DECEMBER 2008

Feinstein International Center

Strengthening the humanity and dignity of people in crisis through knowledge and practice

The Humanitarian Costs Of Climate Change

Mackinnon Webster, Justin Ginnetti, Peter Walker, Daniel Coppard, Randolph Kent

Development Initiatives

HFP Humanitarian Futures Programme

Tufts University | Gerald J. and Dorothy R. Friedman School of Nutrition Science and Policy

Feinstein International Center
Tufts University
200 Boston Ave., Suite 4800
Medford, MA 02155
USA
tel: +1 617.627.3423
fax: +1 617.627.3428
fic.tufts.edu

Cover photo: [Somalia] Women wash clothes in the flood-waters at an internally displaced persons camp in Arare, 12 km from Jamame, southern Somalia, 15 December 2006. Thousands of Somalis have been displaced by what is described as the worst floods in the country in 10 years. ©Manoocher Deghati/IRIN

Contents

ABSTRACT

Using existing international databases that track disaster occurrence and humanitarian costs, this research attempts to improve understanding of how climate change may affect international humanitarian spending. Employing four distinct methodological approaches, a range of potential impact scenarios is developed. The findings indicate that climate change will have a significant impact on humanitarian costs and the increase could range from a 32% increase, taking into account only changes in frequency of disasters, to upwards of a 1600% increase when other criteria, such as intensity, are also taken into account. Further, the report highlights that extreme weather events do not occur in isolation and the increasing interconnectedness of world economic and political systems has made disasters more complex and destructive. The report makes a number of recommendations, including the need for more rigorous and systematic collection of disaster-related data and more constructive interaction between the humanitarian and climate change communities on future research, planning, and action.

Why This Topic Is Important

Natural disasters[ii] affected on average more than 250,000,000 people per year in the past decade.[iii] A closer look at these data indicates that the global number of people affected has been increasing steadily, by an estimated 50,000 to 60,000 people per decade, since the early 1970s. The number of reported disasters has also increased year on year, from an average annual total of 90 in the 1970s, to a figure close to 450 per year in this present decade. At the same time, the number of people killed by natural disasters has, on average, decreased, dropping from a decade annual average of approximately 99,000 in the 1970s to a low of 66,000 per year this decade.

Natural disasters matter. They directly destroy lives, as reflected in the disaster fatality rates, and they devastate and wreak havoc on livelihoods, with long term consequences, as suggested by the disaster-affected numbers.

Other than earthquake and tsunami events, all natural disasters are triggered by weather-related phenomena: drought, floods, cyclones and high winds, and extreme heat and extreme cold events. Extreme events do not cause disasters. In fact, while we use the term natural disasters throughout the report, this term is misleading. Natural disasters are triggered by extreme natural phenomena and become disasters because of the vulnerability of the people and places where they occur—what currently constitutes a disaster, with appropriate preparedness and risk reduction efforts, need not be a disaster in the future. An extreme weather event needs vulnerable people to act upon, people whose livelihood systems are insufficiently robust to withstand the extra shock. Thus, residents in London survived the severe flooding of 2000-1 because of the Thames barrier and the payout from flood insurance and other livelihood adaptations,[iv] but the subsistence farmers on the Mekong delta were less lucky, seeing most of their assets washed away, and with them, years' worth of building flood-resistant livelihoods.

People's vulnerability to extreme natural events is a product of economics, politics, and location—we will comment more on this later. But it is the climate, and its daily projection as weather, that provides the hazards that act upon that vulnerability.

This research and resulting paper were commissioned by the Policy Development and Studies Branch of the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA), supported by the Red Cross/Red Crescent Climate Centre and the International Strategy for Disaster Reduction (ISDR) Secretariat, as an explicit input into the December 2008 round of UNFCCC meetings, in Poznan, Poland, in order to raise awareness of the disaster

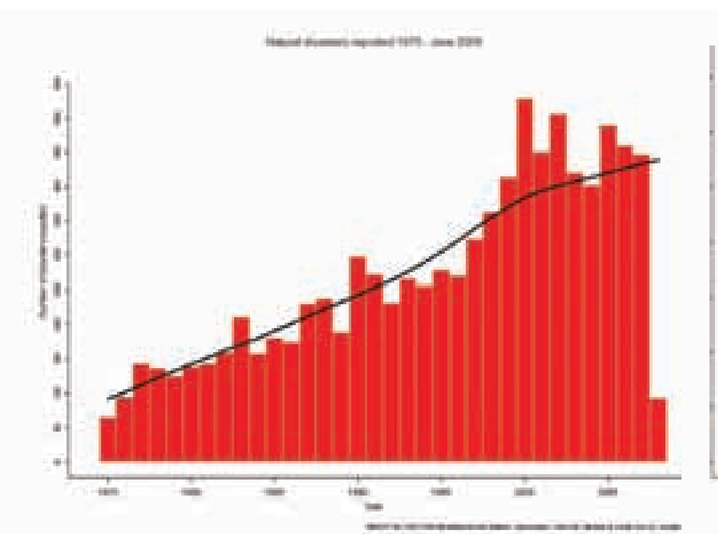


Figure 1. The recent rise in number of disasters

(Source: CRED EM-DAT)

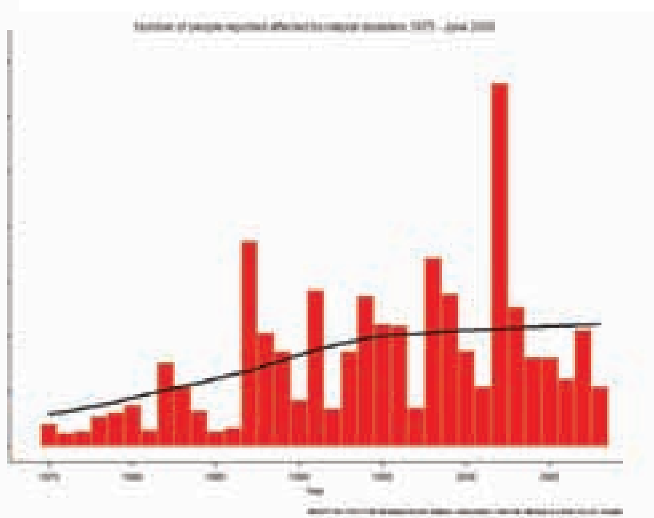


Figure 2. The number of people affected by recent disasters

consequences of climate change.

The research focuses on two issues: estimating the consequences of climate change for the cost of necessary humanitarian operations, and exploring the more complex humanitarian consequences of climate-related changes in disaster patterns.

To date, very little quantitative work has been done explicitly seeking relationships between spending on humanitarian relief and disaster type, location, and year of occurrence. General research has been presented in the past, most notably in the annual World Disasters Reports,[v] but more work is needed to identify trends and generate reasonable projections of future costs, particularly in light of the potential effects of climate change. We hope this paper will go some way, as an early step, to rectifying this and to providing factual evidence upon which to make future projections and decisions.

Additionally, most authors have focused solely on the direct disaster consequences of extreme weather events. We want to go beyond that, believing that, in an increasingly complex world, the propensity for extreme weather events to interact with political and economic processes to cause much larger and more complex emergencies than expected needs to be spelled out. Drought in the 1970s in Ethiopia led to famine, which also contributed to the overthrow of centuries of imperial rule.[vi] Flooding from Hurricane Katrina in New Orleans devastated people's assets and livelihoods in a matter of days, but it has also led to a profound change in the demographics of the city.[vii]

This paper represents a starting point in a research process. We hope people will use this work to raise awareness within the UNFCCC of the importance of acknowledging the potential humanitarian cost of climate change and of the value of investing in disaster preparedness. We also hope that the scarcity of data on this subject will stimulate others to propose further research, and yet others to fund such research. Advances in research and information on this topic will enable planning for the future to be based upon evidence, not simply ideology or speculation.

Background: What Does History Tell Us?

History, old and recent, tells us that climate change and vulnerability will combine to cause not only simple, immediate disasters but more long-reaching, complex ones.

Brooks[viii] has shown how climate change in the mid-Holocene period in the Sahara led pastoralists and hunter-gatherers to fall back to environmental "refuges" which in turn became some of the world's first urban settlements. In a 2007 publication, Zhang and co-authors analyzed paleo-climate data for northern Europe and China. Their research found significant correlations between cycles of temperature change, war, food production, and population totals. In their words, "the findings suggest that worldwide and synchronistic war–peace, population, and price cycles in recent centuries have been driven mainly by long-term climate change."[ix] Using more recent data, from 1950 to 2000, Nel and Righarts showed that "natural disasters significantly increase the risk of violent civil conflict both in the short and medium term, specifically in low- and middle-income countries that have intermediate to high levels of inequality, mixed political regimes, and sluggish economic growth."[x]

Since then, further research has also supported assertions that the economic and political stress caused by increasing and repeated natural disasters leads to increased civil unrest, resultant conflict, and often reactive violent oppression.[xi] A community that is already under economic and political stress may tip from survival to collapse under the impact of extreme weather events and the increasing vulnerability of its population. Understanding the potential effects of climate change on disasters in the future will provide one lens through which to better understand these complex linkages.

Background: Our Present State Of Knowledge

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) asserts that, regardless of the different emissions scenarios, the planet is committed to 0.2 degrees (C) per decade of warming for the first part of this century due to pre-existing emissions of greenhouse gases.[xii] The report examines the historical coupling of climate change and weather-related hazards and includes regional projections that hint at the change in frequency and intensity of these hazards, or "extreme events," which in turn trigger humanitarian crises and disasters. The IPCC report does not, however, contain *disaster* predictions.

In 2006, *Disasters Journal* produced a special-issue edition focusing on climate change and disasters. In their editorial introduction to the edition, Helmer and Hilhorst highlight four critical findings from the nine papers that make up the volume.[xiii] First, it is not the slow change of climate that we should be worried about, but the possibility of increased frequency and scale of severe weather events. It is these extreme events which trigger disasters. Second, policymakers, at least in the short term, will not stop climate change, so they need to focus on disaster vulnerability. Third, it is therefore critical to understand vulnerability to disasters. Vulnerability is a human process, albeit a complex one, thus it is within our power to alter it. Environmental change, conflict, poor health, poverty, and political exclusion are all part of the complexity that makes up vulnerability. The effects of extreme weather events will be filtered through these lenses. Finally, and sadly, most of our international, and many of our national, institutional arrangements for addressing climate change, disasters, and development act in glorious isolation from each other, politically, financially, and administratively. These recent papers and others, such as Andrew Dlugolecki's 2007 report to the UNFCCC,[xiv] leave us with four critical questions to answer.

First, for defined time periods and geographical locations, what will climate change do to the frequency and scale of extreme weather events? We have data, for a few locations and a few time periods, but nothing close to enough. In this present study, we are therefore looking at aggregated periods. In part of our analysis, we look sixteen years into the past—the only continuous period for which a robust global disaster response data set exists—and twenty-two years into the future, long enough to average out some of the noise of natural variation but short enough to be relevant to policymakers.

Second, how is vulnerability to disasters likely to change over the coming decades? Vulnerability is context-specific. All we are learning about how communities react to and adapt to stress tells us that local history, economy, politics, and social change combine with national and international drivers to make up vulnerability.[xv] At this point, any attempt to project trends in vulnerability on a national basis, let alone a regional one, is pure speculation. So, for the quantitative parts of this study, we assume that vulnerability remains constant.

Third, how will increasing hydro-meteorological hazards and vulnerability combine to give us future disasters? Whilst we cannot answer this in detail, we do know that the combination will not be a simple one. It will bring about unexpected results. It will combine with other existing stresses (political, economic, or military, for example). It will lead to cascades of secondary effects. This is the inherent nature of a complex system. We will explore this set of possible consequences in the section on Complexity and Climate Change.

Fourth, so what? Faced with the evidence, the speculation and the risks, how can and should institutions concerned with humanitarian response react? This question we will address in the concluding section of this paper.

Data And Methodology

Data Sources

Our historical data were drawn from three main sources that, on various levels, track disasters and the international communities' response to them.

The first data source is UN OCHA's Financial Tracking Service (FTS).[xvi] This is a real-time database that compiles reports of international aid in response to emergencies, including data from the UN, NGO, Red Cross/Red Crescent Movement, bilateral aid, in-kind aid, and private donations. Since 2000, FTS has tracked humanitarian appeals—typically flash appeals and consolidated appeals, in the UN parlance—and their corresponding donations. Some appeals include figures on the number of people affected and the number of intended beneficiaries, but this information is not included in a systematic manner. With data going back to 1992, FTS also provides a report of general donations in response to natural disasters, even when an appeal was not issued. Appeals have not been issued for all emergencies. In addition, the difference between the appeal issued and the amount funded highlights some of the difficulty in determining the actual humanitarian cost of disasters where appeal data are not available. The challenge of data consistency in calculating the true cost of humanitarian crises is addressed below.

The International Federation of Red Cross and Red Crescent Societies (IFRC) maintains a Disaster Management Information System[xvii] (DMIS) that tracks its humanitarian appeals and expenditures. The DMIS was the second source of data for this paper. IFRC has compiled data since 1919. It includes information on disasters until mid-2005. Appeals from 2005-2008 are available on the IFRC website, but data on the international response to these later appeals are not consistently available. One advantage of the IFRC data is the systematic inclusion of the intended number of beneficiaries for any given appeal. With this information, we were able to go beyond looking at the cost per type and location of emergency and explore the average cost of a disaster per beneficiary.

A third source of data was the International Emergency Disasters Database[xviii] (EM-DAT), compiled by CRED at the University of Louvain. The database contains data since 1900 on the occurrence of disasters. In addition to listing over 16,000 disasters, EM-DAT includes figures on the number of people affected by an emergency. Data from EM-DAT provide an overview of all reported disasters, not just those for which there was a UN or IFRC appeal. It therefore provides a more complete picture, but still one that is a subset of the total number of disasters. If the disaster is not reported in the international community, from at least two sources, it is not included in EM-DAT. The dataset does, however, allow us to make a tentative comparison of disasters appealed for as a percent of total disasters reported. EM-DAT does not include any data on financial response to disasters.

Methodology

Understanding climate change's impact on humanitarian costs is a relatively new research area. Our research used four exploratory models to project future humanitarian costs as related to climate change:

1) Projecting frequency of future disasters

In model one, we developed a three-part methodology that aimed to understand current disaster occurrence and costs, estimate future hazards and extreme weather events, and overlay this information to hypothesize about possible future occurrence and cost of events. We focused our analysis on four regions: Central America, East Africa, South Asia, and Southeast Asia.[xix] The regions were chosen on the basis of the high frequency of natural disasters and the diversity of potential climate change effects. Using these data sources, we built a database of disaster events since 1992 in the four specific regions, with corresponding information about these events, including country, date, type of disaster, and, when available, UN appeal amount, IFRC appeal amount, amount contributed, number of people affected, and number of intended beneficiaries.[xx] These data provided the foundation of our analysis of costs of disasters in the past and currently.[xxi]

In the absence of hard forecasts from the IPCC, we constructed three extreme-event occurrence projections (low, medium, and high) based upon the expected 0.2 degree-per-decade warming during the period of analysis. We liaised with six leading climate scientists to develop three potential scenarios for the impact of climate change in each of the selected regions. The scenarios estimated a low, medium, and high impact (as a percentage change) on frequency of disasters through the year 2030. To derive disaster cost estimates for the period 2009-2030, we made a linear extrapolation from our research on current cost and frequency within each region. Specifically, we calculated the average annual frequency for each type of disaster in each of the four regions. Next, we multiplied this new figure by the percent change for each scenario to receive low, medium, and high frequency values for 2030. To estimate the amount of contributions in 2030 for each type of disaster, we multiplied the region-specific average cost of the disasters by their projected 2030 frequency value. Finally, we added the total contributions for all of the disaster types across all four regions for each of the three scenarios in order to arrive at low, medium, and high estimates for total contributions in 2030.

2) Projecting intensity of future cyclones and floods

In model two, once we determined low, medium, and high disaster frequency scenarios, we attempted to account for changes in the intensity of extreme events. As was the case when predicting frequency, we faced both gaps and a great deal of uncertainty in the literature on climate change and extreme event intensity. That said, the state of research on intensity of cyclone impact was such that we could include a scenario that accommodated the expected increase in cyclone intensity on humanitarian contributions. By drawing upon research that correlates extreme precipitation events with warmer temperatures, we then modified our flood-spending prediction accordingly. We found that there is not enough evidence to project intensity of future droughts or other events; therefore this model only includes cyclones and floods.

3) Projecting total international spending on disasters

Our third model aimed to move beyond specific regions and better understand total international spending on disasters. For this model, we used the IFRC-DMIS database, as it has the most consistent global spending data of all the data bases available. We explored the relationship between total spending on humanitarian response and total spending on hydro-meteorological disasters—those we expect to be directly impacted by climate change. As Figure 12 shows, the trend over the past generation is actually towards *less* spending on climate-related disasters, both as a percentage of total spending and in absolute terms! Interpreting this trend, though, is problematic. The categorization of disaster appeals from the IFRC has not remained constant. From 1990 onward, we see a new category of appeal, "socio-economic," appearing in the data set along with "mixed regional programs." Also, since around 2000, we see annual appeals, rather than specific disaster-related appeals, appearing in the database. We have no way of telling from these data if contributions to a socio-economic appeal are to help long-term victims of flooding, civil war, or population displacement. Therefore, we do not believe this analysis, in the end, turns out to be as useful as the other three models.

4) Projecting future disaster occurrence and affected populations

Finally, using the EM-DAT database, our fourth model aimed to project occurrence and the number of people affected by disasters. Starting with the total number of climate-related disasters recorded and people affected per year, we did a regression analysis based on occurrences between 1975 and 2008. Climate-related disasters were defined as those recorded in the EM-DAT database as drought, extreme temperature, flood, storm, or wildfire. We then projected these trend lines to 2030 using both a linear best-fit projection and an exponential best-fit projection. Figures 13 and 14 illustrate these findings. Statistically, for this data, these two methods provided very similar degrees of explanation of the data spread and so could be regarded as equally probable projections. In this model, we cannot separate out the possible causes of the trends observed. They may reflect increases in climate-related hazards, or increases in vulnerability to these hazards, or even simply better reporting of disasters. Our assumption is that most of the observed change in the past generation is due to actual changes in the frequency and severity of disasters.

Ifs, Buts, And Caveats

In carrying out this research, a critical finding is that, for a profession that deals every day in life-and-death decisions and the allocation of scarce resources, there is a stunning paucity of rigorous data upon which to judge the efficiency, effectiveness, and impact of humanitarian response. To generate truly significant results, one would need historical data that accurately traced the frequency and severity/intensity of hydro-meteorological disasters, their correlation with extreme events, and the cost per beneficiary for each disaster type and region. In addition, one would need climate data on extreme events predicted through 2030; currently, the majority of the IPCC projections compare climate trends from 1980-1999 to 2080-2099, making it difficult to estimate the frequency of these events during the shorter time frame of only the next few decades.

We have no reliable record of the true frequency and severity of disaster occurrence. Some countries (but not all) keep their own databases of disasters, but do not use a common methodology or terminology.

The EM-DAT database is the only comprehensive database, but it has severe limitations. First, it is held and compiled by a private non-governmental organization and relies upon voluntary funding, thus its continued existence is fragile. Second, no state sources are obliged to report to it. It gathers disaster information from media reports, the reports of aid agencies, and other publicly available sources. Small disasters and localized not-reported disasters fail to appear. Third, the figures in the database for the numbers of people affected by a disaster are based upon numbers publicly reported, but there is no standard or rigorous methodology behind what is reported. EM-DAT passes on the "affected population" information reliably, but we can say nothing confidently about what these figures mean. We cannot compare, for instance, what 100,000 people affected in Vietnam means when compared with 100,000 people affected in Jamaica, the United States, or Sudan.

Lastly, in this paper we have assumed business-as-usual adaptation supported by current levels of funding under the UNFCCC and Kyoto Protocol regime. The UNFCCC has estimated that USD 28-67 billion will be needed annually by 2030 and the World Bank estimates that USD 10-40 billion per year is needed for adaptation; current spending, however, is only USD 0.515 billion per year and the funds accrued by the Kyoto Protocol's Adaptation Fund are expected to fall far short of these estimates.[xxii] Currently, many of the activities that are recognized as "climate change adaptation" are also measures that reduce disaster risk. Thus, if agreement is reached in Copenhagen on a robust adaptation mechanism, we will have overestimated the number and severity of disasters.

Humanitarian Cost

It is difficult to define what criteria should be used to determine the actual cost of a disaster. Theoretically, one could measure: the total reported insured losses; the total financial value of all assets lost which can be directly attributed to the disaster; the total value of all assets lost plus lost income and productivity during the disaster; or, all the above plus future losses yet to be realized as a result of income not earned by those who are dead or injured. Alternatively, one could focus on the cost to the humanitarian agencies to provide assistance. This approach is also ambiguous as one can measure, as we did, the financial cost of what international agencies report they spend on each disaster (the most commonly available figures),[xxiii] the value of what they appeal for (but often don't get) to respond to disasters, or the value of the international response, plus the national response (which is only occasionally published), plus the value of the spontaneous local, including private sector, response (which is hardly ever calculated, but significant in aggregate).

For the purposes of this report, we have gone with data available, namely, the international reported cost to humanitarian agencies of responding to disasters, but we hope the point is well made that we can say nothing definitive about how this relates to any calculation of the true cost of all disasters to those who survive them and have to rebuild their livelihoods.

Caveats On Predictions

In concert with the IPCC's Fourth Assessment Report, we have assumed 0.2 degrees (C) of warming per decade through 2030 for methods one and two. The global circulation climate models cited by the IPCC predict that surface air temperatures will rise by 0.64 to 0.69 degrees (C) between 2011-2030 compared to the period of

1980-1990.[xxiv] The amount of warming, predicted to vary from region to region and within regions, is incorporated into our estimates of extreme event frequency. We attempted to avoid a dampening of intraregional variability by projecting changes in disaster frequency *within* regions. However, some dampening still exists. In East Africa, for example, drought risk may be decreasing in some parts of the region while increasing in others.

With regard to warming, we have also assumed a continuation of existing trends with no "abrupt changes" such as those that could result from the crossing of a climate threshold. One such climate surprise was the sudden collapse of the Wilkins ice sheet in Antarctica last year.[xxv] And, though unlikely, the predicted amount of warming might also underestimate the amount of methane released into the atmosphere due to the thawing of permafrost or increased warming due to loss of albedo from the faster-than-expected melting of ice in the Arctic.

The traditional definition of climate involves a thirty-year average (for temperature, precipitation, etc.) in a given locale; climate *change* is typically measured by comparing two or more thirty-year averages. Thus, the period considered for parts of this paper, from 1992-2030, raises another limitation. For such a brief period of time, it is difficult to distinguish extreme hydro-meteorological events associated with climate change from those caused by natural climate variability or other processes such as the El Niño-Southern Oscillation (ENSO) and Pacific Decadal Oscillation.

We have examined a scenario of climate change impacts on top of natural variability, rather than produced a prediction of actual hazards at a particular point in time. By basing our analysis on extreme events, we have focused on the tail end of the distribution, where there is a great deal of uncertainty.

There is a significant possibility that we have underestimated the number and magnitude of future disasters, for two reasons. The first, as Dlugolecki noted, is that "[global climate model] projections of extreme events are sparse; they are averaged across large regions often, which conceals significant sub-regional effects; they find it difficult to discriminate a climate signal from underlying natural variability, which is high; they are not designed to explore the effects of extremes, yet damage varies strongly in a nonlinear way as the intensity of a climate variable rises."[xxvi] Our estimation of cyclone disasters was complicated by the fact that recent research on tropical storm frequency suggests a decrease in the overall number of storms but an increase in the number of intense tropical cyclones.[xxvii] Dlugolecki observes that the IPCC's own "projections concerning extreme events in the tropics remain uncertain. The difficulty in projecting the distribution of tropical cyclones adds to this uncertainty," and "research on changes in extremes specific to Africa, in either models or observations, is limited."[xxviii] If we had adopted the "high" scenario from Dlugolecki's report, a 70.7% increase from 2003-2030, our estimates would increase by nearly 50%.

The second reason that our initial estimates in method one are likely too conservative derives from the fact that we assumed a linear relationship between extreme events and disasters. For example, if we double the number of extreme events, we will double the number of disasters. This is a reasonable first approximation, but that is all it is. Many scientists believe that, in the case of cyclones, for example, this relationship between intensity and impact is at least cubed. Consider the commonly used equation to express relationship between cyclone intensity and damages: D = xWy, where D is damage, W wind speed, and x and y are constants. Studies of hurricane damage from 1900-2005 found a value of y to be 3.9.[xxix] Other scientists believe that the value of y is greater still. What's more, climate scientists predict that intensity of cyclones may increase by as much as 18 percent by 2050.

On the other hand, some of our conservative underestimates will be offset due to "double counting," because disaster frequency during our baseline period of 1992-2008 was also affected by climate change. In short, we have estimated a percent increase in frequency *on top of* pre-existing climate change.

Lastly, because this paper includes only disasters for which there was international reporting and response, we have filtered out of our baseline period the smaller disasters that were responded to domestically. There is evidence that these smaller disasters are increasing in frequency even more quickly than the larger disasters. Cumulatively, the increase in frequency of disasters, large or small, is likely to wear down coping mechanisms and decrease the coping capacity of those affected by disasters over time.

Caveats On Cost

We have assumed that the cost of responding to disasters increases linearly with their number—a reasonable starting assumption. There are two things to consider here.

First, disasters are the combined effect of hazard and vulnerability. Our analysis is unable to say anything about changing vulnerability. Second, will states continue to respond to humanitarian crises as they do today, with the same ad-hoc, post-disaster voluntary-funded system? For a national and international agency like the IFRC, will the relationship between the numbers of people needing assistance and the number it provides for remain constant? In the absence of any evidence for a change in the political and policy environment which determines funding, we have assumed a status quo projection.

At present, bush fires, heat waves, cold snaps, and ice storms do not figure heavily in the response data bases. Approximately six humanitarian appeals have been issued for these types of events in the time period on which we focused. There are not enough data to provide us with meaningful average or median cost figures, but international contributions for four extreme fire events in Southeast Asia totaled more than USD 30,650,000. In the future, heat waves in Europe and wildfires in Southeast Asia and the United States may become sufficiently frequent and severe to appreciably affect the volume of humanitarian response and hence cost,[xxx] but, without a baseline from which to project, we cannot, using this paper's methodology, make any meaningful projections of their potential future costs.

Where possible, we have excluded from our analysis the 2004 Indian Ocean tsunami and its response. This disaster, in its size, nature, and scope of response, is so far off the scale that its inclusion in the database distorts all calculations of what is "normal" or to be "expected," but such infrequent and extreme events are a reality. Whilst tsunamis are unlikely to be triggered by climate change, other extreme events, for example, massive flooding in Bangladesh caused by a combination of sea-level rise and increased storm intensity and frequency, are a possibility as are more Hurricane Katrina-like events, but we have no basis on which to say anything conclusive about these unknown unknowns.

One of the most infuriating phrases economists use in their projections is "all other things being equal" because we know, with the bright eyes of hindsight, that all other things are not equal. We use this excuse-phrase when our models and the data they are based upon are simply too rudimentary to make meaningful *predictions* which we are confident will coincide with reality. So, instead, we make *projections*. Often, we simply do not have the data or the models to do anything more meaningful than make simple linear projections. These projections are still useful for they help us think about what changes we might have to make to the way we predict, mitigate, and respond to disasters. They show us what will happen if we go on with business as usual, but do not make the mistake of assuming they show us what the future will be. They do not!

Disaster Events And Humanitarian Spending Today

Since 1992, nearly USD 2.7 trillion has been spent on international response to cyclones, floods, and droughts in the regions on which we have focused our research. Using the data that we were able to compile, we aimed to deconstruct this total in order to better understand the costs of humanitarian assistance. Through understanding what is currently spent on natural disaster response, we will better be able to speculate potential humanitarian costs due to a change in the occurrence and/or intensity of future natural disasters.

We found that the amount of resources committed to humanitarian response varies greatly from region to region, and between the types of emergencies. For example, between 1992 and 2008, the average total contributions to respond to a cyclone in Central America were USD 61,991,759, compared with USD 11,677,390 in Southeast Asia and USD 18,383,288 in South Asia. In East Africa, the average total contributions per drought were USD 28,446,859, compared with USD 5,580,599 in Central America. This supports earlier research from CRED that found that the "allocation of humanitarian aid does not seem to be clearly linked to the magnitude of human needs . . . donors seem to show preferences for certain types of disasters over others."[xxxi] Further, the researchers found that spectacular, acute events, which often receive the most media attention, also receive the most international emergency funding. It is important to note that differences in funding might also be impacted by asset values per region, urban/rural impacted areas, the level of development, etc. As the figures below representing data from FTS demonstrate, there is significant variation in contributions when we organized data around types of emergencies and regions.

FIGURE SET: Average $ contributions per type of emergency in four regions

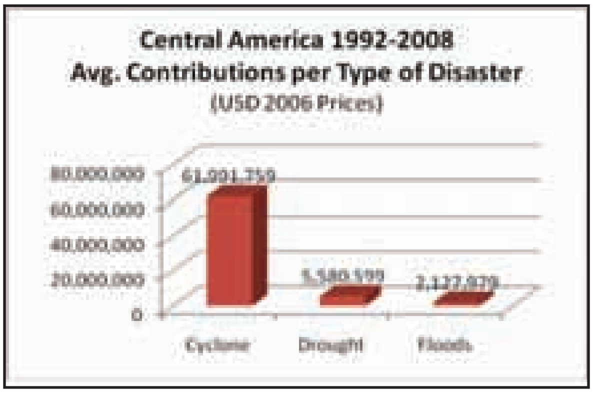


Figure 3. Central America humanitarian costs

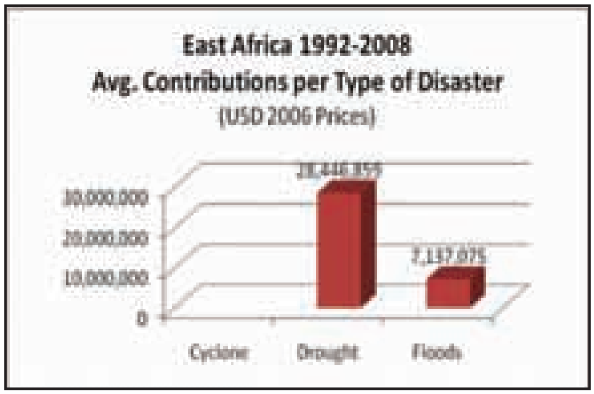


Figure 4. East Africa humanitarian costs

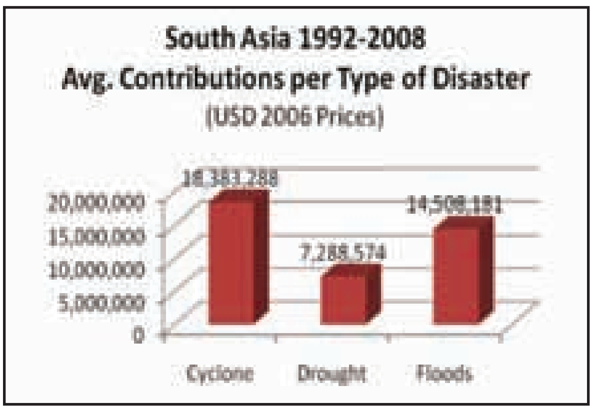


Figure 5. South Asia humanitarian costs

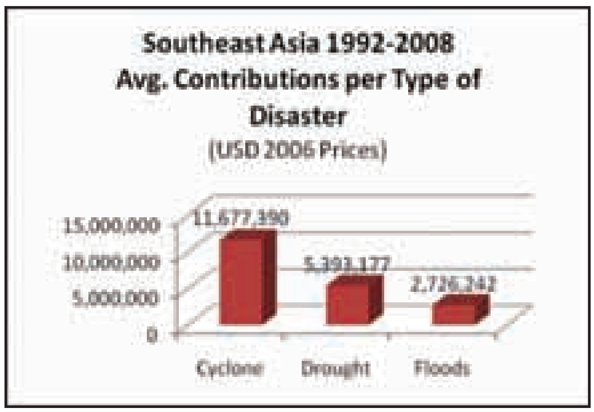


Figure 6. Southeast Asia humanitarian costs

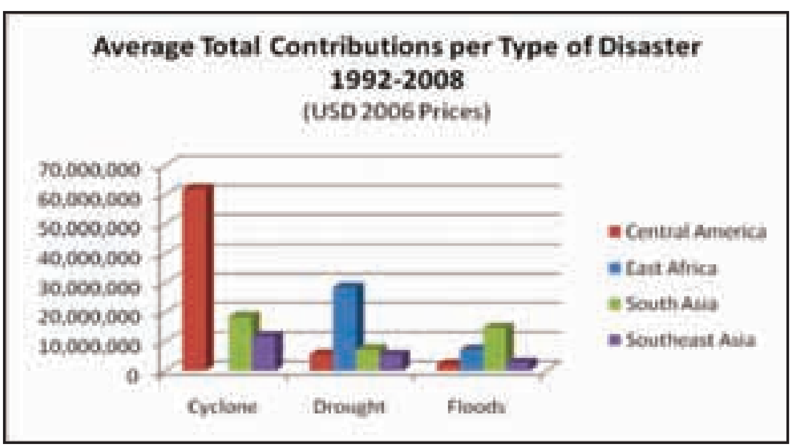


Figure 7. The global picture on present humanitarian costs

Critically, the average contribution turns out, in most cases, to be significantly different than the median. We can see that, in a few cases since 1992, a small number of catastrophic events tend to skew the averages higher. If we look at Central America, for example, the average total contributions for a cyclone is USD 61,991,759, but the median is actually drastically lower at USD 1,538,437. Further, if we remove the response to Hurricane Mitch in 1998, the average total contributions is much lower, at USD 5,001,619. We see this same effect with cyclones in South Asia, where the average total contributions is USD 18,383,288, but, if we remove the response in 2007 to Cyclone Sidr in Bangladesh, the average total drops to USD 4,679,202. That said, even in a relatively brief period of time, 1992-2008, a pattern of catastrophic, highly destructive events does occur. Therefore, we cannot disregard these costs and should be prepared for these events to continue in the future.

As discussed above, we must assume that actual costs are significantly higher than the amount that is donated by the international community. By design, UN appeals and IFRC appeals cover different aspects of humanitarian response, so in cases where both appeals were issued, one would be able to add the two appeals without duplicating appeal objectives. Within our data set, United Nations appeals, which aim to serve as a comprehensive and consolidated compilation of post-disaster needs, are only 51.7% funded on average, with the average appeal requesting USD 44,799,538. If one were to gauge cost by the amount requested in the appeals, then the average numbers would be that much greater.

Estimating Average Cost Per Beneficiary

A useful calculation to understand the cost of a disaster could be based on the amount contributed per intended beneficiary. The only database that systematically includes beneficiary estimates is IFRC's DMIS.

The IFRC data shown in the chart below demonstrate the average costs per beneficiary and provides a useful illustration of the limitations of humanitarian response. Humanitarian response strives to be needs-based and impartial. However, we see from the data that the cost/beneficiary in providing relief to flood victims is USD 11.99 in South Asia, but USD 61.25 in Southeast Asia. Why is that? One plausible explanation is that the agency was consistently able to raise more funds/beneficiary for victims in Southeast Asia than in South Asia, thus the response was not impartial.[xxxii] Will this skewing continue over the next twenty years, or will the international system develop a funding regime that supports the internationally recognized and espoused principles of impartiality and proportionality in humanitarian response? The answer to this will certainly affect future costs of humanitarian response.

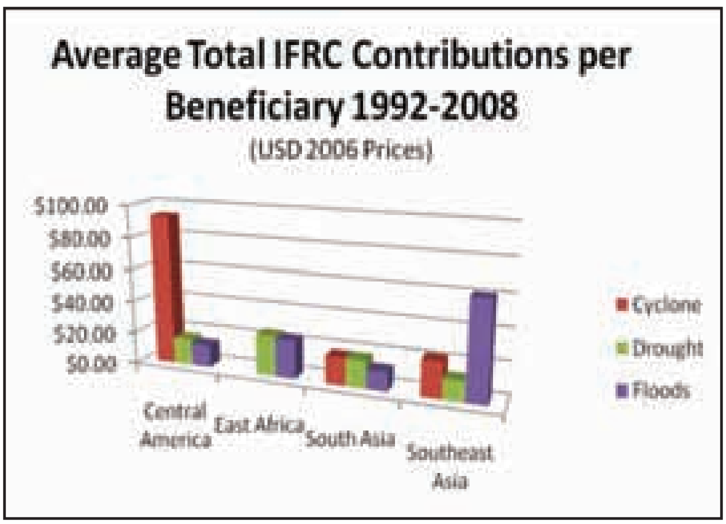


Figure 8. Average total IFRC contributions per beneficiary

Region	Type	Average
Central America	Cyclone	$93.19
Central America	Drought	$16.40
Central America	Floods	$13.86
East Africa	Cyclone	—
East Africa	Drought	$25.23
East Africa	Floods	$23.87
South Asia	Cyclone	$17.41
South Asia	Drought	$17.37
South Asia	Floods	$11.99
Southeast Asia	Cyclone	$22.26

Table 1. Data for Figure 8

One can easily see that estimating disaster cost can be quite difficult. Our data and analysis provide a window in to understanding how these costs vary from region to region and among different types of disasters. Numerous research projects could be, and have been,[xxxiii] carried out to understand the causes or plausible reasons for these discrepancies, but it is not within the scope of our project to speculate on this issue. We do, however, take these discrepancies into account as we project and hypothesize potential future costs. The next section, based on this cost analysis and estimates from climate change experts, will aim to do just that.

The Future Hazardscape

Model One: Projecting Changes In Frequency Of Disasters

What does our quizzing of climatologists tell us about the likely future changes in the occurrence of extreme weather events leading to disasters? We began by looking to the IPCC Fourth Assessment Report to ascertain the impact of a 0.2 degree (C) per decade of warming on disasters. The report includes a few case-by-case projections and these projections typically look ahead to the end of the twenty-first century, rather than focusing on the next two decades. Therefore, we next turned to the source material to determine whether we could improve upon simple linear extrapolations from the projections given in the IPCC Report. We found that the source texts did not offer specific predictions either, but they did provide a basis for making very rough estimates for the potential change in hydro-meteorological disaster frequency over the next two decades. Once we established the rough estimates, we submitted them to six leading climate scientists for comment and refinement. The respondents were willing to offer suggestions, but on the condition that their remarks remained anonymous, due to the great deal of uncertainty in these estimates and also due to the fact that none considered themselves an expert on disaster forecasting.

Table 2 shows what the impact on disaster frequency due to the expected warming could be between 2008 and 2030. To establish a baseline number, we totaled the entire number of each particular disaster type for which there was an international humanitarian response for each region during the period 1992-2008, then we divided by the total number of years, resulting in a total for annual disaster frequency per disaster type for each region. Hydro-meteorological disasters that did not elicit a UN appeal were not counted (due to the gaps in that data). The percent increase, or decrease, is therefore relative to the annual frequency during the baseline period. And, again, the figures below assume no deviation from current adaptation and disaster preparedness measures.

Table 2. Estimated effect of climate change on disaster frequency in 2030

	Southeast Asia	South Asia	East Africa	Central America
FLOODS				
Baseline Frequency (1992-2008)	47	47	26	21
	2.85	2.85	1.58	1.27
LOW IMPACT	0%	0%	0%	-5%
Frequency/Year (2030)	2.85	2.85	1.58	1.21
MEDIUM IMPACT	5%	5%	5%	0%
Frequency/Year (2030)	2.99	2.99	1.65	1.27
HIGH IMPACT	10%	10%	10%	5%
Frequency/Year (2030)	3.13	3.13	1.73	1.34

Table 2. continues on next page

Table 2. *(continued from previous page)*
Estimated effect of climate change on disaster frequency in 2030

	Southeast Asia	South Asia	East Africa	Central America
DROUGHTS				
Baseline Frequency (1992-2008)	3	7	10	4
Baseline Frequency/Year	0.18	0.42	0.61	0.24
LOW IMPACT	0%	0%	0%	0%
Frequency/Year (2030)	0.18	0.42	0.61	0.24
MEDIUM IMPACT	5%	5%	10%	10%
Frequency/Year (2030)	0.19	0.45	0.67	0.27
HIGH IMPACT	10%	10%	20%	20%
Frequency/Year (2030)	0.20	0.47	0.73	0.29
CYCLONES				
Baseline Frequency (1992-2008)	24	14	-	15
Baseline Frequency/Year	1.45	0.85	-	0.91
LOW IMPACT	0%	0%	-	0%
Frequency/Year (2030)	1.45	0.85	-	0.91
MEDIUM IMPACT	10%	10%	-	10%
Frequency/Year (2030)	1.60	0.93	-	1.00
HIGH IMPACT	20%	20%	-	20%
Frequency/Year (2030)	1.75	1.02	-	1.09

Our best-case, low-impact scenario actually projects lower total disaster frequency (and therefore humanitarian response) compared to the baseline period, because climate scientists urged us to consider the possibility of less frequent floods in Central America. At the other extreme, the high-impact scenario predicts an extra USD 26 million (in 2006 USD) in annual humanitarian contributions in 2030.

The figure below depicts the total projected disaster response contributions for the year 2030 for each of our impact scenarios. There is only a USD 28 million difference between our low and high scenarios for these regions. The chief reason for this narrow gap is that our high estimate is, by some standards, still very conservative.

In reality, the future hydro-meteorological hazardscape will likely combine some aspects of

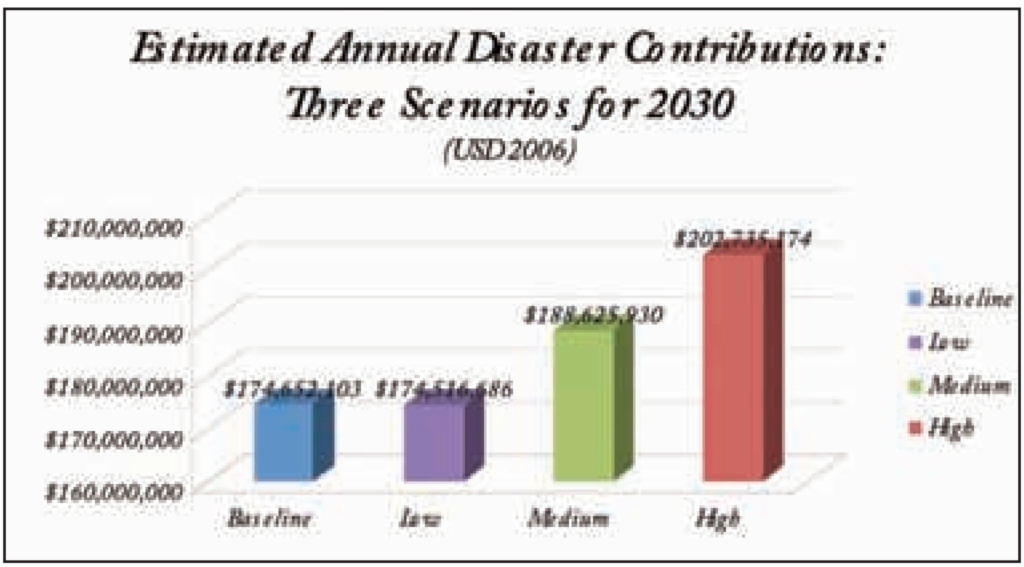


Figure 9. Estimated annual disaster contributions— three scenarios for 2030 for the four target regions

each scenario; for certain hazards, the high scenario may be more accurate, whereas for other hazards, our low or medium estimates may be more prescient. For example, average precipitation is expected to decrease in Central America for all seasons, which suggests a drier climate and increased occurrence of drought. Complicating this assumption, precipitation is likely to be distributed over fewer rainy days (especially during the hurricane season), which then might imply both more drought and also more flooding, even with a mean decrease in regional precipitation.[xxxiv]

Table 2 summarizes the extreme event predictions that we developed with the climate scientists. It includes the baseline disaster data and the projected change in frequency for each hazard, region, and impact scenario. In nearly each case, the low estimate reflects no additional climate impact above the current climate signal. Cyclones may begin to pose a threat to East Africa, but, due to inadequate data, we did not include this hazard for East Africa in this paper.

Model Two: Projecting Intensity Of Future Cyclones And Floods

We projected future financial contributions based on the past average figures, assuming constant cost per disaster type within each region. We did not incorporate existing trends in disaster intensity, which some climate scientists considered to be too conservative. If, on the other hand, we had factored in an increase in intensity and then assumed a cubic relationship between intensity increase and damage, our contribution figures would be much higher. For example, had we assumed a 15% increase in cyclone intensity, a cubic relationship between intensity and impact, and no increase in cyclone frequency, our aggregate annual contributions for cyclone disasters would rise from USD 88,939,380 to USD 135,187,858, a 52% increase.[xxxv] If the increase in intensity were coupled with our medium-impact scenario for cyclone frequency, becoming 10% more frequent, humanitarian contributions for cyclones would rise to USD 148,706,643, a financing increase of 67%. See Figure 10 below:

What is clear from this graph is that the increase in cyclone intensity impacts the expected amount of contributions—the disaster impact—far more than does an increase in frequency. And remember, these estimates are based on a cubed relationship between intensity and impact, a conservative assumption compared with those discussed by Pielke.[xxxvi]

What can be said about the possible increase in intensity of floods? Allan and Soden found “a distinct link between rainfall extremes and temperature, with heavy rain events increasing during warm periods and decreasing during cold periods. Furthermore, the observed amplification of rainfall extremes is found to be larger than predicted by models, implying that projections of future changes in rainfall extremes in response to anthropogenic global warming may be underestimated.”[xxxvii]

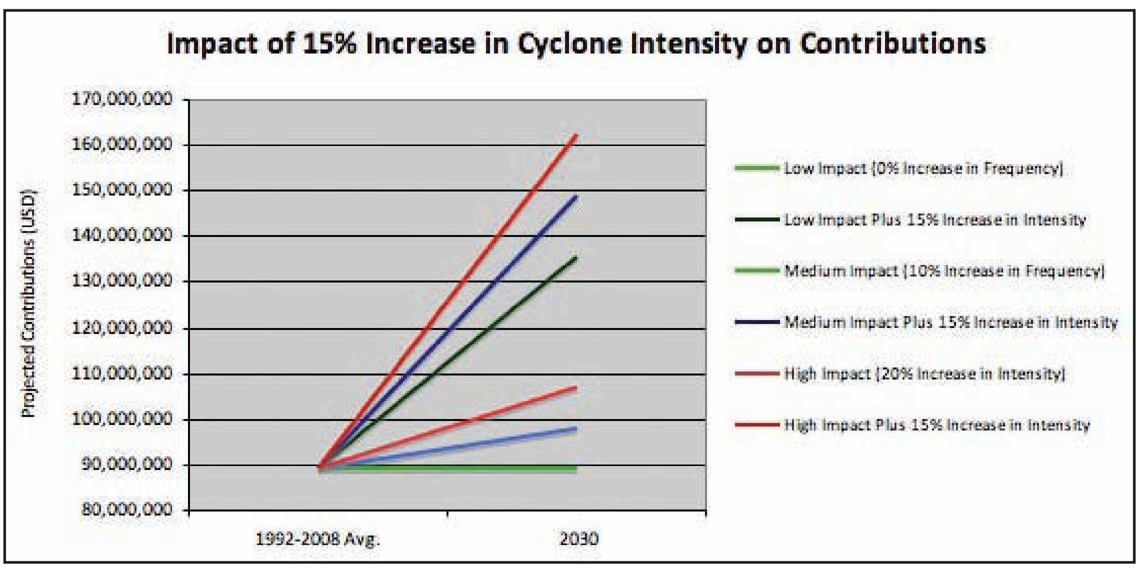


Figure 10. Impact of a 15% increase in cyclone intensity on contributions in the four target regions

The IPCC Report also notes that the potential for climate change to intensify flood patterns may be particularly acute along the coast of East Africa. However, "deriving quantitative estimates of the potential costs of the impacts of climate change (or those associated with climate variability, such as droughts and floods) and costs without adaptation is difficult. Limited availability of data and a variety of uncertainties relating to future changes in climate, social and economic conditions, and the responses that will be made to address those changes, frustrate precise cost and economic loss inventories."[xxxviii] In South and Southeast Asia, more intense rainfall, particularly during the summer monsoon, and increased glacial melting might lead to more severe flooding.

However, we extended our model to incorporate an additional 0.5% increase in flood intensity based upon the expected warming through 2030 (see Figure 11). To do so, we relied on Fowler and Hennessy, and Allan and Soden, who have published on the relationship between atmospheric warming and extreme precipitation events. Saturation vapor pressure increases in a nonlinear fashion as air temperature rises, roughly doubling for every 10 degree (C) increase in the range of -20 to 45 degrees. Fowler and Hennessy's analysis of global climate models suggested a 1.1 to 2.9% increase in global precipitation per degree (C) of warming, but, for this to be truly predictive, it would have to be downscaled to accommodate changes at the regional and subregional level. What's more, the actual impact of additional extreme precipitation events on flood disasters would also need to build upon known flood patterns and on the predicted rise in sea level and its impact on flooding in coastal areas and river deltas, in particular.

In South and Southeast Asia, droughts have been increasing, not only in frequency but also in intensity, due to warmer temperatures. It is estimated that, under the full range of emissions scenarios, 120 million to 1.2 billion people in South and Southeast Asia will experience increased water stress by the 2020s.[xxxix]

Model Three: Projecting International Spending On Disasters

For model three, we looked at the relationship between total spending on humanitarian response and total spending on hydro-meteorological disasters. As Figure 12 shows, the trend over the past generation is actually towards less spending on climate-related disasters, both as a percentage of total spending and in absolute terms! As discussed in the Data and Methodology section, interpreting this trend is problematic. We have no way of knowing if contributions to a "socio-economic appeal" are to help long-term victims of flooding, civil war, or population displacement. We therefore have no way of knowing if the downward trend in donor funding response to weather-related disasters is real or a creation of the

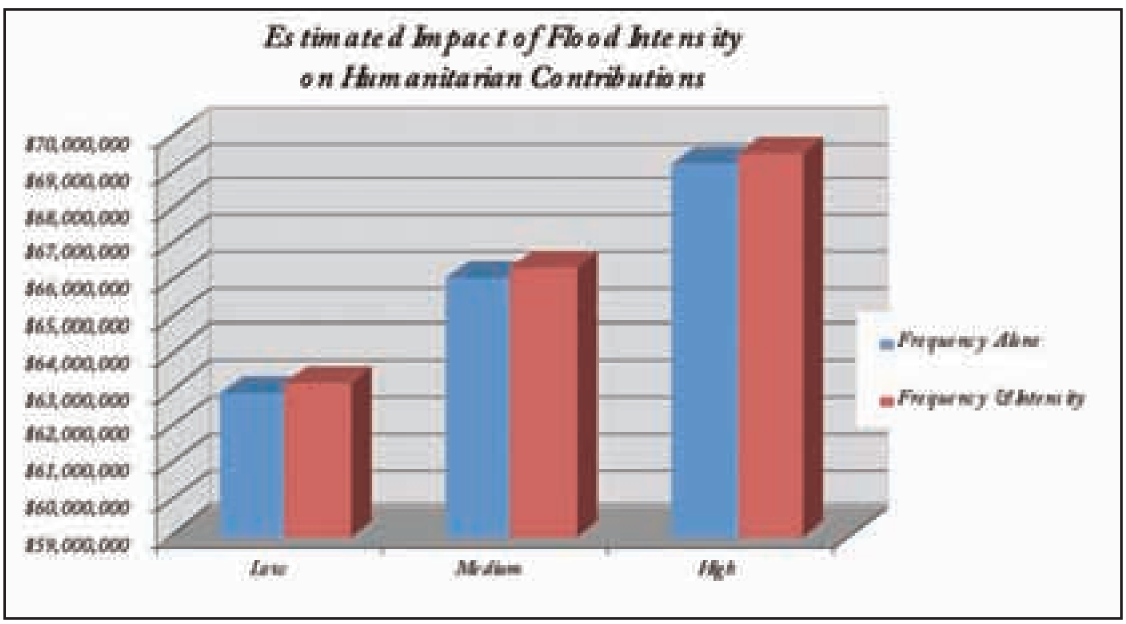


Figure 11. Estimated impact of flood intensity on humanitarian contributions

changed reporting criteria. Once again, this highlights the dearth of credible data from the humanitarian sector upon which meaningful projections may be made.

Model Four: Projecting Trends Of Disaster Occurrence And Affected Populations

Finally, working with the CRED EM-DAT database of total numbers of disasters recorded and people affected, we did a regression analysis from 1975 to 2008 and calculated a best-fit trend line for both a linear and exponential fit. See Figures 13 and 14. The linear method projects a 320% increase in the number of disasters recorded per year over the next twenty years and a 330% increase in the numbers of people being affected, rising to more than 370 million people per year. If this was directly correlated with the costs of disaster response, it would imply at least a tripling in spending. The exponential method projects more than an eight-fold increase in the numbers of disasters and the numbers affected, and hence the spending needed (at 2006 prices). Add in a 4% a year economic inflation factor and this could grow to a near sixteen times increase.

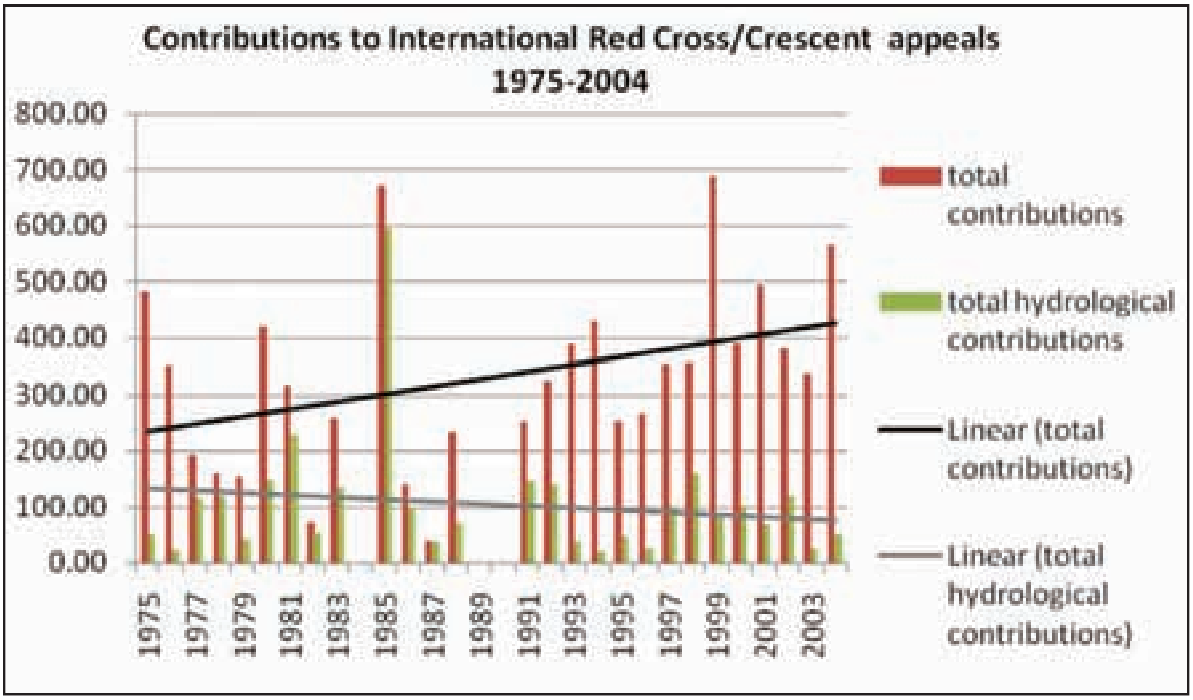
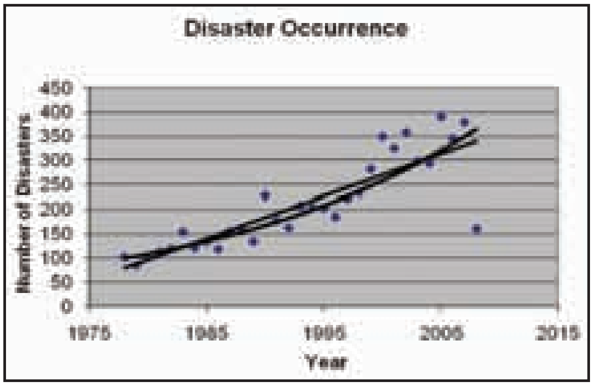
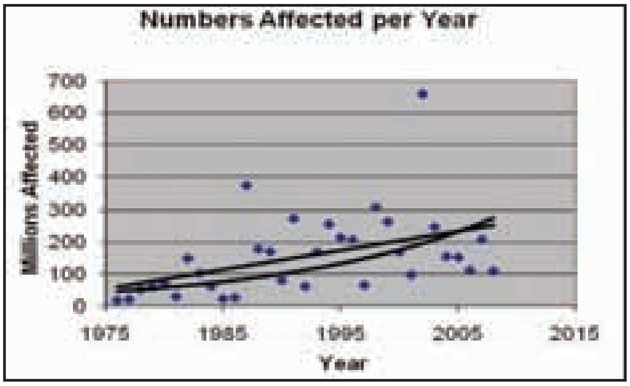


Figure 12. Trends in total and climate-related disaster spending in millions Swiss Francs (CHF) (Source: IFRC-DMIS)





Figures 13 and 14. Linear and exponential trends for global disaster occurrence and numbers of people affected by disaster

Table 3. Comparative projected increases in humanitarian spending

	Model one Disaster frequency prediction -driven	**Model two** Frequency and intensity[xl] prediction-driven	**Model four** Past trend projection-driven
At 2006 USD values	16% increase in response costs	67% increase in response costs	800% increase in response costs
Assuming 4% annual inflation	32% increase in response costs	134% increase in response costs	1,600% increase in response costs

Table 3 above compares the projections in humanitarian response to climate-related disasters, twenty years hence, using methods one, two, and four above, both without and with inflation factored in.

This is difficult data for policymakers to interpret, with a hundred-fold difference in the projections from the most to the least conservative. There are three things we can say about these projections. First, they demonstrate how rudimentary our knowledge still is about the linkages between climate change, extreme events, disasters, and disaster response. Most of the variance in this system still appears as noise to us, thus making it impossible to make accurate predictions. Second, this high degree of uncertainty will be reflected in how the future pans out. We should expect to see unforeseen major increases in demand for humanitarian assistance and thus should attempt to build funding and response systems capable of dealing with this uncertain environment. Third, all the scenarios project increases in needed spending. We can say with some confidence that we will see more climate-related disasters and more need for disaster response.

Consequences For Response And Preparedness

The data and projections presented here suggest that, over the period of the next twenty years, the expected increase in extreme event frequency leading to disasters and hence humanitarian action will vary region to region and type to type, but that, overall, we will likely not see more than about a 20% increase—this less than the variation in humanitarian funding from year to year. However, when we consider the effect increases in intensity will have on disaster impact, we see that we may be looking at a 67% increase in estimated humanitarian spending on cyclones (assuming a 15% increase in cyclone intensity) and an additional 0.5% increase on floods (based upon the increased water storage capacity of warmer air). If, in turn, we factor in increases in vulnerability to disasters, then the figures may go higher still. And if, as we do below, we look at how disasters may combine with economic and political processes to cause complex crises, cost estimates go into the billions.

Even with conservative assumptions, our analysis suggests that far more resources will be required to maintain even the existing levels of preparedness and response. If we know that current levels of contributions are approximately 50-70% of what is actually appealed for, then solely maintaining existing levels would still be considered woefully inadequate.

How prepared is the humanitarian system to handle this increase in need? While a handful of organizations have started to explore how climate change will impact their work in the longer term, few have really begun to tackle the issues of how to be more effective with significantly fewer resources per emergency or per affected person. It is clear that agencies will have to become more prepared, more flexible, and better at what they do.

One trend, however, provides encouragement: in recent decades, the frequency of hydro-meteorological disasters has been on the rise, but the number of fatalities per disaster has been declining during that same period. This may reflect improved early warning systems, particularly for cyclones, which have been monitored by satellite since the 1980s.[xli]

As mentioned, any projection of the humanitarian cost of disasters needs to take into account changes in vulnerability to the life-threatening effects of extreme events. Vulnerability is dependent on a myriad of factors, economic, social, and political. More specifically, we know that communal and state measures taken to mitigate the effects of disasters can drastically reduce loss of live, property, and livelihoods.

The projections in this paper assume no change in state action to reduce the number of hydro-meteorological disasters. We have, however, many examples from the past where such action has been effective. We describe three such programs here as illustrative of what states could do to mitigate the growing threats from climate-related disasters.

Many measures that reduce or manage disaster risk have already been implemented and have mitigated the number of disasters that result from extreme weather events during the last two decades. For example, after Typhoon Sisang made landfall in the Philippines in 1987, destroying more than 200,000 homes, the government initiated a program to provide storm-resistant housing for those living in the most at-risk parts of the country. During its initial phase (1988-1991), at least 27,000 storm-resistant shelters were built and none were destroyed by storms. Since then, the project has been expanded, while the number of cyclones that entered the Philippines' Area of Responsibility rose from roughly sixteen to twenty per year from 1990 to 2003. Precise figures on the number of lives and homes saved due to this project are not available, but it continues to be implemented as of our writing.[xlii]

The Bangladesh Red Crescent Society's Cyclone Preparedness Programme was implemented in the 1960s and is currently active in eleven coastal districts. Volunteers have been trained to help with the dissemination of cyclone warnings, as well as information about evacuation, rescue, first-aid, and emergency relief. Meteorological data is collected from the Bangladesh Meteorological Department (BMD), which issues regular bulletins that are transmitted to the six zonal offices and the thirty sub-district offices over high-frequency radio. These offices, in turn, pass information to villages, whose unit teams spread out and issue cyclone warnings, with each unit serving one or two villages with a population of about 2,000 to 3,000.[xliii]

After Hurricane Mitch, Honduras implemented a multi-sectoral program to reduce vulnerability to storms and landslides. Both municipal and federal government agencies have taken measures to improve disaster awareness, emergency response, early warning systems, hazard mapping, risk analysis, and to develop an action plan in each municipality to identify investments that would further mitigate disasters. Implemented in 2000, with assistance from the World Bank, this project was scaled up in 2007.[xliv] Programs similar to these have been implemented throughout Southeast Asia, following the 2004 tsunami.

These examples lead one to ask, is it not more beneficial or effective to invest in preparedness and mitigation, rather than focusing efforts on response? If activities such as these have the potential to dramatically decrease the number of people affected and/or the number of deaths, perhaps the more effective and cost-effective approach, given that we project an increase in the frequency and intensity of disasters, is to focus efforts on preparedness.

Complexity And Climate Change

The effect of a changing climate will be seen in the changing dynamics and dimensions of humanitarian crises. In order to illustrate the complexity of potential effects of climate change, the following are *possible* future cases in China and Europe. These cases fall into two categories of crisis agent: "cascading impacts" with sequential effects from one crisis agent to another; and "multi-hazard impacts," or interactive disaster agents, affecting vulnerable populations.

Possibility One: Cascading Crises In China—Collapse Of The Three Gorges Dam

In this scenario, China's massive growth through 2010 slows by 2015, harboring excess capacity for stagnant global markets. While growth brings heaving cities, a middle class, and a migratory workforce discontent with inequalities, climate change fatally tests China's new infrastructure and society. Let's imagine one example of a catastrophe in 2015 that could bring cascading effects through China, and to the world, as China seeks USD 1 billion of international assistance,[xlv] whilst coping with USD 275 billion of subsequent costs from efforts to repair political and physical damage.

First, warmer temperatures bring glacial floods from the Tibetan plateau and combine with extreme precipitation further downstream.[xlvi] The

Three Gorges Dam's reservoir exceeds capacity, and the weight of the water triggers irregular seismic activity in one of the six faults that lies within twenty kilometers of the dam.[xlvii, xlviii] Tremors stress the dam wall, causing massive structural failure and resulting in floods that destroy Yichang, Yidu, and Zhicheng (combined populations of over 2.5 million people).[xlix] The deluge then collapses the Gezhouba Dam and breaches the Jingjiang Dyke—a hundred thousand people could drown. In total, over 800,000 people would be at risk, with approximately 280,000 more potentially affected by disease and lack of fresh water. With the Yangtze River Valley thrown into chaos, an estimated 8,600,000 are internally displaced. Taking into account lost production, the economic cost of such a disaster could reach USD 30 billion.[l]

Add to that the possibility that groups of the poor and disaffected, angered at policies that allowed the Dam to be completed, respond with political protests. As China's growth rate slips below 8%, discontent mixes with hunger as local economies suffer.[li] The government mobilizes 200,000 troops to provide aid, but observers also see the mobilization as discouraging protest.

Upheaval leads to a resurgence of a Party eager to maintain control, supported by a population anxious for stability. Areas thought to be harboring dissidents are overrun by troops, and, in the ensuing chaos, over 800 people, mainly university students, are killed and nearly 135,000 severely injured in demonstrations around the country. Nervous foreign investors pull out of Shanghai and Shenzhen, reducing the value of Chinese companies by USD 2 trillion.

Rallies and pro-government actions are organized that result in the equivalent of 150 million people absent for ten working days at a cost to China's economy of USD 25 billion. The government, associating instability with market freedoms, restores regulations limiting private enterprise and ownership, contracting economic growth by two percent, reducing China's output by USD 150 billion,[lii] a high price the government believes is worth paying for stability and control.

As economic regulation tightens, prices rise and corresponding imports, particularly from India, are more affordable, putting China's factories at risk. Cautious of further discontent, China's domestic economic regulations necessitate restrictions on international trade.

This scenario illustrates how one event cascades, multiplying the effects of its consequences for the nation at large and the international community. Over 1 million people would be killed in the collapse of the Dam and subsequent disease and political unrest. Nearly 4 million people are displaced as government forces take to the streets of major cities and towns and underemployed, migratory workers are told to return home to rural areas. Even the short slump in production resulted in billions of dollars of export earnings lost.

Possibility Two: Climate Change In Europe—Simultaneous Hazards

With reference to recent major hydro-meteorological events in Europe, this possibility looks at the effects, in the summer of 2015, of a large flood and heat wave occurring in the same year.[liii] With governments and the public bearing the cost of USD 50 billion in damage,[liv] aid organizations contribute USD 100 million in efforts to help Europe's most vulnerable citizens.[lv] The European Union steps in to assist a failing insurance industry, assuming liability for USD 1 trillion of perceived uninsurable risk.

In the summer of 2015, a multi-hazard crisis sees wide-scale flooding and a record heat wave put compounding pressure on governments and relief agencies.[lvi] The high temperatures stress power stations, as demand increases and production capacity falls.[lvii] Governments may be forced to ration power,[lviii] and reducing the statutory week by one day for a month would cost upwards of USD 100 billion of lost production.[lix] Subsequent heavy rains in Northern Europe solve some problems for power generation, but destroy critical infrastructure, from power to water management. Floods leave 5 million homes without water,[lx] and bottled water must be provided by government services and aid agencies.[lxi] Governments are forced to repair and defend the increasingly critical infrastructure that remains.[lxii]

Where the heat wave twelve years before had caused an estimated USD 15 billion in losses,[lxiii] the wider scale and longer duration of a 2015 heat wave across Europe could cause losses as high as USD 35 billion. Maize yield reduces by 30% and fruit harvests decline by 25% from France to Poland.[lxiv] Governments struggling to control inflation block commensurate increases in wages; protests across Europe reflect the civil unrest of the 1970s. Five days of strikes by manufacturers and public sector workers cost the European economy USD 30 billion.

A new crisis emerges as insurers withdraw coverage from vulnerable households and industrial sectors. Private insurers find themselves unable to protect individuals from risk, and governments become the "insurer of last resort." With the value of asset risks nationalized potentially exceeding USD 1 trillion in the UK and Netherlands alone,[lxv] governments seek the combined strength of the EU to cope.[lxvi]

Health effects of high temperatures and flooding in Europe could be severe, with the elderly and the young most vulnerable. Europe's older demographic suffer severely with as many as 50,000 excess deaths.[lxvii] Salmonella outbreaks occur across Europe as cold storage systems are found to be inadequate. The stagnant water of subsequent floods and high temperatures bring disease-carrying vectors such as the tiger mosquito. To combat the spread of such vectors, pesticides are sprayed across swathes of Northern Europe, and the destruction of indigenous species brings environmental catastrophe as governments attempt to tame an "unfamiliar world."

This scenario of Europe afflicted by multiple hazards suggests how extreme weather can reveal underlying vulnerability. Demographic vulnerability is seen in a lack of support systems for the elderly; systemic vulnerability is exposed in the destruction of expensive yet unprotected infrastructure. The expectation falls on the government and aid agencies in Europe to rescue a struggling system, but assumes that public bodies will have the resources and preparation to do so.

So What?

These scenarios describe far-reaching, yet plausible, humanitarian catastrophes triggered in part by climate change. More frequent severe and extreme weather conditions will reveal uneven vulnerability to climate change, with resonating impacts that reflect global society's interconnectedness.[lxviii] Indicative costs have been ascribed to these possibilities; yet, impacts of climate change could be nonlinear, as increases in frequency and extremity ratchet upwards the cost of vulnerability. Disasters involving multiple hazards or cascading consequences may become the norm for hazard effects. Greater frequency of weather extremes may come to blur distinctions between reconstruction and relief assistance as the time between rescue and recovery is squeezed.[lxix] By way of example, the strongest cyclone recorded in the Gulf of Mexico to date is not Hurricane Katrina, but Hurricane Rita. Rita made landfall on 24 September 2005, before New Orleans could reopen, narrowly missing the city that had exhibited both of the categories of crisis effects described above.

Future Research Needs And Application Issues

This work is very much a first attempt. In writing it, we have become aware of just how poorly the issue of humanitarian costs, and particularly the relationship with climate change, has been documented and researched.

- First, and we keep emphasizing the point, more rigorous collection of disaster related data is required. While projecting into the future is a difficult task, current levels of data do not even provide a full picture of what is going on now nor what has gone on in the past. There is no internationally-agreed standard for collecting data on humanitarian response and no single recognized repository for such data. If we are to refine our models of future humanitarian crises and their costs, then creating a more useful global database is essential. We have the beginnings of such a database in the present UN-FTS, IFRC, and EM-DAT databases. However, a unified, comprehensive, properly-serviced and maintained, publicly accessible database is urgently needed.

- Once better data are available, more research is needed into the relationship among hazards, vulnerability, climate change, and humanitarian response. Without grounding our work with information about what is really taking place, we essentially face the future with plenty of passion but precious little evidence.

- Portions of this report focus on large regions in order derive a potential global estimate for climate disaster contributions. Future research that focuses on a smaller sub-region would enable one to detect trends, and possibly make a more refined correlation between past precipitation trends and disaster frequency/intensity. For example, one might focus on past drought data for the Horn of Africa, examine monthly rainfall totals, and then compare the historical record with future seasonal precipitation estimates.

- As highlighted earlier in this paper, the true cost of a disaster, in terms of both the immediate and long-term economic losses to the affected populations, and any measure of the efforts expended by local populations and their authorities to provide relief for disaster victims, is under-researched and hence under-reported. We report what is available, the international response, presenting it as though it were the totality of response. This is a deeply biased picture. Research is urgently needed, therefore, to gauge the true cost of disasters. We would suggest starting with a case history approach, using field research, in the wake of a representative series of disasters, to estimate both the true local cost of the disaster and the local spending on disaster response. Once such a series of case histories are in place, it will be possible to move to deriving and testing conceptual models to describe the costs of disasters in a more general and accurate way.

- The IPCC Fourth Assessment Report indicates that regional predictions would benefit from increased use and improvement of regional climate models. In Central America, for example, regional models are still being tested and developed; relatively few studies have used these models, and those that do are constrained by short simulation length. In short, the report argues, "both more realistic [global climate models] forcing and improvements in the [regional climate models] are needed."[lxx] Estimating disaster frequency from the extreme tail end of these models may always pose a challenge, but the accuracy of future humanitarian spending calculations could be improved if one were able to incorporate the expected increases in hazard intensity, particularly for regions that are exposed to multiple climate hazards. These estimates could be refined further with more precise knowledge about the relationship between a hazard's intensity and its impact.

- The two possibilities presented here to show the effect of sequential and simultaneous hazards provide a hint of how climate-related disasters may generate costs far beyond those suggested by projections of today's disaster costs. These projections are, however, as much thought experiments as anything else, and are projections, not predictions. To make them more predictive, we would need more detailed country or sub-country level research to explore the linkages between multiple hazards, economic stability, and political action. While potential case studies are useful to highlight vulnerabilities, systematic efforts are needed to better identify risks around these issues and plan for the future.

- The prospect of multiple hazards and reduced periods of recovery between extreme events has far-reaching implications that necessitate increased research and attention in both modeling and development policy. Shorter recovery periods will exacerbate vulnerability to future shocks (both climatic and non-climatic), suggesting that our assumed linear relationship between increasing hazards and disasters may significantly underestimate future humanitarian impacts and costs. This requires an integrated approach for long-term development and humanitarian policy. Disaster risk reduction and recovery/ reconstruction are currently "grey transition" areas that more often than not fall between the cracks of development and humanitarian responsibilities, but will become ever more important for both. Existing policy and program divides between the two will become increasingly problematic and artificial. Current and future efforts to bridge this divide are essential and should be expanded.

Conclusions

While this paper has only skimmed the surface of the relationship between climate change and humanitarian costs, we can draw some tentative conclusions.

First, regarding potential future costs of humanitarian response, our analysis found that the most conservative models still indicate a predictable and severe increase in costs of disasters, even within the next twenty years. At a minimum, we project an increase of spending on climate-related disasters in sample regions of USD 57 million. The worst-case maximum projection yields a rise of over USD 2.7 billion in international climate-related disaster response. What we cannot say with certainty is where in this range the actual costs will lie or what shape this increase will take. The data and, therefore, models simply do not exist to determine what the "right" projection would be, while they do demonstrate that current funding is not impartial or proportional. If we know that there will be a significant increase in costs, but cannot know with certainty where or how much this increase will be and what it will entail, there is every reason to develop a more integrated and proactive method of financing disaster response. At present, national disaster response is left up to each state. In a global economy, this is clearly becoming less and less acceptable. Within large, federated state bodies such as the United States or the European Union, mechanisms are in place to ensure individual states "do their bit." The creation and enhancement of adequate and well-supported standby funding mechanisms would be one significant way to enable humanitarian agencies to respond more predictably and flexibly in response to future unknown needs.

Second, regarding the complexity of future disasters, this research demonstrates the linkages among climate change, politics, and disasters. An increase in frequency and intensity of severe and extreme weather events will impact the vulnerability of individuals and communities, with broad implications for our increasingly interconnected world. Implications of climate change highlight the relevance of the relationship between politics and disasters. Cascading or multi-hazard events provide just a couple of examples of how costs from disasters can easily escalate. They also highlight the usefulness of efforts to understand and respond to the linkages between disasters and politics.

Ultimately, it is the ability of individual households to protect themselves against the physical and economic shock of disaster that will make the difference between survival and failure. With appropriate planning, states can profoundly alter the environment within which individuals act. They can encourage and inform. They can provide the infrastructure of physical protection and response, as we have seen in Bangladesh. They can regulate to encourage the innovative use of insurance and partnership between the private sector and the state. Or they can do nothing.

Third, there is an overwhelming need for more research. The ability to do this research will depend, as discussed above, on improving the availability of data and the databases on humanitarian response. This information is a public good and should be prioritized as such. Common definitions and standards of rigor and reporting need to be established and implemented across the board. With access to improved information, research should be supported that aims to understand the complex linkages related to disasters and climate change. Further, research aimed toward understanding climate change impacts at the country and sub-regional levels may provide greater levels of certainty than the regional approach taken in this research.

Lastly, there is a need for greater dialogue, knowledge sharing, and collaboration between the climate change community and the humanitarian community. While a few mechanisms and platforms have been established to promote greater cooperation, there is a long way to go and much to learn from one another. Present mechanisms may prove to be sufficient, but should aim to bring in more partners, including regional and country-level representatives.

The decisions we take now on how humanitarian response is organized and funded and regarding how we work with disaster-prone populations and with each other will determine how many lives are lost, how many livelihoods are devastated, and how much national wealth is washed away two decades from now, let alone how much we are forced to spend on humanitarian response. We hope this paper has been a first step in highlighting the importance of making these decisions and doing so from the basis of evidence, rather than simply speculation.

APPENDIX 1: KEY READING LIST

In this appendix, we have listed what we would consider to be the essential reading for anyone trying to get to grips with the relationship between climate change and humanitarian response. Readings are organized by the topic in general and by specific disaster types and disaster readings.

General

Adger, W.N. "Vulnerability." *Global Environmental Change Special Edition: Resilience, Vulnerability, and Adaptation: A Cross-Cutting Theme of the International Human Dimensions Programme on Global Environmental Change* 16, no. 3 (August 2006): 268-281.

Auld, H. "Disaster Risk Reduction under Current and Changing Climate Conditions." *WMO Bulletin*, no. 57 (2008): 118-125.

Bankoff, G., G. Frerks, and D. Hilhorst, eds. *Mapping Vulnerability: Disasters, Development and People*. London: Earthscan, 2004.

Burton, I. "The Proximate, Underlying and Ultimate Causes Accounting for the Increasing Costs of Weather-Related Disasters: A Diagnosis and Prescription." White paper presented at the Workshop on Climate Change and Disaster Losses: Understanding and Attributing Trends and Projections, Hohemkammer, Germany, May 25-26, 2006.

Dilley, M. et al. "Natural Disaster Hotspots: A Global Risk Analysis." Disaster Risk Management Working Paper Series No. 5 (2005). The World Bank, Hazard Management Unit, Washington, DC.

Dlugolecki, A. "The Cost of Extreme Events in 2030. A Report for United Nations Framework Convention on Climate Change." United Nations Framework Convention on Climate Change, Bonn, Germany, July 16, 2007. <http://unfccc.int/files/cooperation_and_support/financial_mechanism/application/pdf/dlugolecki.pdf>

Ehrhart, C., A. Thow, M. de Blois, and A. Warhurst. "Humanitarian Implications of Climate Change. Mapping Emerging Trends and Risk Hotspots." Care and Maplecroft, 2008.

Helmer, M., and D. Hilhorst. "Natural Disasters and Climate Change." *Disasters* 30, no. 1 (March 2006): 1-4.

Intergovernmental Panel on *Climate Change (IPCC). Climate Change 2007: The Physical Science Basis. Report of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. New York: Cambridge University Press, 2007. <http://www.ipcc.ch/ipccreports/ar4-wg1.htm>.

Intergovernmental Panel on *Climate Change (IPCC). Climate Change 2007: Impacts, Adaptation and Vulnerability. Report of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. New York: Cambridge University Press, 2007. <http://www.ipcc.ch/ipccreports/ar4-wg2.htm>.

International Federation of Red Cross and Red Crescent Societies (IFRC). "Climate Guide." Red Cross/Red Crescent Climate Centre, The Hague, 2007. <http://www.ifrc.org/Docs/pubs/disasters/resources/about-disasters/climate-guide.pdf>.

O'Brien, K. et al. "Disaster Risk Reduction, Climate Change Adaptation and Human Security." Report prepared for the Norwegian Ministry of Foreign Affairs by the Global Environmental Change and Human Security (GECHS) Project, GECHS Report 2008:3 (2008).

Sperling, F., and F. Szekely. "Disaster Risk Management in a Changing Climate." The World Bank, Washington, DC, 2005.

Stern, N. *The Economics of Climate Change: The Stern Review*. New York: Cambridge University Press, 2006.

UNISDR (United Nations International Strategy for Disaster Reduction). "Links between Disaster Risk Reduction, Development and Climate Change." Report prepared for the Commission on Climate Change and Development, Sweden, 2008.

Van Aalst, M. "The Impacts of Climate Change on the Risk of Natural Disasters." *Disasters* 30, no. 1 (March 2006): 5-18.

Wisner, B., P. Blaikie, T. Cannon, and I. Davis. *At Risk: Natural Hazards, People's Vulnerability and Disasters*. 2nd edition. London and New York: Routledge, 2004.

Droughts

Alcamo, J., M. Floerke, and M. Maerker. "Future Long-Term Changes in Global Water Resources Driven by Socio-Economic and Climatic Changes." *Hydrological Sciences* 52, no. 2 (April 2007): 247-275.

Below, R. et al. "Documenting Drought-Related Disasters: A Global Assessment." *Journal of Environment and Development* 16, no. 3 (September 2007): 328-344.

Wang, G. "Agricultural Drought in a Future Climate: Results from 15 Global Climate Models Participating in the IPCC 4th Assessment." *Climate Dynamics* 25, no. 7-8 (December 2005): 739–753.

Floods

Douglas, I., K. Aam, M. Maghenda, Y. McDonnell, L. McLean, and J. Campbell. "Unjust Waters: Climate Change, Flooding and the Urban Poor in Africa." *Environment and Urbanization* 20, no. 1 (April 2008): 187-205.

Groisman, P.Y., R.W. Knight, D.R. Easterling, T.R. Karl, G.C. Hegerl, and V.N. Razuvaev. "Trends in Intense Precipitation in the Climate Record." *Journal of Climate* 18, no. 9 (May 2005): 1326-1350.

Parker, D. *Floods*. 2 vols. London and New York: Routledge, 2000.

Storms

Anthes, R.A., R.W. Corell, G. Holland, J.W. Hurrell, M.C. MacCracken, and K.E. Trenberth. "Hurricanes and Global Warming—Potential Linkages and Consequences." *Bulletin of the American Meteorological Society* 87 (2006): 623-628.

Emanuel, K. "Increasing Destructiveness of Tropical Cyclones over the Past 30 Years." *Nature* 436 (2005): 686-688.

Emanuel, K. et al. "Hurricanes and Global Warming: Results from Downscaling IPCC AR4 Simulations." *Bulletin of the American Meteorological Society* 89, no. 3 (2008): 347-367.

Webster, P.J., G.J. Holland, J.A. Curry, and H.R. Chang. "Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment." *Science* 309 (2005): 1844-1846.

Central America

Eakin, H. "Institutional Change, Climate Risk, and Rural Vulnerability: Cases from Central Mexico." *World Development* 33, no. 11 (November 2005): 1923-1938.

Liverman, D.M. "Vulnerability and Adaptation to Drought in Mexico." *Natural Resources Journal* 39, no. 1 (1999): 99-115.

Manuel-Navarrete, D., J.J. Gómez, and G. Gallopin. "Syndromes of Sustainability of Development for Assessing the Vulnerability of Coupled Human-Environmental Systems. The Case of Hydrometeorological Disasters in Central America and the Caribbean." *Global Environmental Change* 17, no. 2 (May 2007): 207-217.

Trujillo, M., A. Ordones, and C. Hernandez, eds. *Risk-Mapping and Local Capacities: Lessons from Mexico and Central America*. Oxford: Oxfam, 2000.

East Africa

ActionAid International. *Unjust Waters: Climate Change, Flooding and the Protection of Poor Urban Communities: Experiences from Six African Cities. Africa's Urban Poor are Struggling to Cope with Climate-Induced Flooding*. London: Action Aid International, 2007.

Eriksen, S.E.H., K.L. O'Brien, and L. Rosentrater. "Climate Change in Eastern and Southern Africa: Impacts, Vulnerability and Adaptation." Report prepared for the Norwegian Ministry of Foreign Affairs by the Global Environmental Change and Human Security (GECHS) Project, GECHS Report 2008:2 (2008).

Hellmuth, M.E., A. Moorhead, M.C. Thomson, and J. Williams, eds. *Climate Risk Management in Africa: Learning from Practice*. New York: International Research Institute for Climate and Society (IRI), Columbia University, 2008.

South Asia

Beck, T. "Learning Lessons from Disaster Recovery: The Case of Bangladesh." Disaster Risk Management Working Paper Series No. 11 (2005). The World Bank, Hazard Management Unit, Washington, DC.

Khan, M.A. *Disaster Preparedness for Natural Hazards: Current Status in Pakistan. How Prepared is Pakistan for Natural Disasters?* Kathmandu: International Centre for Integrated Mountain Development, 2007.

Mirza, M. M. Q., R.A. Warrick, and N.J. Ericksen. "The Implications of Climate Change on Floods of the Ganges, Brahmaputra and Meghna Rivers in Bangladesh." *Climatic Change* 57, no. 3 (2003): 287-318.

Moench, M. and A. Dixit, eds. *Adaptive Capacity and Livelihood Resilience: Adaptive Strategies for Responding to Floods and Droughts in South Asia*. Kathmandu: Institute for Social and Environmental Transition, 2004.

O'Brien, K. L., et al. 2004. "Mapping Vulnerability to Multiple Stressors: Climate Change and Globalisation in India." *Global Environmental Change* 14, no. 4 (December 2004): 303-313.

Southeast Asia

Huigen, M.G.A., and I.C. Jens. "Socio-Economic Impact of Super Typhoon Harurot in San Mariano, Isabela, the Philippines." *World Development* 34, no. 12 (December 2006): 2116-2136.

Jasparro, C., and J. Taylor. "Climate Change and Regional Vulnerability to Transnational Security Threats in Southeast Asia." *Geopolitics* 13, no. 2 (2008): 232-256.

Shaw, R. S.V., R.K. Prabhakar, H. Nguyen, and S. Price-Thomas. *Drought-Management Considerations for Climate Change Adaptation: Focus on the Mekong Region. How Can Communities in Viet Nam Adapt to Recurring Droughts?* Viet Nam: Oxfam Viet Nam, 2007.

Humanitarian Spending

Department for International Development (DFID), United Kingdom. *Natural Disasters and Disaster Risk Reduction Measures: A Desk Review of Costs and Benefits*. 2005.

Hallegatte, S. "Accounting for Extreme Events in the Economic Assessment of Climate Change." FEEM Working Paper No. 01.05, 2005.

Kemfert, C., and K. Schumacher. "Cost of Inaction and Costs of Action in Climate Protection. Assessment of Costs of Inaction or Delayed Action of Climate Protection and Climate Change." White paper presented at the Workshop on Climate Change and Disaster Losses: Understanding and Attributing Trends and Projections, Hohemkammer, Germany, May 25-26, 2006.

Walker, P., B. Wisner, J. Leaning, and L. Minear. "Smoke and Mirrors: Deficiencies in Disaster Funding." *BMJ* 330, no. 7485 (2005): 247-250.

ENDNOTES

[i] This paper has been jointly authored by Mackinnon Webster, Justin Ginnetti, and Peter Walker of the Feinstein International Center at Tufts University; Daniel Coppard from Development Initiatives; and Randolph Kent from the Humanitarian Futures Program at King's College London. This study was commissioned by the Policy Development and Studies Branch of the United Nations Office for the Coordination of Humanitarian Affairs (OCHA), in consultation with the Red Cross/Red Crescent Climate Change Centre and the International Strategy for Disaster Reduction (ISDR) Secretariat. The views and analysis presented, however, are those of the authors alone and do not necessarily reflect the views of the United Nations or Red Cross/Red Crescent.

[ii] These figures are derived from the International Emergency Disasters Database http://www.emdat.be/. Their figures for natural disasters include not only those triggered by hydro-meteorological events, but also by earthquakes and tsunami. However, earthquake- and tsunami-triggered events are small in number and affect relatively few people (with the exception of the 2004 Indian Ocean tsunami). The inclusion of these events in the term "natural disaster" has little effect on the overall trends.

[iii] It is important to remember that these figures only reflect the prominent disasters—those that are reported internationally and may receive international assistance. Lower-level, but much more frequent, small-scale events typically slip under the international radar.

[iv] London Assembly, Environment Committee, Greater London Authority, London Under Threat? *Flooding Risk in the Thames Gateway*, October, 2005.

[v] World Disasters Reports 1993 to 2007. http://www.ifrc.org/publicat/wdr/index.asp.

vi C. Legum, *Ethiopia: The Fall of Haile Selassie's Empire* (New York: Africana Pub. Co., 1975).

[vii] K. F. McCarthy, *The Repopulation of New Orleans After Hurricane Katrina*, Bring New Orleans Back Commission, Rand Corporation, 2006.

[viii] N. Brooks, "Cultural Responses to Aridity in the Middle Holocene and Increased Social Complexity," *Quaternary International* 151 (2006): 29-49 (download).

[ix] David D. Zhang, Peter Brecke, Harry F. Lee, Yuan-Qing He, and Jane Zhang. "Global Climate Change, War, and Population Decline in Recent Human History," *Proceedings of the National Academy of Sciences* 104, no. 49 (December 4, 2007): 19214–19219.

[x] Philip Nel and Marjolein Righarts, "Natural Disasters and the Risk of Violent Civil Conflict," *International Studies Quarterly* 52, no. 1 (2008): 159–185.

[xi] M. Alamgir, *Famine in South Asia* (Westport, CT: Greenwood Press. 1980), 68. And Peter Walker and Daniel Maxwell, *Shaping the Humanitarian World* (Routledge Publications, due for publication fall 2008), chap. 2, referencing S. Sharma, *Famine, Philanthropy and the Colonial State* (New York: Oxford University Press 2001), chap. 3.

[xii] Intergovernmental Panel on Climate Change (IPCC), "Climate Change 2007: Synthesis Report. Summary for Policymakers," 2007, p. 7, http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf.

[xiii] Madeleen Helmer and Dorothea Hilhorst, "Natural Disasters and Climate Change," Disasters 30, no. 1 (2006): 1-4.

[xiv] A. Dlugolecki, "The Cost of Extreme Events in 2030: A Report for United Nations Framework Convention on Climate Change," UNFCCC, Bonn, 2007, <http://unfccc.int/files/cooperation_and_support/financial_mechanism/application/pdf/dlugolecki.pdf>.

[xv] See, for example, H. Young, A. Osman, and R. Dale, "Strategies for Economic Recovery and Peace in Darfur. Why a Wider Livelihoods Approach is Imperative and Inclusion of the Abbala Arabs is a Priority," Feinstein International Center, 2007, https://wikis.uit.tufts.edu/confluence/display/FIC/Strategies+for+Economic+Recovery+and+Peace+In+Darfur--Why+a+wider+livelihoods+approach+is+imperative+and+inclusion+of+the+Abbala+Arabs+is+a+priority.

[xvi] http://ocha.unog.ch/fts2/pageloader.aspx?page=emerg-emergencies&section=ND&year=2008.

[xvii] https://www-secure.ifrc.org/dmis/index.asp.

[xviii] http://www.emdat.be/.

[xix] The regions were: CENTRAL AMERICA-Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, and Panama; EAST AFRICA-Djibouti, Ethiopia, Eritrea, Kenya, Somalia, Sudan, Tanzania, and Uganda; SOUTH ASIA-Bangladesh, India, Nepal, Pakistan, and Sri Lanka; and, SOUTHEAST ASIA-Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam.

[xx] The data for floods does *not* double-count flooding caused by cyclones. When one of our source databases classified a disaster as both (i.e., cyclone/flood), we counted that event as a cyclone.

[xxi] Although the absolute number of disasters since 1992 included in the compiled database was large and comprehensive, the number of cases which included all the relevant data points was much smaller, and the numbers of these cases per disaster type or region were too small to support a statistically rigorous analysis. Therefore, while we had hoped that ratios such as cost per UN beneficiary, or UN appeals/contributions compared with IFRC appeals/contributions, could be calculated and then extrapolated to the other disasters in the database for which this data was not complete, the small sample size prevented this analysis from being performed.

[xxii] A. Möhner and R.J.T. Klein, "The Global Environment Facility: Funding for Adaptation or Adapting to Funds?" Stockholm Environment Institute (SEI), Climate & Energy Working Paper, June 2007.

[xxiii] It is important to note that some agencies may occasionally issue both a regional and national appeal. For our study, we have included all UN and IFRC appeals, so it is possible in a very limited number of circumstances that the same disaster had more than one appeal calculated in to the average cost.

[xxiv] G.A. Meehl, T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver, and Z.-C. Zhao, "Global Climate Projections," in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (Cambridge: Cambridge University Press, 2007).

[xxv] Timothy M. Lenton, Hermann Held, Elmar Kriegler, Jim W. Hall, Wolfgang Lucht, Stefan Rahmstorf, and Hans Joachim Schellnhuber, "Inaugural Article: Tipping Elements in the Earth's Climate System," *Proceedings of the National Academy of Sciences* 105, no. 6 (2008): 1786-1793. And Eric Rignot, Jonathan L. Bamber, Michiel R. van den Broeke, Curt Davis, Yonghong Li, Willem Jan van de Berg, and Erik van Meijgaard, "Recent Antarctic Ice Mass Loss from Radar Interferometry and Regional Climate Modelling," *Nature Geosci* 1, no. 2 (2008): 106-110.

[xxvi] A. Dlugolecki, "The Cost of Extreme Events in 2030: A Report for United Nations Framework Convention on Climate Change," UNFCCC, Bonn, 2007, <http://unfccc.int/files/cooperation_and_support/financial_mechanism/application/pdf/dlugolecki.pdf>.

[xxvii] G. A. Meehl, T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver, and Z.-C. Zhao, "Global Climate Projections," in Climate Change 2007: *The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (Cambridge and New York: Cambridge University Press, 2007), 751.

[xxviii] J.H. Christensen, B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr, and P. Whetton, "Regional Climate Projections," in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (Cambridge: Cambridge University Press, 2007), 849 and 871.

[xxix] R.A. Pielke Jr., "Future Economic Damage from Tropical Cyclones: Sensitivities to Societal and Climate Changes," *Philosophical Transactions of the Royal Society A* 365, no. 1860 (November 15, 2007): 2717-2729.

[xxx] D. Hogan and J.L. Burstein, *Disaster Medicine* (Philadelphia: Lippincott Williams & Wilkins, 2007). See chapter 23, Heat-Related Disasters.

[xxxi] D. Guha-Sapir, D. Hargitt, and P. Hoyois, *Thirty Years of Natural Disasters* 1974-2003: The Numbers (Belgium: Centre for Research on the Epidemiology of Disasters, Presses Universitaires de Louvain, 2004), 51.

[xxxii] This is not a critique of the IFRC or those who work for them, but of the voluntary and supply-driven funding system which skews funds towards the politically important (to the donor), or the spectacular and media- accessible.

[xxxiii] For example, see Guha-Sapir et al.

[xxxiv] For more information, see J.H. Christensen, B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr, and P. Whetton, "Regional Climate Projections," in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (Cambridge: Cambridge University Press, 2007), 894-895.

[xxxv] For a 15% increase in cyclone intensity, the equation is (1 + 0.15)3 - 1 = 0.52, or 52%; annual contributions for 2030 = baseline contributions x 1.52, or USD 88,939,380 x 1.52 = USD 135,265,680. See R.A. Pielke Jr., "Future Economic Damage from Tropical Cyclones: Sensitivities to Societal and Climate Changes," *Philosophical Transactions of the Royal Society A*, 365, no. 1860 (November 15, 2007): 2722.

[xxxvi] Ibid., 2717-2729.

[xxxvii] R.P. Allan et al., "Atmospheric Warming and the Amplification of Precipitation Extremes," *Science* 321, no. 5895 (September 12, 2008): 1481.

[xxxviii] M. Boko, I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo, and P. Yanda, "Africa," in *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* eds. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (Cambridge: Cambridge University Press, 2007), 447 and 453.

[xxxix] R.V. Cruz, H. Harasawa, M. Lal, S. Wu, Y. Anokhin, B. Punsalmaa, Y. Honda, M. Jafari, C. Li, and N. Huu Ninh, "Asia," in *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (Cambridge: Cambridge University Press, 2007), 469-506.

[xl] This figure does not include intensity increases for droughts.

[xli] Bettencourt, S. et al., "Not if But When: Adapting to Natural Hazards in the Pacific Islands Region. A Policy Note," The World Bank East Asia and Pacific Region, Pacific Islands Country Management Unit, 2006, p. 4.

[xlii] Building and Social Housing Foundation, "The Core Shelter Housing Project, Philippines," 1991. Building and Social Housing Foundation (BSHF) Database of housing projects, http://www.worldhabitatawards.org/winners-and-finalists/project-details.cfm?lang=00&theProjectID=114. And UNFCCC/Nairobi Work Programme Database on local coping strategies, <http://maindb.unfccc.int/public/adaptation/adaptation_casestudy.pl?id_project=75>. And PAGASA (Philippine Atmospheric, Geophysical and Astronomical Services Administration), "Documentation and Analysis of Impacts of and Responses to Extreme Climate Events," Climatology and Agrometeorology Branch Technical Paper No. 2001-2 (2001).

[xliii] UNFCCC/Nairobi Work Programme Database on local coping strategies, <http://maindb.unfccc.int/public/adaptation/adaptation_casestudy.pl?id_project=37>.

[xliv] World Bank, "Natural Disaster Mitigation—Additional Scale-Up Financing: Honduras," Project Information Document No. 39861 (2007), http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2007/05/24/000310607_20070524110236/Rendered/PDF/398610PID0P105386.pdf.

[xlv] Three times the support received for the Sichuan Province Earthquake, May 2008.

[xlvi] Reference melting of glaciers in Tibetan Plateau, e.g., http://www.wwf.org.uk/what_we_do/tackling_climate_change/china__india_and_nepal__the_melting_glaciers_of_the_himalayas.cfm.

[xlvii] L. Chen and P. Talwani, "Reservoir-Induced Seismicity in China," *Pure and Applied Geophysics* 153, no. 1 (November, 1998): 133-149.

[xlviii] M. Barber and G. Ryder, "Damming The Three Gorges: Dam Safety Analysis," online at http://www.threegorgesprobe.org/pi/documents/three_gorges/Damming3G/ch10.html.

[xlix] R. Stone, "China's Environmental Challenges: Three Gorges Dam: Into the Unknown," *Science* 321, no. 5889 (2008): 628 – 632.

[l] Based on IMF forecast per capita productivity, with 10 million affected over six months.

[li] For example, while 8% growth is high, it is also needed to maintain societal "growing pains." http://www.economist.com/opinion/displaystory.cfm?story_id=12471135.

[lii] GDP value based on International Monetary Fund, World Economic Outlook Database, October 2008.

[liii] For example, as occurred in Europe in 2007: http://news.bbc.co.uk/1/hi/world/europe/6917002.stm.

[liv] N. Paklina (2003): In 2002, widespread European flooding caused USD 18 billion of damage, of which only $3 billion was covered by insurance claims. (OECD)

[lv] For example: http://www.reliefweb.int/rw/rwb.nsf/db900SID/ACOS-64-CAKB?OpenDocument.

[lvi] Such a heat wave was experienced in France in 2003, and there has been wider European flooding over the last decade.

[lvii] Rising river temperatures reduce the cooling efficiency of thermal power plants (conventional and nuclear), while flows of rivers would be reduced.

[lviii] In France, in the summer of 2003, six power plants were shut down completely; if the weather had continued, 30% of power production would have been at risk (Létard et al., 2004).

[lix] Estimate based on International Monetary Fund, World Economic Outlook Database, April 2008. Constant prices, 2007 USD. Assumes actual output fall equivalent to half a day for four weeks across Benelux, UK, Ireland, France, Germany, Denmark, and Spain.

[lx] Smaller floods of 2007 disrupted water supply to 150,000 homes.

[lxi] The Red Cross helped 5,000 UK flood victims in 2007 and delivered 140,000 liters of bottled water. 49,000 households and over 7,000 businesses were flooded.

[lxii] See note on problems of increasing frequency of flood events. Such a calamity almost occurred when the UK's Walham Switching Station came close to inundation and a subsequent loss of power to 600,000 homes, a vulnerability that had not been adequately assessed.

[lxiii] N. Stern, *The Economics of Climate Change* (Cambridge: Cambridge University Press, 2007), Viii.

[lxiv] Cross-chapter case studies from the report accepted by Working Group II of the Intergovernmental Panel on Climate Change; Ciais et al., 2005.

[lxv] Kortenhaus and Samuels (2004)

[lxvi] ABI, Ibid

[lxvii] France saw 35,000 in 2003.

[lxviii] K. O'Brien and R. Leichenko, "Human Security, Vulnerability and Sustainable Adaptation," Human Development Report 2007/2008, Human Development Report Office Occasional Paper 2007/9, United Nations Development Programme.

[lxix] Ibid.

[lxx] J.H. Christensen, B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr, and P. Whetton, "Regional Climate Projections," in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (Cambridge: Cambridge University Press, 2007), 893.

Feinstein International Center

Feinstein International Center
Tufts University
200 Boston Ave., Suite 4800
Medford, MA 02155
USA
tel: +1 617.627.3423
fax: +1 617.627.3428
fic.tufts.edu