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Managing the risk of extreme events in a changing climate

Trends and opportunities in the disaster-related funding landscape

In late April 2015, the Uganda Red Cross Society (URCS), German Red Cross and Climate Centre conducted a drill rehearsing standard operating procedures for the new forecast-based funding project that will make funds available for humanitarian action before disaster strikes. In the picture Patrick Wabwire receives two jerrycans as part of the practice humanitarian distribution triggered by an adverse forecast. (Photo: Eddie Jjemba/Climate Centre)

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1. Introduction

The scientific literature is increasingly clear about the connections between anthropogenic climate change and the number and severity of extreme weather events. Here, we will focus on climate-related disasters, including events such as storms and drought and the associated disaster effects. In 2012, the Intergovernmental Panel on Climate Change (IPCC) released its Special Report on Managing the Risks of Extreme Events and Disasters (SREX) to assess the state of the science on climate and disasters. This Report concluded that anthropogenic influence is likely to have already resulted in an increase in maximum temperatures, an intensification of extreme precipitation, and extreme coastal sea levels around the world. It demonstrated that there is a trend of rising risks in global disaster losses, which have increased several orders of magnitude since 1980 due to changes in hazards, vulnerability, and exposure.

Such effects are expected to increase as climate change progresses; according to the SREX (2012) report, parts of the planet could see increasing likelihood of extremely hot temperatures or changes to the number of heavy precipitation events. While there are still uncertainties about future global precipitation changes (Kundezewicz et al., 2014), estimates of the cost of adapting to a 2 degree Celsius increase in the global mean temperature have been placed at $70-100 billion per year by the World Bank (2010). In a study on river floods in the European Union, for example, Rojas et al. (2013) estimated that the avoided losses due to adaptation could exceed Euro 53 billion/year by the 2080s. One clear implication is that development processes cannot continue without acknowledging this risk landscape; investment in infrastructure and development must anticipate and plan for these changing risks (World Bank 2010).

IPCC SREX notes that a climate event cannot cause a “natural” disaster without exposure of vulnerable people to the climate-related hazard. Furthermore, attribution of a single disaster event to climate change is very difficult, given the internal variability in the climate system, but also the underlying socioeconomic factors that influence the extent and magnitude of the damage caused by a single weather event. Even disregarding climate change, the concentration of people and economic assets in flood prone areas has been increasing rapidly (Jongman et al., 2012; Bouwer et al., 2007). Fortunately, this also means that we are not just in nature’s hands: human behaviour and planning can help reduce risk in anticipation of changing climate conditions.

With this in mind, much has been written to define the concept of “disaster risk” (Cardona, 2003, Manyena, 2006, UNISDR, 2009). Here, we adopt the definition of disaster risk as used in the IPCC SREX report (IPCC, 2012), as being derived “from a combination of physical hazards and the vulnerabilities of exposed elements… signify[ing] the potential for severe interruption of the normal function of the affected society once it materializes as disaster”. This is illustrated in Figure 1, where the strength of three components, hazard, vulnerability, exposure, is affected by climate variability, climate change, disaster risk management, and climate change adaptation.

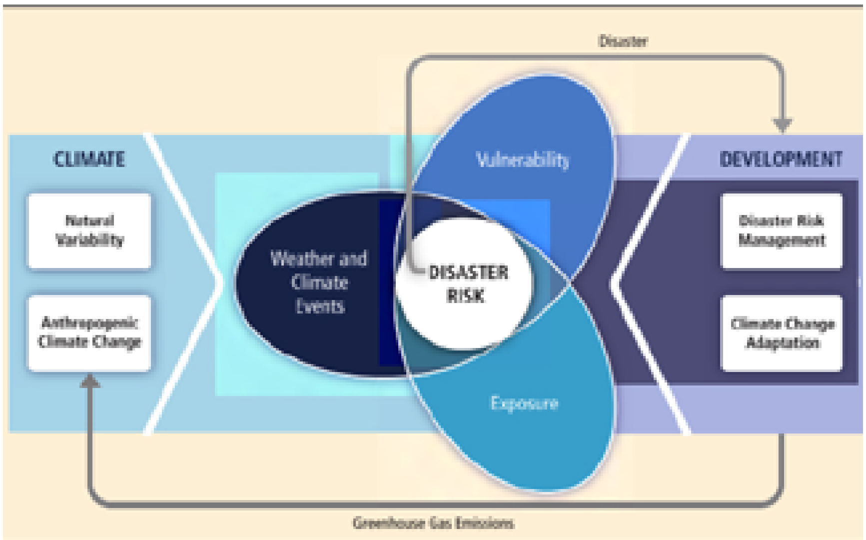

Figure 1. Schematic depicting the intersection of hazard, vulnerability, and exposure to create disaster risk, and several underlying drivers that control each aspect. Based on Figure 1-1 in IPCC (2012).

Based on this understanding of risk, the key question going forward is how the evidence of changing risks in a changing climate should inform international financing for disasters (Jongman et al., 2014). Adaptation to changing patterns of extreme weather events will be a key component of climate change adaptation; adaptation-related funding (through UNFCCC-related funds or donor agencies) particularly focuses on the least developed countries, which are likely most affected by a changing climate.

Policy makers must determine how best to invest disaster-related funds, given an understanding of global distribution of climate effects as well as trends in vulnerability and exposure. While many of our findings are applicable to national investments, this paper focuses specifically on international and development-related funding mechanisms, which amounted to over $100 billion between 1991 and 2010 (Kellett and Caravani, 2013). Building on the premise that risking risks of disaster due to climate change will require wise resource allocation, this paper outlines three categories of activities to which funding can be allocated to the management of changing climate and weather extremes.

The first is long-term **disaster risk reduction** (DRR), which seeks to reduce exposure and vulnerability to future disasters; this can encompass everything from flood protection measures to improving latrine coverage. In light of the changing climate, such efforts should not only address the vulnerability and exposure to past patterns of weather and climate hazards, but include a clear recognition of changing climate. This area or work is recognized in the Cancun Adaptation Framework, and reflected in many current adaptation projects.

On the other side of the spectrum, another option is to accept (part of) the risks, and to ensure appropriate mechanisms are in place for **disaster response and reconstruction**. These elements have now also become part of the emerging "**loss and damage**" debate in the UNFCCC. Traditionally however, this has in international financing long been the role of humanitarian organizations for immediate response and early recovery, as well as development agencies and development banks for longer-term reconstruction. Clearly, such efforts can be climate-smart by ensuring they do not contribute to future vulnerability, in what is known as "building back safer".

This policy brief also highlights an intermediate category of options, which has often fallen between the cracks of on the one hand long-term funding for adaptation and disaster risk reduction, and on the other hand existing mechanisms for ex-post disaster response and reconstruction. This category is systematic action based on forecasts of (temporarily) increased likelihood of hazard occurrence, such as rainfall forecasts for the coming days, weeks, or months. Although many early warning systems exist, there are very few international funding mechanisms that can provide financing based on such a warning. Such “**forecast-based financing**” can fund short-term actions to reduce the risk of an expected disaster before the event actually happens, with the understanding that there is a probability that it may not occur at all. Such actions are different from long-term risk reduction in the sense that they can only be justified once the probability of a hazard has significantly increased, for instance when a seasonal forecasts predicts a particularly heavy rainfall season in an area without adequate stock of flood relief items, or when the projected path of a hurricane indicates high risk for a fishing village. By allocating and rapidly deploying resources ex-ante for disaster management measures in light of the increased risk, effectiveness and efficiency can be substantially enhanced compared to waiting for the disaster to happen before any funding is released. Furthermore, by using climate information across timescales, these actions explicitly build on scientific information about changing risks, implicitly reflecting the already-changed global climate without relying solely on long-term climate projections.

Here, we will go into depth for each category of funding mechanisms, providing an overview of trends over the last few decades, and opportunities going forward in a changing climate. These three categories are continuous and interlinked, and a combination of techniques to address disaster risk, forecast-based risk, and disaster consequences will be necessary in every context. The balance between them will be affected by differences in available resources and risk drivers. Ultimately, disaster-related financing is context-specific, addressing unique local drivers and interaction effects; it will differ substantially depending on the context in question.

2. Long-term disaster risk reduction

In 2005, the international community developed the “Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters”, which was adopted by 168 governments worldwide, and is supported by the United Nations International Strategy on Disaster Risk Reduction. In the past decades, but particularly since the adoption of the Hyogo Framework, there has been a rapid growth of policy and practice, as well as advances in techniques and best practices to reduce disaster risk.

Changes to disaster risk over time are due to both changes in climate variability and also changes in the socio-economic structure of vulnerable communities. Locally-appropriate actions to lessen the vulnerability and exposure of the target system can reduce the long-term risk of disaster, often as part of regular activities by companies and communities, or regular plans and programs by government agencies at different levels. Some examples include structural improvements to houses; ecosystem management and restoration to reduce extreme runoff; and changes in agriculture practices and crops to increase resilience to disaster (German Red Cross, 2013).

Trends

Disaster risk reduction seeks to identify the hazards that exist in a location, based on long-term risk and the primary people, systems, and natural systems that are exposed and vulnerable to the hazard. A number of tools and methods have been developed to target these components; the composition of which has varied through time.

In the 1980s and the 1990s, aid investments in disaster prevention and preparedness were focused on large-scale flood prevention infrastructure projects (Kellett and Caravani 2013). Over time, we have seen a shift characterized by increasing numbers of smaller projects, less focused on large-scale infrastructure (*see Figure 2*).

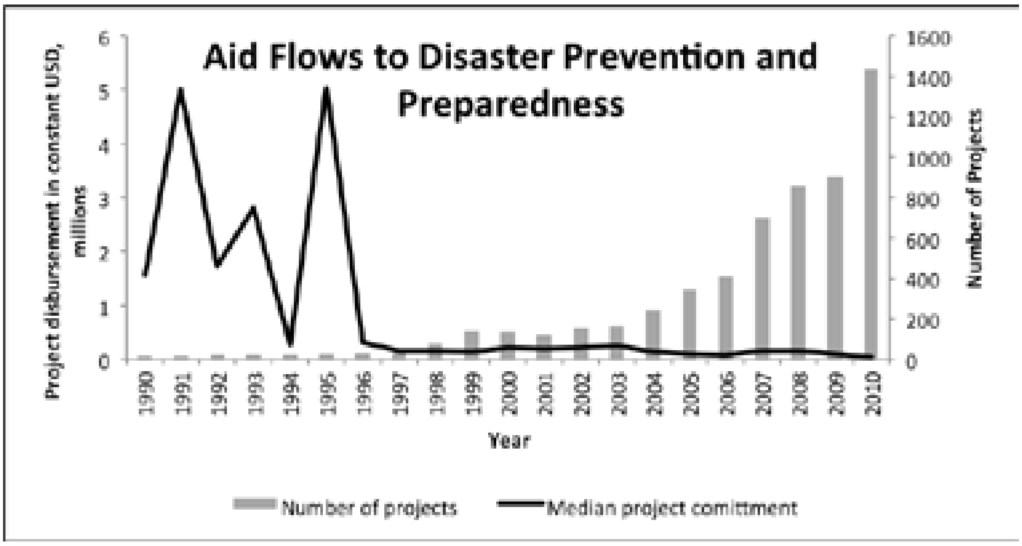

Figure 2. Aid flows over time, demonstrating the general increase in number of disaster prevention and preparedness projects in the last two decades, and the concurrent decrease in median project funding. Commitment amounts are from AidData in constant 2009 USD (Tierney et al. 2011).

In recent years, this transition from focus only on hard infrastructure to "softer", smaller, and more integrated projects has been dominated by the concept of "resilience". Many major aid programs have issued specific policies on resilience. The United States Agency for International Development (USAID) 2012 Resilience Agenda defines resilience as the ability to "mitigate, adapt to and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth", while the European Community Humanitarian Office (ECHO) outlines a similar definition in their Thematic Policy Document number 5: "Disaster Risk Reduction: Increasing resilience by reducing disaster risk in humanitarian action" (ECHO 2013).

Other than this trend in size, patterns in disaster risk reduction over time are remarkably sporadic, often dominated by investments in single projects (Kellett and Caravani, 2013). The decision to invest in disaster risk reduction is mediated by several factors, and is closely connected to post-disaster response. There is evidence that investment in disaster preparedness can be triggered by the incidence of a disaster in the recent past (Birkmann et al. 2010, Gillen 2005). For example, Hurricane Sandy spurred $200 million USD investment in wetland restoration to reduce flood risk in New York City and nearby coastal developments, and prompted the Federal Emergency Management Authority to release updated flood risk maps for the area (Tollefson 2013). In the European Union, major flooding events in past decades led to a European Commission directive aimed at uniform flood protection for all EU citizens (Alfieri et al. 2012).

One of the most constant risk reduction investments through time has been that of insurance, with the percent of global assets insured rising since the 1950s. Insurance has been a longstanding technique to finance risk and reduce economic insecurity, allowing for risk pooling and transfer of risk among the participants. While many assets are uninsured in the developing world, insurance payouts for weather-related disasters in these areas triple the amount of financing provided through international aid mechanisms (Mills, 2005). However, when compared with the Global North, low-income countries have been shown to have very low rates of insured losses post-disaster, which is magnified by additional indirect impacts on the growth and development of these countries in the long term (Linnerooth-Bayer and Mechler, 2009). In recent years, several insurance mechanisms specifically targeting developing countries have been established, such as the Caribbean Catastrophe Risk Insurance Facility and the African Risk Capacity. Due to changes in climate as well as human vulnerability and exposure, it is expected that insurance mechanisms will need to adapt over time in their scope, mechanisms, and coverage (Jongman et al., 2014; Botzen et al., 2010, Mills, 2005).

Index insurance has been a relatively recent innovation in the field of disaster risk reduction, making insurance available to people in areas that risk significant losses due to weather and climate variability. Because the payouts are based on large-area weather measurements, this reduces costs associated with confirming individual farmer losses and insurance claims, and has been popular with smallholder farmers. With access to insurance, these famers are able to invest in high-risk, high-reward agricultural strategies, and reap larger development rewards. In addition, this financial technique can immediately enable adaptation to increasing numbers of extreme events due to climate change by reducing income fluctuations that would have been caused by crop losses due to climate variability (Suarez and Linnerooth-Bayer 2010).

Opportunities

While existing efforts at long-term disaster risk reduction will likely also reduce the risk of disasters influenced by anthropogenic climate change, adaptation to changing risks suggests that DRR should not only focus on past and present risk, but also take into account projected future changes to risk in the target location. Practitioners bridging this gap have developed guidance to incorporate both disaster risk reduction and climate change adaptation; an example is the Minimum Standards for Climate-smart Local Disaster Risk Reduction, developed in the context of the 9-country *Partners for Resilience* program (Red Cross / Red Crescent Climate Centre, 2013). Such practical, hands-on tools will be essential to bridge the existing practice on disaster risk reduction and the emerging financing for climate change adaptation. See below excerpt: Minimum Standard action 1.4.

> *Community develops a longer term risk reduction plan to address key risks, including potential long-term adaptation needs to gradual, certain changes (e.g. sea level rise, salt intrusion) as well as a contingency plan for unexpected climate related risks (e.g. new extreme events, cyclones hitting new areas)*

To facilitate the use of climate change projections by DRR and adaptation practitioners, the Intergovernmental Panel on Climate Change, as well as other scientific institutions, generated plausible scenarios of future manifestations of the world's climate and contingent impacts (e.g. Dankers et al., 2013). Such scenarios are used to inform decision-making and disaster risk reduction policies; for example, in the UK, the environment ministry has used UK climate change scenarios to mandate a threshold level of sea level rise for consideration when planning coastal defence strategies in the country (Hulme and Dessai, 2008). However, further research into the methods for quantifying and communicating climate change uncertainties are needed to prevent misunderstandings between scientists and policy makers (Coughlan de Perez et al., 2014, Enserink et al., 2013). Several techniques have been proposed to design scenarios that inform adaptation decisions, including the selection of extreme events with societal consequences as the framing of the scenarios (Berkhout et al., 2013). Such framing specific to the adaptation decision context can enable actors to integrate both disaster risk reduction and climate change adaptation.

In international donor financing, many DRR programs have so far been funded out of humanitarian aid budgets (UNISDR and OECD, 2013). There is discussion whether this should remain the prime focus for funding or whether, to secure a more integrated approach, DRR should be financed out of both earmarked funding for long-term developments as well as humanitarian aid. The funding for climate change adaptation, also still in its infancy, provides a new dimension to this discussion. Between 2003 and 2011, several hundred climate change adaptation projects were improved, and while the initial portfolio of projects did not generally target DRR, more than half of the projects approved in 2011 had a DRR component (Kellett and Caravani, 2013). Policymaking through the resilience lens, which has received increased attention in the last years, could help to break down these traditional divides.

Clearly, disaster risk reduction and climate change adaptation are related and complementary. Much has been written on the relationship between these two, from papers emphasizing the overlap (i.e.: Munang et al., 2013, Mercer, 2010, Mitchell et al. 2010) to others specifying the differences between the two approaches (i.e.: Etkin, 2012). Ultimately, DRR efforts moving forward will need to explicitly assess changing climate risks, and practitioners from both fields will need to collaborate to achieve shared goals.

Disaster response and reconstruction – and the connection to loss and damage

Trends

Even if much is invested in long-term DRR, it is extremely unlikely that all disasters will be avoided. The most extreme events will have consequences on vulnerable people and on poor countries' economies, and these cannot be entirely mitigated, including through adaptation to climate change (Dow et al., 2013, Adger et al., 2009). Traditionally, such costs have been borne either by individuals, companies or governments themselves, or, in the case of international assistance, through the humanitarian system for response and early recovery and by development agencies and development banks for reconstruction.

In recent years, it has been questioned whether the international system is providing the most effective response to the challenge of disaster response and reconstruction. Analyses of the World Bank's portfolio of reconstruction projects, but also reviews of the humanitarian response such as DFID's Humanitarian Emergency Response Review (Ashdown, 2011), have all emphasized the need to focus more on ex-ante investment in resilience and anticipation of risks, rather than ex-post financing for response and reconstruction.

However, they also recognize the fact that in light of continued increases in risk, and the fact that even without all the capacity constraints facing many developing countries, it is not economically feasible to reduce all risk to zero. There will be a continued need for humanitarian response, and there will be a need to quickly help communities and economies recover from shocks. In fact, general use of risk reduction terminology has shifted since the year 2000 to favour the terms "disaster risk reduction" and "disaster preparedness" over "disaster prevention", characterizing a shift in mentality to acknowledge that disasters cannot be completely prevented (see Figure 3). In such cases, we can still do better by being smarter, anticipating disaster response needs (see the next section) and incorporating disaster risk reduction techniques during reconstruction.

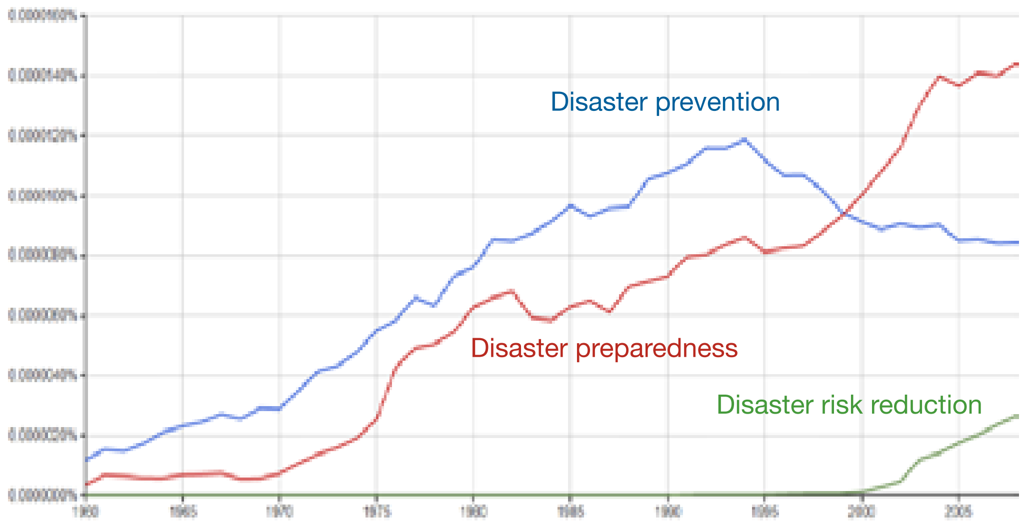

Figure 3. Incidence of the terms "disaster preparedness" red, "disaster prevention" in blue, and "disaster risk reduction" in green from 1960-2008. This is calculated as the percent of all 2-word or 3-word phrases, respectively, occurring in books published in English that have been indexed by Google (Michel et al. 2010).

This concept was mentioned in the previous section, where we highlighted that disaster events can catalyse support for risk reduction. This can be encouraged during the reconstruction phase in what is popularly known as "building back better". However, recent deliberations on this term have suggested that it is usually very easy to rebuild "better" in a developing country context, and that "building back safer" is a more specific term to encourage disaster risk reduction efforts. Building back safer ensures that subsequent reconstruction is not only of better quality but is also not rebuilt in high risk environments (ALNAP and Provention Consortium Secretariat, 2012). Further it is argued that in addition to better reconstruction, community involvement, access to information, advice and appropriate low cost construction materials should be part of the reconstruction process (ibid). The IFRC and SKAT (2012) note that the ability to conduct maintenance is essential to ensure that reconstruction that is built back safer remains safer. To ensure that such ability is present, it is important to get to know the community through capacity assessment (IFRC, 2010) and to ensure their engagement in the process (Sphere Project, 2011).

Opportunities

While these discussions are taking place in the context of disaster response and reconstruction, another discussion has started in the UNFCCC, in the context of Parties' concerns about "loss and damage". This is interpreted partly as long-term loss and damage due to gradual climate change, such as inundation of large areas of land due to sea level rise, but also in the context of extreme events, which will often be the occasion on which gradual changes manifest themselves as impacts on society (even in the case of sea level rise, it is often a major storm surge that causes the immediate damages).

In the 17th Conference of the Parties (COP) to the UNFCCC in Cancun, 2011, discussions began on how to understand and reduce "loss and damage", including due to changing patterns of extreme weather events due to anthropogenic climate change. A work programme was established to conduct a literature review, convene expert meetings, and identify methods and gaps in the global understanding of how to address this issue. At COP 18 in Doha, 2012, commitments were made to establish "institutional arrangements, such as an international mechanism" on loss and damage in the following COP, based on further research and consultations to be carried out in 2013.

In 2013, parties to the 19th COP to the UNFCCC agreed upon a *Warsaw international mechanism for loss and damage associated with climate change impacts*. The mechanism encourages the sharing of technological support and guidance on loss and damage, as well as dialogue and coordination of experts and stakeholders. In addition, it acknowledges the importance of disaster risk reduction strategies, agreeing to "enhance the knowledge and understanding of comprehensive risk management approaches to address loss and damage associated with the adverse effects of climate change, including slow onset impacts" (UNFCCC 2014).

In the context of increasing climate risks, humanitarian costs are projected to rise significantly, and the burden on developing countries' economies and well-being will be significant. It remains to be seen whether the UNFCCC Loss and Damage discussion can help address some of these challenges, and whether its explicit climate focus could be used to enhance existing mechanisms for response and reconstruction, incentivizing a focus on climate resilience.

Short-term forecast-based action to reduce losses

Trends

Many adaptation options that would avoid disaster are not always feasible to implement as permanent, long-term disaster risk reduction measures. For example, it might not be economically or politically feasible to permanently relocate people living in the floodplain near a river, but it would be very feasible to evacuate and house them for a day or two in specially set-up temporary shelter, before a flood happens. Other disaster risk reduction measures, such as building levees or elevating houses, will reduce the risk of flood disaster only up to a certain flood level; extreme events that surpass that threshold could have drastic effects. For both of these reasons, there will be residual risk of disaster even after many DRR projects are completed – and we know that science-based forecasts with hours, days, or even weeks of lead time allow us to anticipate the time windows when those residual risks are increased due to extremely unusual atmospheric conditions.

This highlights the potential benefit from a different, complementary approach, more consciously focusing on short to medium term anticipation of higher levels of risk based in information from weather and climate forecasting. For such an approach to be successful, two components must be in place: (1) an early warning system, and (2) the mandate and (3) the ability to act based on an early warning.

As technology to forecast extreme events has become available, early warning systems are becoming more available worldwide, and policy directives have spurred investment in early warning systems in recent years. Examples from a number of governments and private sector organizations are showcased in Table 1. In the European Union, several risk management legal frameworks embed early warning systems into the disaster preparedness and response cycle, and these European Union directives have stimulated the creation of national policy frameworks for integrated disaster management (Alfieri et al. 2012). Early warning systems are specifically encouraged as a component of preparedness for natural disasters, and this has catalysed effort from member states to improve existing early warning systems (ibid.). Indeed, the EU now has an operational flood forecasting system called EFAS. Globally, the Hyogo Framework for Action places a similar emphasis on early warnings, encouraged by the Platform for the Promotion of Early Warning within UNISDR (ibid.)

Action based on existing early warning systems has been instrumental in saving lives and livelihoods. In regions vulnerable to landfall of tropical cyclones, it is common to have operational early warning systems depicting the probability of landfall. Evacuation of 800,000 people immediately prior to Cyclone Phailin in India is a well-known example of action that could only be taken based on an active and well-disseminated storm warning. Such actions are normally not justifiable based on long-term storm risk to the region, but with a short-term forecast of substantially increased risk they become much less controversial. Examples of potential forecast-based humanitarian actions for floods, tropical cyclones and malaria risk at different timescales can be found in IFRC (2008).

Aside from storm forecasts, there are several other types of early warning systems currently in operation for weather-related events; a review of European-based initiatives included operational warnings for landslide and debris flow, surface water flooding, coastal flooding, riverine flooding (Alfieri et al., 2012). For climate-related disasters, many funders have invested in early warning systems to develop alerts based on both observed and forecasted variables. For example, the Famine Early Warning System (FEWS-NET) is operational in East Africa, and provided early warnings before the 2011 Somalia Famine. Such systems anticipate extreme events before they occur, to enable people to respond *shortly before* the possible disaster. The types of activities that would be taken based on these forecast triggers are not necessarily the same as what would be implemented in long-term disaster risk reduction, because the temporarily increased risk of disaster can justify more extreme and costly actions.

Sector	Type of Warning	Lead Time	Action	Cost/ Benefit
Government (State government of New York City) (Tollefson 2013)	Flood and droughts, based on threshold levels of rainfall.	Seasonal and short term	Adjust reservoir levels	Cost of alternatives, are $200-500 million for a new intake system at one reservoir or increasing the size of a second reservoir. A new filtration system could run up to $10 billion. Cost of forecast based system = $8 million.
Government of Australia (Keys 1994)	Severe Storms-triggered by predictions of hailstones of 2cm diameter or greater, winds gusts of 90km/h or greater, very heavy rain, which could produce flash flooding, or the potential for tornado activity).	1-2 days	Radio broadcasts of severe thunderstorm advice	Total cost of storms $193-$329 million in 1993 prices.
Government of Australia (Kempsey business district) (Gissing 2002)	Flood Forecast-ALERT system. Automatic Local Evaluation in real time. Threshold based.	24 hours	Provides flood warning to residents and local businesses	Estimated Direct damage of $2.5 million-Estimated preparation costs by businesses of $100 000. Avoided losses estimated at 56% of Direct damage.
UK government (Colne Barrier) (Dale et al. 2013).	Tidal Flooding. Threshold = forecasted level of 3.1 meters.	10 days	Close the barrier at Wivenhoe	Cost of £4000 per closure, costs of flooding are thought to be much higher an example of a forecast benefit of £101, 144 in 2011 given. Can act as a reference figure though this represents only one instance and will vary for different forecasts.
AT&T (AT&T 2012)	Hurricane forecasts	Not given	Topping up fuel at generator cell sites, installing and testing high capacity back up batteries at cell sites, installing quick connector generator plugs, distributing portable generators, adding capacity to the wireless network, preposition of resources.	Not given.
Oil and Gas Producers in the gulf of Mexico (Considine et al. 2004)	Hurricane forecasts	48 hours	Evacuation of offshore drilling rigs and ceasing production	Value of forecast estimated at 8 million per year during the 1990s.

Table 1. Selected examples of forecast-based action and estimated cost-benefit calculations.

However, while increasing numbers of early warning systems are established worldwide, investment in the second and third required components, the mandate and resources to act based on a warning, has lagged behind. When they are under development, researchers are able to identify potential benefits of using climate-related forecasts, but many of these forecasts are under-utilized, which was also the case in the Somalia Famine (Hillbruner and Moloney 2012, Patt 2009). A Chatham House report concluded that “Famine early warning systems have a good track record of predicting food crises but a poor track record of triggering early action”, recommending that donors invest in the enabling environment for at-risk people to take action based on a warning, and develop plans for organizational level response (Bailey, 2013). Reviews of European (Alfieri et al., 2012) and American (Powerll et al., 2012) early warning systems found that additional effort is required to ensure that such warnings are disseminated to the appropriate audiences in understandable formats, and that “resources are available for the actions to reduce risk and that management plans for these crisis situations exist” (Alfieri et al., 2012).

It is rare to find forecast-based contingency plans in humanitarian organizations (most of those that exist are based on forecasted storm tracks), and even rarer to find finance mechanisms available to humanitarian organizations on the basis of forecasts or early warnings. Criticism of many recent disasters suggests that, while early warnings might have been available, the lack of action to reduce disaster risk can be attributed to a lack of plans, mandate, and resources to take action at this timescale.

There do exist a few small-scale pilots in place in the humanitarian sector, which we will expand upon here as rare positive examples. In Bolivia, Oxfam GB worked with the La Paz municipal government to establish a hazard monitoring system. What set this apart from other such early warning systems was that, upon receipt of an imminent landside warning in 2011, Oxfam GB obtained funding from ECHO under the Small Scale Response Mechanism to finance large-scale evacuation and provision of emergency shelters. It was this operational plan and financial mechanism that allowed the early warning system to provide results for the residents, and prevent any casualties that would have resulted from the subsequent landslide (ECHO 2013).

In another example, pilot index-based risk transfer products have been developed for Peru and Vietnam that provide insurance payouts based on ENSO indices. This funding is designed to arrive before climate-related disaster effects commence, and the ENSO index is a reliable metric with a long history of measurement that can be used to calibrate the mechanism. While this was developed with a narrative that is reminiscent of disaster response, that of reimbursing businesses for losses, it reduces the risk of even more catastrophic consequences that ensue when groups of borrowers default simultaneously (Skees et al. 2007). In fact, the educational component of this financial mechanism encourages recipients to use the payout to reduce the risk of now-likely disaster, such as clearing drainage systems before likely ENSO-related flooding (Skees and Collier 2010). Research has shown the value of linking forecasts, insurance, and development investments (Carriquiry and Osgood, 2011), for example, theoretical studies have shown value to Malawian farmers in varying agricultural inputs based on ENSO, in conjunction with index insurance schemes in that area (Osgood et al., 2008).

Based on our review, there is a substantial lack of literature on the systematic use and funding for such mechanisms in the humanitarian and development sectors. Practitioners do not adequately take advantage of science-based forecasts to develop forecast-triggered action systems, and there are notably fewer and less robust systems in developing countries than in the developed world. Furthermore, they are almost exclusively focused on the very short period before a disaster when there is a so-called “deterministic” forecast of a very likely time, place and intensity of an event. Longer-term forecasts, such as the ENSO example, may provide less precise information in many locations, but much more time to act.

Opportunities

Thanks to rapid scientific advances in the past decades, improved climate services enable forecasting at different timescales, not only including imminent storm warnings, but also 10-day rainfall forecasts and seasonal forecasts. The latter presents the longest opportunity to take action; seasonal forecasts give an indication of rainfall for the coming three-month period, based on global signals from the El Niño Southern Oscillation (ENSO). With a three-month lead time, practitioners could preposition relief items in regions expected to receive unusually large amounts of rainfall, or institute school feeding programs in places expected to be unusually dry.

Can we anticipate a disaster 3 months ahead of time?

Kenya	Both times in the past 10 years that seasonal forecasts from the International Research Institute for Climate and Society (IRI) predicted exceptionally high (top 15%) rainfall within Kenya, a major flood required international disaster relief.
Philippines	Statistically, when the IRI predicts that the coming three months will be "unusually wet" over the Philippines, chances of a major flood disaster nearly double, according to preliminary calculations[1].
Vanuatu	In El Niño years, the risk of a drought in Vanuatu is drastically increased; in two out of every three years in the past with an El Niño warning, a national drought emergency has ensued.

Table 2. Regional examples of the association between seasonal climate forecasts and disaster risk.

Evidence suggests that acting based on forecast thresholds to anticipate disaster incidence can be highly cost-effective. Ratios calculated by the sources in Table 1 indicate that the cost of preparatory activities can be orders of magnitude less than the cost of response, therefore justifying several instances in which the institution might act in vain. In an example from the Red Cross in the 2008 West Africa flood season, early action based on a seasonal forecast resulted in much higher humanitarian effectiveness (up to 3 days to reach the average beneficiary instead of 40 in similar floods the year before), and a 30% lower cost per beneficiary (Braman et al. 2013).

A key advantage to this methodology in a changing climate is that we are not restricted to relatively coarse and long-term climate modelling efforts to inform forecast-based financing, which often primarily signal rising uncertainties. Instead, as a way to address those rising uncertainties, this mechanism focuses on the better-predictable weather and climate forecasting on shorter timescales. Such information actually implicitly reflects the already-changed climate conditions, but provides it in the context of predictions of near-term weather and seasonal climate.

For example, currently, there is no scientific consensus for the influence of climate change on ENSO (DelSole et al., 2013, Santoso et al., 2013). Countries that are highly affected by El Niño and La Niña would certainly be interested should scientists project that climate change will strengthen or weaken these systems, and would use such information to make long-term DRR investments. However, with such a lack of consensus, it is not clear what type of long-term investments will be the most worthwhile. As an alternative, complementing general DRR investments with a forecast-based financing system will allow countries to respond to disaster risk as it evolves with the changing climate, reducing the need for surety in long-term projections of how extreme events might change. An early warning system with forecast-based financing will be able to disburse money and take action based on real time seasonal forecasts indicating a heighted risk of disaster, whether or not this was originally anticipated by climate models to be an effect of climate change. In regions with high uncertainty, this financing system will be particularly important, and offers a "low-regrets" option to climate change adaptation that explicitly acknowledges the current scientific uncertainty.

[1] This calculation is derived by comparing IRI seasonal forecasts of rainfall in the top 33% with georeferenced disbursements of the International Federation of Red Cross and Red Crescent Disaster Relief Emergency Fund for a flood-related disaster.

Practical Components

Adaptation programs that would facilitate such forecast-based approaches would need to have three components, as highlighted above. The first would be the development of an early warning system (1), in which forecasts are identified and the appropriate actions to take based on a forecast are selected by all associated parties (2). This is necessary to ensure that decision-makers are not left deliberating the best option once a short-term forecast of enhanced risk has been issued; at that point time would be wasted and many opportunities would be missed. The end result is a series of forecast-based contingency plans, which indicate the rainfall or temperature forecast threshold that should trigger action, and what action would be appropriate based on that trigger. Forecast-based actions to reduce losses may include mobility, storage, diversification, communal pooling, and market exchange (Agrawal 2008). For example, a forecast of increased likelihood of a wet season in the coming 3 months might trigger the building of storage containers for food, while a forecast of 20mm of rain over the coming 5 days might trigger relocation and storage of foodstuffs in those containers, or implementation of financial strategies to better cope with the likely shock – all of which would lead to reduced losses, disruption and suffering.

Each of these activities will cost money to carry out, but the overall cost of the short-term disaster preparation activities will be much less than the cost of responding to a disaster and rebuilding what was damaged. Therefore, the third component (3) of forecast-based funding will be the disbursement of the required funds to carry out the appropriate action when the forecast is triggered. This will require a new type of financing, in which funds will be available for disbursement only when a forecast trigger has been reached, at which point the appropriate amount of money will be released to carry out the risk-reducing action based on that forecast.

Even if the early action has no cost associated with it, decision-makers (including humanitarian workers) face a risk when acting unilaterally based on a forecast. An individual can be accused of wasting time and energy if the disaster does not materialize (Suarez and Patt, 2004), whereas the proposed forecast-based financing system internalizes this risk and authorizes early action based on pre-calculated probabilities. These probabilities are calculated in such a way that the benefit of funding early action every time the trigger is reached will outweigh the cost of sometimes acting in vain (*see Table 3 below*)

	Does the extreme event materialize?	
	Disaster	No Disaster
Action	**"Worthy Action"** *(Decide to act, then event materializes and losses are avoided)*	**"Act in Vain"** *(Decide to act, then event doesn't happen – perceived as wasteful)*
Inaction	**"Fail to Act"** *(Decide not to act, then event occurs leading to avoidable losses)*	**"Worthy Inaction"** *(Decide not to act, then event doesn't happen)*

Table 3. Illustration of possible outcomes of forecast-based action, adapted from Suarez and Tall (2010)

It should be noted that, using existing aid norms, forecast-based financing would be very difficult to fund. Long-term programmes consider such actions to be too focused on the risk of a specific event, and thus belonging to the humanitarian response financing. Humanitarian response funding however, is traditionally only allocated once a disaster has already happened, or at least predicted as "imminent". Policy recommendations from SREX and other adaptation resources encourage the establishment of early warning systems, but few mechanisms address financing to facilitate action once the early warning is issued – whereas such funding often does become readily available after a major disaster has happened.

There are a few pilots of this approach currently in place. The German Red Cross has recently piloted a "Preparedness Fund" that will provide forecast-based financing in two pilot countries, Uganda and Togo, beginning in 2015. This will consist of the three required components: forecasts, plans of action based on forecasts, and funding available to facilitate the action once a forecast is issued.

Adaptation funds could be one of the channels that would facilitate investment in such forecast-based financing, which can be a critical bridge between long-term disaster risk reduction and post-disaster response. Donors can also consider funding the advanced purchasing of emergency supplies, as indicated in Bailey, 2013. In the short term, a larger number of pilot projects should be established to create a body of standard operating procedures for forecast-based financing, as examples for scaling up and replication.

Conclusion

The lines between these three categories are, and should be, blurry; a combination of all existing approaches to manage disaster risk will be required to effectively manage the rising risk of climate-related disasters, including risk reduction, response, recovery, and reconstruction (IPCC, 2012). However, the most effective strategies will have a stronger emphasis on anticipation and resilience.

In that light, is important to note that the three categories of financing modalities outlines in this paper: long-term disaster risk reduction, disaster response and reconstruction, and forecast-based financing, are not mutually exclusive in their objectives. In fact, they are highly complementary: long-term risk reduction should build capacity for effective use of forecasts and preparedness for effective response; on the other hand, actions funded through response and forecast-based financing can also immediately help reduce long-term risk. For example, a sanitation campaign might be carried out when forecasted flood risk is higher than usual (mechanism 3), because long-term flood risk might not justify such extensive engagement on that topic in that location. However, this campaign can have long-term benefit to the population, who are likely to remember the lessons in everyday life.

For all three categories, adaptation financing has the potential to be the "oil in the machinery" for climate risk management. In recent years, many reports have emphasized the need to break down the barriers between humanitarian response and long-term development financing (Smith et al., 2014, Bailey, 2013, Mitchell et al., 2010), so that both could focus more on anticipation and resilience, and thus more effectively address the rising risks. If applied strategically, adaptation financing can help contribute to those synergies. On the other hand, there is also a downside risk. If climate financing for the management of climate extremes, in the context of adaptation funds, or even for loss and damage, would create yet another silo, with yet another set of separate financing mechanisms, the existing coordination challenges would actually grow, and the increasing financing to address climate-related extremes may not yield the results so many vulnerable people are desperately waiting for.

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