DISASTER MANAGEMENT

Confronting Disaster Losses

Action on disaster risk reduction can support sustainable development under climate change.

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Global costs of weather-related disasters have increased from an annual average U.S.$8.9 billion (1977–1986) to U.S.$45.1 billion (1997–2006). In coming decades, the number of people at risk from extremes will very likely grow, and extreme weather will likely increase (*1*). To date, societal change and economic development are mainly responsible for increasing losses. After adjusting for societal changes, loss time series reflect the climatological record (*2*).

By 2015, loss potentials among the world's 10 largest cities, most of which are in developing countries, are projected to increase from 22% (Tokyo) to 88% (Shanghai, Jakarta) (*3*). A repeat of the July 2005 floods in Mumbai (see figure, right) in 2015 could cause 80% higher losses and affect 20% more people, independent of climate change. Greenhouse gas emission reductions are of central importance, but they cannot decrease hazard risk for decades. In this context, we offer three recommendations for decision-makers.

What if this disaster should happen again? Indian dabbawalas (lunch box carriers) walk through a flooded railway track, after torrential rains paralyzed Mumbai, 27 July 2005. The city's weather bureau said that Mumbai received 944.2 millimeters (37.1 inches) of rainfall in 24 hours.

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Improve data collection. With few exceptions, records of disaster losses are of poor quality, inhomogeneous, and collected using a wide range of methods for different purposes, making research extremely challenging. Improved data could be used to evaluate disaster policies, estimate return periods, identify factors that drive loss trends and could potentially offer the prospect of an early-warning system for changes in the earth-climate system. Currently, the most comprehensive loss databases are held by insurance companies and are not publicly available. An open-source, peer-reviewed database would enable the scientific community to study worldwide disasters.

Expand the role of disaster risk reduction in adaptation. The cost-benefit ratio of disaster risk reduction ranges from 1:2 to 1:4 (*4*), but efforts remain underfunded. In particular, inadequate pricing of costs and benefits leads to inappropriate valuation of investment and financial calculations in risk-reducing measures (*5*). Risk reduction is not usually referred to as climate adaptation, but may be described as plant breeding and selection, flood-risk reduction, public health care, and so on. Developing countries have many opportunities to integrate climate adaptation in disaster risk-reduction efforts (*6*). More generally, disaster aid is probably best spent on ex ante risk reduction (*7*).

Develop and apply innovative finance mechanisms. Industries with greatest exposure have responded to increasing losses with innovative products. Catastrophe bonds are a mechanism used to transfer peak risks to the capital markets, with the range of hazards covered continuing to expand, recently to the flood risks in the U.K. (*8*). Previously uninsured flood risks in Belgium and the Netherlands are to be covered through public-private insurance constructions. Existing development financing within local communities, for example, investment funds for small infrastructure improvement in El Salvador, support risk reduction (*9*), and community groups in India have developed deficit rainfall insurance (*9*). In Colombia, microentrepreneurs offer affordable and easy to understand life and property microinsurance to the most vulnerable. The World Bank–sponsored Caribbean Catastrophe Risk Insurance Facility offers governments cover against hurricanes and earthquakes with funds available a few days after the event (*10*). The Munich Climate Insurance Initiative brings together the World Bank, insurers, nongovernmental organizations, and the scientific community to develop finance solutions for adaptation in developing countries (*11*).

If present trends continue, global disaster losses will keep outpacing average economic growth. Therefore, disaster risk reduction must be core to climate adaptation policies. Numerous mechanisms for action exist that can contribute to the aim of sustainable development.

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References and Notes

1. Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007* (IPCC, Geneva, 2007); www.ipcc.ch.
2. R. A. Pielke Jr., C. N. Landsea, *Bull. Am. Meteorol. Soc.* **80**, 2027 (1999).
3. See Supporting Online Material (SOM).
4. R. Mechler, *Cost-Benefit Analysis of Natural Disaster Risk Management in Developing and Emerging Countries* [GTZ (German Society for Technical Cooperation), Eschborn, 2005].
5. C. Benson, J. Twigg, *Measuring Mitigation: Methodologies for Assessing Natural Hazard Risks and the Net Benefits of Mitigation* (ProVention, Geneva, 2004).
6. R. Few, H. Osbahr, L. M. Bouwer, D. Viner. F. Sperling, *Linking Climate Change Adaptation and Disaster Risk Management for Sustainable Poverty Reduction* [Vulnerability and Adaptation Resource Group (VARG), Washington, DC, 2006]; www.climatevarg.org.
7. J. Linnerooth-Bayer, R. Mechler, G. Pflug, *Science* **309**, 1044 (2005).
8. Allianz, press release, 10 April 2007; www.allianz.com.
9. K. Warner, L. M. Bouwer, W. Ammann, *Environ. Hazards* **7**, 32 (2007).
10. Munich Re, press release, 1 June 2007; www.munichre.com.
11. Munich Climate Insurance Initiative, www.climate-insurance.org.
12. L.M.B. acknowledges support from the Climate Changes Spatial Planning Programme and R.A.P. from the NSF under grant 0345604.

Supporting Online Material
www.sciencemag.org/cgi/content/full/318/5851/753/DC1

10.1126/science.1149628

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Supporting Online Material for

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Published 2 November 2007, *Science* **318**, 753 (2007)
DOI: 10.1126/science.1149628

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Increasing weather related losses

According to data collected by Munich Re, global weather-related economic losses (inflation adjusted, 2006 dollars) have increased from an annual average of U.S.$8.9 billion from 1977–1986 to U.S.$45.1 billion from 1997–2006. However, because of issues related to data quality, the low frequency of extreme event impacts, limited length of the time series, and various societal factors present in the disaster loss record, it is still not possible to determine the portion of the increase in damages that might be attributed to climate change brought about by greenhouse gas emissions (*S1*). This conclusion is likely to remain unchanged in the near future (*S1*).

Munich Re's data comes from their NatCat®SERVICE database and includes losses from designated great natural weather catastrophes. Great natural catastrophes match the criteria that an affected region's ability to help itself is distinctly overtaxed and hence interregional or international assistance is necessary. As subsidiary criteria serve substantial overall losses defined as exceeding $10^6 \times 5\%$ of per capita GDP (developed countries) or at least U.S.$300 million (developing countries) and/or more than a thousand fatalities, and/or more than a hundred thousand people made homeless. This data set is generated to be homogenous since the 1970s, as it does not include smaller weather events that would be underreported earlier in the record. Annual losses in Munich Re's global data set are highly correlated ($r^2 = 0.68$) with annual U.S. hurricane losses from 1970–2005 (*S2*).

Inflation-adjusted data from Munich Re indicates that the average annual losses from the period 1977–1986 to the period 1997–2006 increased at a decadal rate of about 125%. Over the same period, annual growth in real GDP was smaller, and averaged 35 to 45% between decades (*S3*, *S4*). The larger increase in disaster losses could reflect more rapid relative growth in vulnerable locations, changes in climate events (regardless of cause), or both. Median annual losses increased between the two periods by a decadal rate of about 55%. The increase in median losses is lower than the mean because the size of the largest losses increased by a greater amount. The largest annual loss in the most recent decade reached U.S.$180.9 billion (2005); during 1977–1986, it was U.S.$24.1 billion. As median loss potentials increase because of changes in population and per capita real GDP, so too will the potential for extreme losses as risk becomes increasingly more concentrated.

Attribution of loss increases

Societal change and economic development are mainly responsible for increasing losses in recent decades, as convincingly shown in analyses of long-term records of losses (*S1*). After adjusting for societal changes, resulting time series accurately reflect documented trends (or lack thereof) and variability consistent with the observed climatological record of weather events (*S1*, *S5*). This implies that the net result of the adjustments has to a significant degree successfully removed the signal of societal change from the loss record.

A community perspective on the relation between climate change and disaster losses was developed at an international workshop (*S1*) in May 2006, summarized in the accompanying Table S2. The consensus reached at that workshop can inform expectations for the immediate future and decision-making in the context of those expectations.

Projections of future losses

Within the next 20 years projected changes in the intensity and frequency of extreme events—depending on the time scale and hazard—remain uncertain. The most severe effects of human-caused climate change are expected in the second half of the century (*S6*). In the immediate future, disaster losses will increase already as a result of societal change and economic development, independent of climate change.

Growing population and capital in mega-cities exemplify loss potential increases in the near future. Most of these cities are located in vulnerable coastal areas and river plains in developing countries. The continents most prone to large numbers of fatalities in disasters—Asia, Africa, and Latin America—currently contain around 275 cities with more than a million people. This number is expected to grow to over 400 during the next decade (*S7*). Table S1 presents the projected increase in population and economic loss potentials for the world's 10 largest cities. The loss potentials are the percentage changes in projected real GDP (*S7*), which includes United Nations population estimates (*S8*). In all, loss potentials of 79 of the world's 151 largest cities are expected to grow faster than 3.5% annually and 70 by more than 4.0%.

The relatively more rapid loss potential increase in cities helps to explain why disaster losses have increased faster than real global GDP. These data suggest that developing countries are repeating the dramatic increase in loss potentials observed in the U.S. Gulf and Atlantic coast counties. From 1950 to 2005, more than 130 of 177 coastal counties saw their loss potentials increase faster than real global GDP with increases of more than 10% annually in some counties (*S2*). The median annual increase was about 4% (*S2*), which equates to a 48% increase over a 10-year period.

Supporting References and Notes

S1. P. Höppe, R. A. Pielke Jr., Eds., *Climate Change and Disaster Losses: Understanding and Attributing Trends and Projections*, report of a workshop, Hohenkammer, Germany, 25 to 26 May 2006 (University of Colorado, Boulder, and Munich Re, Munich, 2006); http://sciencepolicy.colorado.edu/sparc/research/projects/extreme_events/munich_workshop/.

S2. R. A. Pielke Jr. *et al*., *Nat. Hazards Rev.*, in press.

S3. Organisation for Economic Cooperation and Development, *The World Economy* (OECD, Paris, 2001); www.theworldeconomy.org/publications/worldeconomy/statistics.htm.

S4. International Monetary Fund, *World Economic Outlook: Globalization and Inflation* (IMF, Washington, DC, 2006); www.imf.org/Pubs/FT/weo/2006/01/index.htm.
S5. M. W. Downton, J. Z. B. Miller, R. A. Pielke Jr., *Nat. Hazards Rev.* **6**, 13 (2005).
S6. Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: The Physical Science Basis* (IPCC, Geneva, 2007); www.ipcc.ch.
S7. PriceWaterhouseCoopers, *UK Economic Outlook: March 2007*; www.pwc.com/uk/eng/ins-sol/publ/ukoutlook/pwc_ukeo-mar07.pdf.
S8. United Nations (UN), *World Urbanization Prospects: The 2005 Revision* (2006); www.un.org/esa/population/publications/WUP2005/2005WUPHighlights_Final_Report.pdf.
S9. The 25 to 27 May 2006 workshop in Hohenkammer, Germany, was sponsored by Munich Reinsurance Company, GKSS Research Centre, Tyndall Centre for Climate Change Research, and the U.S. National Science Foundation.

Table S1. Increase in mega-city disaster loss potential from 2005 to 2015. Ranking is by population at 2015. Population estimates (*S9*), estimated GDP (U.S.$ billion at 2005 Purchasing Power Parity) (*S9*).

City	Population estimates (million)			Estimated GDP (U.S.$ billion at 2005 Purchasing Power Parity)		
	2005	2015	Change (%)	2005	2015	Increase in loss potential by 2015 (%)
Tokyo, Japan	35.2	35.5	0.8	1191	1452	22
Mumbai, India	18.2	21.9	20.2	126	226	79
Mexico City, Mexico	19.4	21.6	11.1	315	489	55
São Paulo, Brazil	18.3	20.5	12.0	225	336	49
New York, USA	18.7	19.9	6.2	1133	1408	24
Delhi, India	15.0	18.6	23.6	93	170	82
Shanghai, China	14.5	17.2	18.8	139	261	88
Kolkata, India	14.3	17.0	18.9	94	167	77
Dhaka, Bangladesh	12.4	16.8	35.5	52	94	81
Jakarta, Indonesia	13.2	16.8	27.3	98	184	88

Table S2. Consensus (unanimous) statements of the Hohenkammer workshop (*S1*):

1. Climate change is real and has a significant human component related to greenhouse gases.
2. Direct economic losses of global disasters have increased in recent decades with particularly large increases since the 1980s.
3. The increases in disaster losses primarily result from weather-related events, in particular storms and floods.
4. Climate change and variability are factors that influence trends in disasters.
5. Although there are peer-reviewed papers indicating trends in storms and floods, there is still scientific debate over the attribution to anthropogenic climate change or natural climate variability. There is also concern over geophysical data quality.
6. IPCC (2001) did not achieve detection and attribution of trends in extreme events at the global level.
7. High-quality long-term disaster loss records exist, some of which are suitable for research purposes, such as to identify the effects of climate and/or climate change on the loss records.
8. Analyses of long-term records of disaster losses indicate that societal change and economic development are the principal factors responsible for the documented increasing losses to date.
9. The vulnerability of communities to natural disasters is determined by their economic development and other social characteristics.
10. There is evidence that changing patterns of extreme events are drivers for recent increases in global losses.
11. Because of issues related to data quality, the stochastic nature of extreme event impacts, length of time series, and various societal factors present in the disaster loss record, it is still not possible to determine the portion of the increase in damages that might be attributed to climate change due to GHG emissions
12. For future decades the IPCC (2001) expects increases in the occurrence and/or intensity of some extreme events as a result of anthropogenic climate change. Such increases will further increase losses in the absence of disaster reduction measures.
13. In the near future the quantitative link (attribution) of trends in storm and flood losses to climate changes related to GHG emissions is unlikely to be answered unequivocally.

Policy implications identified by the workshop participants

14. Adaptation to extreme weather events should play a central role in reducing societal vulnerabilities to climate and climate change.
15. Mitigation of GHG emissions should also play a central role in response to anthropogenic climate change, though it does not have an effect for several decades on the hazard risk.
16. We recommend further research on different combinations of adaptation and mitigation policies.
17. We recommend the creation of an open-source disaster database according to agreed-upon standards.
18. In addition to fundamental research on climate, research priorities should consider needs of decision-makers in areas related to both adaptation and mitigation.
19. For improved understanding of loss trends, there is a need to continue to collect and improve long-term and homogenous data sets related to both climate parameters and disaster losses.
20. The community needs to agree on peer-reviewed procedures for normalizing economic loss data.