mostly an ex post property of resilience, investments made ex ante can create rapidity ex post. These "four Rs" are picked up in the next sections on measuring and operationalizing resilience.

Well in line with the thinking laid out here, Figure 10 shows how the IFRC (2012) visualizes the key components of a resilient community. This framework, while high-level, places people and their agency at the literal center of thinking on disaster resilience.

The example of smart and soft interventions introduced in section 3.3 can be used to illustrate these properties. Notably, maintenance of key drainage points reduces losses associated with multiple assets because it enhances robustness by reducing flood severity, redundancy if drainage is possible at various points, and rapidity by encouraging flood waters to drain as quickly as possible. Raising house plinths also protects multiple assets by providing robustness by resisting flood impacts on assets, resourcefulness by providing a place to locate assets in the event of a flood, and rapidity by protecting housing which is a basic need for returning to some normalcy. Strengthening overall health care enhanced resourcefulness during an event and rapidity because accrual of debt was reduced following a disaster. Enhancing overall health care

Figure 10. Conceptual framework of community resilience
Source: IFRC (2012)

Box 7: Resilient system properties

Recent work by Cabell and Oelofse (2012), building on a review of resilience literature, identifies several specific system properties for resilient systems. Their indicators establish a set of conditions required for resilient systems which provides a more concrete application of the "four Rs" for a context-specific assessments. Below we add in parenthesis the corresponding generalized resilient property to the Cabell and Oelofse (2012) resilient agroecosystem indicators. According to this work, some properties of resilient systems include:

- *Being appropriately connected (Redundancy):* A description of the quantity and quality of relationships between various system elements. A small number of very strong relationships would imply dependency and inflexibility, reducing resilience (Gunderson and Holling, 2002)
- *Exhibiting functional and response diversity (Resourcefulness):* These traits indicate the variety of services that components input to a system (functional) and the possible responses of these components to change (response), which buffers against change and allows for a return to normal after events (Berkes et al., 2003)
- *Being optimally redundant (Redundancy):* Duplication of critical system components in the case of failure (Low et al., 2003)
- *Being spatially and temporally heterogeneous (Resourcefulness or Robustness):* Indicates diversity of the landscape and changes with time, and can be seen as analogous to diversity above (di Falco and Chavas, 2008)
- *Being exposed to disturbance (Rapidity or Robustness):* Systems which are exposed to frequent but low-impact disturbances may result in increasing resilience in the long term as long as systems are not pushed past critical thresholds (Fletcher et al., 2006)
- *Being coupled with local natural capital:* The system does not, to a large degree, overly tax the local natural resource base, and does not rely heavily on importing or exporting resources or waste (Ewel, 1999; Robertson and Swinton, 2005)
- *Exhibiting reflective and shared learning (Resourcefulness):* Indicates that both individuals and institutions learn from the past and present to try and anticipate change and work toward desirable outcomes (Milestad et al., 2010)
- *Honoring legacy (Rapidity):* The system learns from the past, and those past conditions and experiences influence future pathways (Cumming et al., 2005)
- *Building human capital (Resourcefulness):* The system should take advantage of "resources that can be mobilized through social relationships" (Nahapiet and Ghoshal, 1998)
- *Being reasonably profitable (Robustness):* The system is able to financially support itself without relying on subsidies or other outside involvement (Holling, 2001)

impacts not only human capital (health) but also financial capital; there are obvious co-benefits for wellbeing even in the absence of a disaster.

Frameworks such as the "four Rs" and the one developed by the IFRC (2012) provide a highly generalized framework for features improving resilience, but much work has been done at a more specific level in establishing resilient system properties in hazard and sustainable development literature. Most are place- and context-specific, and use a variety of approaches. These include case studies, focus groups and interviews, as well as quantitative indicator approaches. Box 7 shows some properties of resilience, as defined by Cabell and Oelofse (2012) (p. 30). These are an example of resilience thinking applied to the context of agroecosystems.

Cabell and Oelofse's (2012) research, while originally set out for the agroforestry sector, demonstrates how analyzing resilience from a systems perspective allows us to identify ex ante indicators of resilience by looking for resilient properties. Some of the indicators exhibit more than one of the "four R" properties and some seem to overlap. The key for research going forward is to understand how these sources of resilience affect the latent resilience of the system and therefore how they can best be prioritized and built into the system. In section 6 we outline how some of these properties can help identify metrics for measuring resilience.

5.3 Toward resilience in practice: Iterative Risk Management (IRM)

We have outlined the ways in which the Sustainable Livelihoods framework provides a measure of outcome, which is the system performance (the quality of life being provided to the community members) and the ways the "four R" properties give a way to methodically look for sources of resilience being built into the system. However, as the system is dynamic and operating in a changing environment, the system, in order to maintain system functioning, must undergo continuous monitoring, self-checking, evaluation, and fixing of weaknesses or potential vulnerabilities (i.e., where one of the properties may be weak).

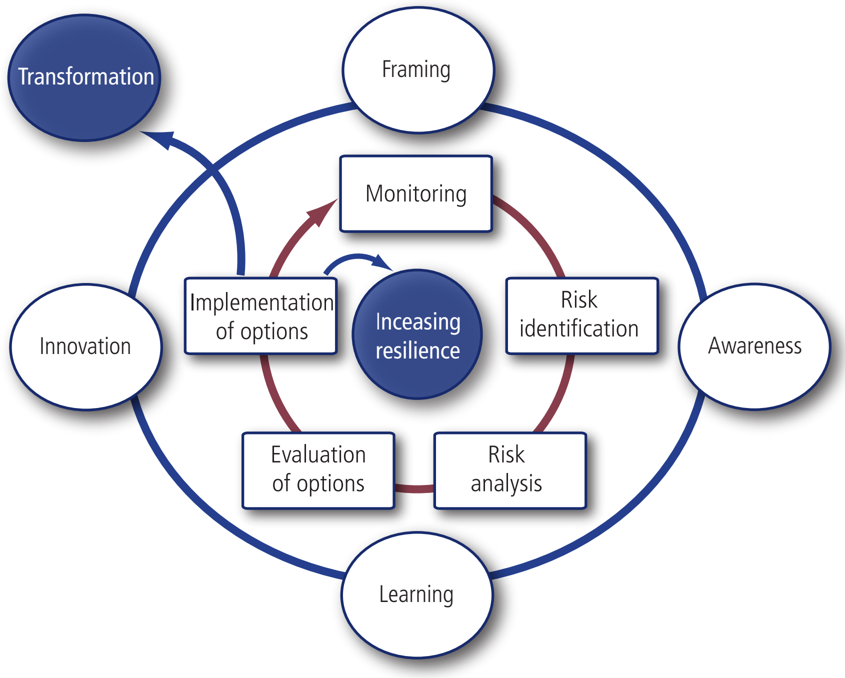


Figure 11. Iterative Risk Management
Source: Williges et al. (2014), adapted from IPCC (2012)

The IRM monitoring function keeps track of the current and emerging risks as well as the performance indicators and key resources in the system. The risk reduction function seeks to reduce the likelihood of disruptions, while the preparation function seeks to plan for when disasters do occur. Risk reduction, therefore, could avoid the risk altogether by suggesting an adaptation or balancing the risk by not taking the full development opportunity (for example, leaving some open space areas in a community).

The process gathers information from experts and stakeholders, is adaptive, and provides feedback for mutual learning to iterate and further adapt or transform. Especially with respect to climate change adaptation, IRM is recognized as a useful way forward by the IPCC (2012) because it can address issues such as data availability, long time scales, uncertainty in future conditions, operationalization, and quantification, which are commonly acknowledged problems in risk management.

IRM first prescribes an awareness process that identifies risks from both the expert and community perspectives, then investigates and evaluates the risks and generates potential risk reduction options that are acceptable and effective. This process prioritizes ex ante risk reduction action. However, because it is embedded in the system it is only one of the processes that aids the overall goal of the system and must thus balance risk reduction options with the development opportunities. It operationalizes resilience because the participatory approach, outlined below for the IRM process, can itself encourage resourcefulness and innovative approaches to solve problems posed by risks (build resilience).

Figure 11 represents a framing of IRM being developed by IIASA (Williges and Mechler, forthcoming). Of fundamental importance are two cycles: the inner cycle represents the analytical cycle, which creates expert knowledge about risk following the typical stages of risk management (risk identification, risk analysis and evaluation, evaluation of options, implementation monitoring). The outer cycle describes the process of drawing expert knowledge together with stakeholder participation. This cycle works effectively toward two outcomes: increased resilience or transformation, depending on what is required to address the problem, the underlying capacities and preferences of the system, and possibly how many times the cycle has repeated.

The notion of risk management which is both iterative and participatory is being taken up by the DRM profession (IFRC, 2012) and is concurrently being taken forward by the IPCC (2012). The iterative process allows for learning regarding the non-physical aspects of disaster (i.e., social, cultural, and institutional factors). As this learning is incorporated and innovation occurs, risk is reduced over time. The iterative nature of this approach means there is a flexibility to change practices in response to not only new information and experience, but also changing environmental conditions.

What does this imply concretely for community resilience? A community using the IRM approach would (1) monitor the performance measures, which indicate how well the system is functioning at balancing opportunity and risk exposure. It would do this within (2) a process for identifying and then assessing the risks to the community's performance. Next it would (3) seek solutions to reduce the risks by looking at solutions in terms of the "four Rs" of resilient systems (i.e., how the solution contributes to building robustness, creating flexibility (redundancy), enabling greater resourcefulness, or contributing to rapidity (learning and smarter recovery). It would finally (4) implement them effectively (and perhaps innovatively) by taking into account the effect on the whole system and behavioral economic considerations in its analysis of costs and benefits.

The IRM process is best practice in DRM, coming from decades of experience by organizations such as the IFRC. Box 8 describes community-based disaster risk reduction (CBDRR) – a process developed by the IFRC to engage at the community level on risk reduction. This process embeds the iterative, community-owned notions discussed above.

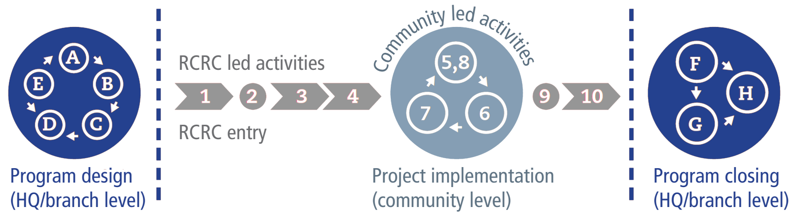
We propose that embedding resilience thinking in an IRM framework can lead to bolstering resilience in practice. This encompasses the entire resilience cycle including reducing current risk, preparedness, response, and recovery. It does this with a focus on adaptive and participatory learning, for more successfully adapting or building back with improvement. The focus on information (awareness and monitoring) within a dynamic, iterative cycle embeds the complex interactions between adverse events and human well-being that we advocate as an essential aspect of resilience.

The IRM approach is a generalized model of a participatory approach that can help strengthen resilience within communities in the face of changing risks over time. However, there are many barriers to implementing risk reduction strategies. As the systems approach identifies, competing incentives and cognitive biases may create short-term barriers to increasing resilience. As just one example, at the writing of this document, the US Congress is struggling to address long-standing problems in the National Flood Insurance Program. Changing such a program benefits some and hurts others, making for a difficult political decision, which may lead to a continuation of the program in its current form. Addressing such a barrier is fundamental to the transformation process described in the IRM approach, and the systems approach provides insights with respect to identifying and overcoming them.

Next, we describe the specific approach that will be used to study IRM in the field. This program not only aims to build resilience but also to provide an opportunity for capturing knowledge and studying how to overcome barriers to managing

Box 8: Disaster Risk Management in practice: IFRC's CBDRR

The International Federation of Red Cross and Red Crescent (RCRC) Societies practices, to different degrees, a process called community-based disaster risk reduction (CBDRR). CBDRR is centered on a community-based organization (CBO) that is either already in existence or that is formed and trained with the support of the Red Cross. The CBO works in partnership with the society and regional/national level authorities to generate community-level risk reduction initiatives. Figure 12 shows a "typical" CBDRR process from establishment of the CBO, undertaking of initial vulnerability-capacity assessments (VCA) and hazard mapping, through to handover to the established CBO. The iterative nature of the process is shown via the cycles in the figure, and it is emphasized that it is the community itself, via its CBO, that identifies and prioritizes its own actions to reduce risk (IFRC, 2012).



Program Design

A Context assessment
B Stakeholder identification and engagement
C Establishing community selection criteria
D Defining program aims, objectives and approach
E Establishing program management systems

Implementation

1 Meeting with community leaders (RCRC entry to the community)
2 Baseline survey
3 Meet with whole community
4 Form and train the CBO
5 Assessment, monitoring and evaluation (VCA and community led monitoring and evaluation
6 Planning (action/risk reduction plan and community updates)
7 Implementation (training and simulations, provision of funds and equipment, mitigation projects, advocacy)
8 Community M&E (repeat 5)
9 Endline survey
10 Handover to the community

Closing

F Evaluation
G Learning
H Dissemination and handover to external partners

Figure 12. Typical community-based DRM within the IFRC
Source: IFRC (2012)

risk in a sustainable, growth-supporting way.

The IRM approach in practice

IRM is an approach to risk management that links expert risk analysis together with stakeholder participation. The purpose of IRM is to continuously monitor, reduce, prepare for, respond to and recover from a disaster risk effectively and efficiently. The concept describes what in general a risk management process should be able to do, however it has been recognized that there are a number of practical challenges to implementation and support within communities. We detail an example (the enhanced integrated risk management program (e-IDRM) developed by Zurich and the IFRC) which is a practical implementation of the more generalized theoretical IRM. It builds on the IFRC's CBDRR program as described in Box 8. It will be used in this project to test the framework and develop a resilience measure as well as study ways to overcome barriers.

The Zurich Resilience Alliance is a unique partnership of research and practice communities to build resilience and knowledge of resilience. Practitioners in the field seek to operationalize resilience while providing data to researchers to study effectiveness and impact across contexts. The following framework, the Enhanced Integrated Disaster Risk Management Programming (e-IDRM), is an adaptation of an established community-based programming framework. The "integrated" in e-IDRM emphasizes the participatory, stakeholder-directed focus of this community-based programming framework. This should not be confused with the "iterative" in IRM as described above. We emphasize that both the IRM approach and the e-IDRM programming framework are participatory (integrated) and iterative.

We will now outline the basic steps for this programming (again building upon the CBDRR method described in Box 8). Key components in the e-IDRM program are: stakeholder participation throughout the process; clear, transparent assessments and communication throughout the process; objective ways to identify and prioritize projects that are implementable and effective; capturing the effect of projects over time and communicating the results back to the community and larger stakeholder groups.

The first step of the e-IDRM framework is an overall context assessment which includes a) an expert-based hazard and risk assessment which is then shared and further developed with stakeholders; and b) an underlying root cause analysis which identifies potential solutions which address root causes rather than addressing symptoms. Next, stakeholders at the national, regional and local levels are identified and engaged. Closely linked with this stakeholder process is engagement with community leaders to ensure acceptance and enhance motivation for the project.

Baseline surveys are then conducted and repeated periodically over time to capture changes in conditions, in order to establish and demonstrate the effects and outcomes. Whole-of-community meetings, with appropriate representation from all groups, are established as the focal point for the participatory approach. From this engagement a Community Based Organization (CBO) is established within the community to take ownership of initiatives to enhance disaster resilience. The CBO should be strong enough that it will continue after the end of the project cycle.

Within the Zurich Flood Resilience Alliance we will explore the viability of enhancing typical Vulnerability-Capacity Assessment (VCA) processes with community led monitoring and evaluation, via the CBO. Ideally this process will contribute to the identification of solutions which are desired and applicable by the community, as well as contribute to community-wide awareness of their disaster risk.

All identified potential solutions are evaluated according to their impact on risk, and costs and benefits (broadly defined to include equity and acceptability as well as economic efficiency). Activities which are identified by stakeholders and the community as appropriate and desired should be encouraged to be implemented. Evaluation is undertaken at both the community and expert levels, including overall project evaluation and re-measurement of indicators to track changes over time. Learning is shared amongst all parties to ensure engagement, sustainable impact and foster a culture of sharing and learning; results over time and post hazard event can begin to be compared to create body of evidence-based knowledge of effective resilience building.

That is, a systematic approach that is repeated over time generates comparable data that can be collected and analyzed. As detailed in section 6, measuring the impact of projects and interventions on a community's resilience requires collecting data on both potential sources of resilience and resilient outcomes (losses avoided and speed of recovery of losses). The e-IDRM programming generates this data when the methodology is carried out in a cyclical way. This data - captured both before and after event - allows researchers to test and learn what the most effective sources of resilience are for communities in different contexts, and feed that learning back and disseminate globally.

6 Measuring Resilience

The ability to benchmark and measure resilience over time and compare how resilience changes as a result of different actions and hazards is a critical aspect of making communities more resilient to disasters. By making this attribute more transparent we can learn how to best build it, as well as the different ways it can manifest in a system.

In section 6.3 we discuss some of the resilience metrics and methodologies that have been proposed in the literature. We are not aware of any that have been implemented across different countries and monitored over time, nor that have any been comprehensively developed based axiomatically on the properties of resilient systems. In the sections below we review the literature on measuring resilience, drawing a distinction between measurement ex ante and ex post. We then set out a measurement framework based on our systems perspective of resilience that captures both outcomes in terms of pursing development objectives and the processes that drive resilience. The exact metrics will be explored through a series of pilot tests throughout this project.

6.1 Tracking resilience: The problem of two time-frames

There is much debate in the resilience literature regarding whether there can be resilience (or whether resilience can be measured) without an event occurring. That is, it is not until an event happens that we find out whether we are resilient to it or not. This distinction is critical, yet many of the definitions above blur it by emphasizing an ex ante ability to do risk management with an ex post response and recovery outcome.

Research from different disciplines can help illuminate which socioeconomic criteria are often considered when evaluating post-disaster recovery. That is, while engineers, sociologists, ecologists, economists, and others do not always use the term "resilience," their metrics can be conceptualized as ex post resilience indicators.

Ex post measures tend to look at processes that relate to specific performance metrics for the community, organization, or region to determine whether there was a timely recovery after a disaster and at what cost (Rose, 2007). For example, measures such as population size, GDP, number of businesses, unemployment, or employment rates could be compared to the pre-event or historical "normal" trends to determine whether recovery had occurred. The difficulty with these measures is that it is hard to find the counterfactual in order to compare the recovery and therefore know whether this was a resilient recovery.

Another example of an ex post flood resilience indicator is event-related fatalities, which has been shown to be a function of several factors, each meriting a specific response. Jonkman and Kelman (2005) studied fatalities associated with 13 floods in Europe and the United States, and found that two-thirds of them were due to drowning (other causes included physical trauma, electrocution, and carbon monoxide poisoning). To minimize fatalities, the authors recommend ex ante community education regarding the sources of personal risk during floods and suitable precautionary actions. Yet there is no systematic testing of this link between ex ante sources of resilience and the ex post indicator of resilience.

Another indicator which has been used as a proxy to measure ex post resilience is the extent of physical damage from a flood event, which has been studied extensively. For example, Kreibich et al. (2010) studied three flood events in Germany to estimate causes of flood damage in the commercial sector. Flood damage was positively related to water depth and whether the event caused the water to be contaminated (e.g., by chemicals or sewage). Flood damage tended to be less for larger firms that were more likely to take precautionary measures and had a greater capacity for emergency response, firms with previous flood experience, and entities that owned the property at risk. Using econometric models, Kreibich et al. (2010) provide estimates of the contribution of each factor to flood damage in the commercial sector.

Recovery is a fundamentally time-sensitive aspect of resilience. Macroeconomics is one field that has concerned itself with recovery from natural disasters. While distinctions exist between economic recovery at the levels of community and country, certain elements of the macroeconomic literature can inform community recovery. von Peter et al. (2012) show the effect of natural disasters on economic output (GDP) and estimate the time of recovery to pre-event levels of output. von Peter et al. (2012) note that economic development and the geographic size of a country are important predictors of GDP loss and recovery such that less developed and more geographically concentrated economies are less resilient to natural disasters. Noy (2009) notes that the net impact of a disaster is significantly affected by the ability of an economy to mobilize reinvestment. This capacity to mobilize investment is positively associated with economic development indicators such as literacy rates (Human Capital), income per capita (Financial Capital), openness to trade (Social Capital), government size (Financial and Physical Capital), and institutional quality (Social Capital).

Given these results, we might ask what capacity we can build ex ante in order to be resilient. DRM and resilience literature to date, and the perspective espoused in this paper, emphasizes the importance of ex ante actions. Additionally, policymakers and the community in general would like to know before a risk event occurs if they have balanced risk and opportunity as much as possible and whether they have built the capacity to withstand and recover into their communities. Quantitative frameworks that measure ex ante resilience look at the capacity of a region, community, or area. The capacities generally fall into 3–9 broad categories, such as economic, financial, social, infrastructure, institutions, and natural resources.

For example, the macroeconomic literature identifies two financial capacities that affect economic recovery and are likely relevant at the community level in developed and emerging economies: credit and insurance. Specifically, Noy (2009) shows that recovery is positively influenced by the size of local credit markets but unaffected by stock markets, suggesting that financing for households and small and medium firms may be particularly important to facilitating reinvestment after an event. von Peter et al. (2012) also find that transferring risk to insurance markets may reduce the consequences of natural disasters. Their results suggest that it is only the uninsured portion of the loss that creates negative economic consequences. For well-insured events, the economic effect is neutral or even positive. von Peter et al. (2012) speculate that these positive effects are the result of insurance helping finance reconstruction.

Unfortunately, studies like the ones described above are narrow in that they focus mostly on financial capital, and apply at the national level. Many of the community-level resilience indicators that have been applied to date are limited in either scope or context. For example, the US National Academy of Sciences' recent report outlines a number of indicators that measure aspects of resilience capacity similar to that of Cutter et al. (2010), which develops a conceptual framework for measuring disaster resilience and applies it to the southeastern United States. Their index is built on five capacities: social, economic, institutional, infrastructure, and community capacity. The Resilience Capacity Index developed by Foster at the University of Buffalo Regional Institute covers metropolitan regions in the USA and measures 12 indicators, which are then aggregated by equal weighting into three capacity categories: Regional Economic, Socio-Demographic, and Community Connectivity.[1] The scores on these three capacities are then aggregated to one resilient capacity score for that region. So far, one year of data is available and covers 361 metropolitan areas in the United States.

6.2 Measuring resilience – Process and outcomes in a systems perspective

The systems perspective provides a framework conducive for measuring resilience as both an outcome in terms of performance (i.e., providing wellbeing and development opportunities) and as the process to achieve an acceptable performance, which is the source of the systems' resilience.

Tracking the holistic capital profile of the community in the SL framework over time shows us whether and how wellbeing is growing over time and is an outcome measure. It tells us if disaster risk is being exacerbated over time or is being managed in a balanced way with development opportunities. While the framework is generalized, it can be made specific for each community based on the key performance indicators it chooses (the components of the five capitals that are important for them to maintain and grow). Just like any organization, deciding on what to measure is important because it will keep the focus on those goals.

Suppose we have a community in a flood-prone area in a low-income country. By tracking the five asset categories pre- and post-event, we can observe how development, disasters, and DRM activities occurring in the community are eroding or supporting wellbeing. Capitals must be measured regularly over time – at all stages of the IRM cycle. In the ex ante period, tracking wellbeing in the SL framework shows the level and trends in the five capitals, and how they are growing in response to specific investments or interventions. In the ex post period, the five capitals show the effect of the disaster and how various capitals are utilized to cope and recover. By observing the interaction between the five capitals over time, the impact on performance can be observed.

When an intervention is being decided upon, the SL framework supports expert and participatory understanding of the impact of the event and the potential interventions on the community's wellbeing and development opportunities. Using a participatory approach to risk assessment, informed by those with specific knowledge, the stakeholders can determine:

a. Current community wellbeing and development opportunities as defined by the levels of the capitals currently present as well as resources and amenities available
b. The direct impacts of flood on the capitals and for different stakeholders
c. The way the capitals would be utilized to cope with flood by different stakeholders
d. How the direct impacts and coping strategies would interact to result in indirect impacts on the capitals, and how these would differ among stakeholders

For example, a disaster may lead to consumption-smoothing but less saving, leading to an erosion of financial capital over time.

The participatory process would then identify policy options acceptable to stakeholders and examine their impact on wellbeing across the assets and between stakeholders. Pre- and post-disaster outcomes, both direct and indirect, would then come under consideration.

An options analysis based on the SL framework might identify unforeseen impacts that lead to certain options being disregarded. The remaining acceptable options are the ones considered by the stakeholders to have preferred outcomes pre- and post-event. This approach does not prescribe an optimal outcome, leaving trade-offs between capitals as a matter for the participatory process. It may be that option A is more equitable, but option B is more economical; which one is ultimately chosen depends on the values that dominate the process. It is not the goal here to prescribe what these values are, but to provide holistic information to inform the stakeholder process.

It is desirable for policymakers and stakeholders alike to know what types of interventions may support wellbeing over time and the mechanisms by which this occurs. Above, we discuss the properties of a resilient system according to various authors and in particular identify the "four Rs" (robustness, redundancy, resourcefulness and rapidity) from systems thinking.

The "four R" properties help to evaluate where there may be weaknesses in one or more of these four areas and thus where the communities' systems may be vulnerable should a disaster event occur. They also help to identify policies to address the weakness in terms of how it will enhance the system in one or more of these four properties, which can then be evaluated and prioritized using multi-criteria Cost-Benefit Analysis.

Extending our example of the flood-prone communities, the properties of a resilient system would shed light on why one community has fared better than another in the same disaster, despite identical capital levels. An examination of the financial capital profiles of the two communities might reveal that Community A had a diversified income base whereas Community B is dependent on a single industry. This redundancy has been demonstrated to be a source of quicker recovery after a disaster. However, communities without this specific redundancy may have other

1 See http://brr.berkeley.edu/rci/site/faqs for a detailed description and the current data.

sources of resilience that could allow them to efficiently recover, given that they prefer to have an undiversified livelihood base. This project will explore these sources and substitutions through detailed case studies as it develops a standard measuring tool for the benchmarking and tracking of community flood resilience. Similarly, different capital profiles between communities may endow them with properties of resilience. In Figure 13, Community A has higher absolute capital than Community B; Community A has correspondingly higher asset risk, but despite higher capital it has lower resilience due to the properties of that capital. Community A has lower resilience than Community B; therefore, its long-term development risk is higher. Long-term risk to development then feeds back into the asset portfolio of the respective communities, with a higher development risk in Community A having a greater detrimental impact than in Community B.

The hypothetical example above illustrates the relationship between community capitals/assets (holistically defined), resilience, and long-term risk to development. When this framework is used to consider one community through time we can see how interventions designed to enhance resilience can alter the outcomes for long-term development and community assets.

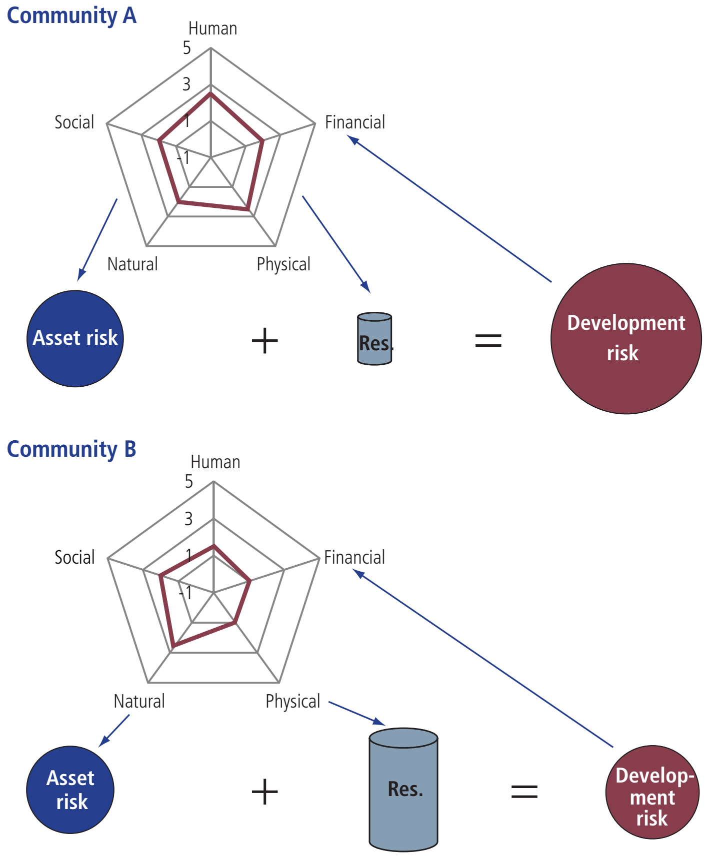


Figure 13. Capitals, resilience, and risk in two communities

6.3 Resilience Indicators

While resilience theories have informed wide-ranging disciplines for a long time, an effort to identify operational indicators has received little attention until now (Carpenter et al., 2005). We have seen a rapid rise in such efforts in recent years, along with a growing global interest in resilience. For example, a Global Resilience Index is now being developed at the Earth Institute in Columbia University (UN, 2013), international and national aid agencies are also proposing their versions of resilience indicators (Alinovi et al., 2009; USAID, 2013), and a number of regional disaster resilience indicators have also been developed (Cutter et al., 2010; Resilience Capacity Index, n.d.). Twigg's (2009) Characteristics of Disaster Resilience Community is designed for, and in cooperation with, NGO and civil society organizations; it systematically and extensively explores many aspects of disaster resilience. Finding appropriate measurements is seen as an important first step in operationalizing the concept.

These recent efforts to develop resilience indicators share common challenges, however. Resilience as a "revealed concept" means that measuring it directly is difficult, unless we observe how a system, nation, or community fares under a disturbance (Carpenter et al., 2005). We propose the development of a comprehensive set of metrics grounded axiomatically in properties of a resilient system to help guide the exploration of potential sources of resilience and test their effect on outcomes in order to drive an evidence-based understanding of flood resilience. Using the five-capitals framework, potential resilience indicators, for example, might include: Physical capital –the number of access roads and bridges (source) and the number of households with uninterrupted access to utility services post-flood (outcome); Social capital - the number (or percentage) of stakeholder groups represented on a planning board discussing ways to reduce losses from future disasters and the number of times they meet (source), and the number of community members engaged in aiding others in recovery (outcome); Human capital – diversity of skills/training in the community (source) and the number of days children are displaced from schooling (outcome); Financial capital – the average household savings in the community (source) and the amount of days of lost income (outcome); and Natural capital – the degree of soil absorption (or capacity for natural run-off) (source) and the percentage of protective barriers eroded (outcome).

While resilience informs a wide range of disciplines, indicator development should be understood as an ongoing process of interdisciplinary inquiry and dialog. Resilience indicators play an important role in shaping global discourse, while providing room for cross-sectoral and cross-disciplinary learning. Furthermore, given that resilience is a complex social-ecological systems concept, defining appropriate scales of analysis both geographically and temporally becomes important. Clarifying specifics such as "resilience of what to what" (Carter et al., 2001) and identifying the potential end-users ("indicators for whom?") and potential purposes ("indicators for what?") brings clarity into the complex process of resilience indicator development (de Sherbinin et al., 2013).

7 Conclusions: Making the Resilience-shift Happen

The theory and practice of DRM is undergoing a transition toward holistically embracing resilience. Our review has described this ongoing transition, ongoing reconceptualization, definitions, and approaches for operationalizing this concept in terms of both a quantitative and process-based framework.

This white paper started by highlighting salient issues relating to disaster risk and development that will be increasingly relevant under future socioeconomic and climatic changes. We also identified key challenges currently facing DRM theory and practice that will be exacerbated by these future changes. The central challenge is the integration of disaster risk and development objectives so that they can be mutually reinforcing rather than inadvertently undermining one another over time.

The overarching objective of both development and DRM is to promote the wellbeing of people. We described the dynamic interconnection between disaster risk and development in section 2. We presented evidence that an integrated approach is required for development and growth goals to be achieved in an uncertain and changing environment. However, to date, neither the DRM or development communities of practice have fully operationalized this, despite increasing acknowledgment of the need. DRM still tends to focus on hard infrastructure and response and recovery rather than recognizing development opportunities that could manage the risk and achieve greater wellbeing. Development organizations tend to focus on projects with tangible impact measures for donors but do not incorporate the risk-adjusted costs. These can be higher, for instance, if the development initiative increases value exposed to hazard or increases vulnerability due to erosion of natural capital. Similarly, it could be lower if the development increases the capacity for DRM, for example, increasing communication lines that could be used also for early warning or a means to communicate information on preparedness.

The concept of resilience has grown in popularity in response to these challenges and clearly provides a useful entry point for a more holistic and people-centered approach on DRM and development alike. There is concern regarding the "resilience buzz," which in practice may simply re-badge DRM as resilience building. We argue that good DRM, particularly when it emphasizes and operationalizes ex ante action, can indeed enhance resilience. As this review proposes, operationalizing resilience of a community's socioeconomic system to disaster risk is an IRM process that can incorporate a number of context-specific practices and policies through stakeholder participation. An overarching test of the policies and practices are their effects on enhancing key properties of a resilient system (the "four Rs"). By widening the lens to resilient properties, a more holistic approach to managing risk can be achieved. Strategies with properties which enhance disaster resilience, previously not considered to contribute to risk reduction, may now be recognized. For example, a change to a diversified livelihoods system based on seasonality may now be recognized as increasing the redundancy of the community's system and thus building resilience to floods. Simply building a dam without accounting for the benefits of diversification would take away this source of redundancy and might inadvertently weaken the resiliency of the system. A proper accounting of the resilience properties of the dam versus the change in livelihood would need to be made and then weighed against their impacts to decide on the best course of action for that community.

This full resilience-accounting requires the ability to measure both sources of resilience and resilient outcomes in order to test for appropriate indicators that could help identify ex ante the latent quality of resilience in a community before an event happens. This is a major quantitative gap in the resilience research to date and arguably why concrete, measurable progress on the ground that goes beyond the usual debate about just definitions and concepts has not been widely established. What is needed is the ability to benchmark and track these sources and outcomes and develop a measure of resilience.

This white paper laid out a methodological approach within a systems framework that can be taken to case study communities where the implementation of resilience strategies through an IRM-type process can be studied and its effectiveness analyzed and documented. By systematically collecting data from these communities and testing them within this framework, we will be able to build up an evidence-based measure of the intangible quality of resilience in communities. The remainder of the project work-streams in the Zurich Resilience Alliance are aimed at doing just that.

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