Building Resilience to Disasters of Natural and Technological Origin

OVERVIEW AND BACKGROUND

Disasters impose huge social and economic costs on societies. By reducing exposure and adopting new strategies to increase resilience, these costs can be reduced. While experience from recent disasters provides useful lessons, a more effective guide to building resilience can be based on systematic scientific risk surveillance and ranking. Since a strategy built on this basis is common to a range of disasters, regardless of their cause, implementing these strategies can be an important investment. It is urgent that national governments build resilience strategies into national, as well as international cooperation and development assistance plans.

DISASTERS

Natural disasters include events such as earthquakes, landslides, hurricanes, floods, typhoons, volcanic eruptions, and disease pandemics. Technological disasters include accidental or human-induced breakdowns in socially critical infrastructures such as dams and levees, energy systems, and information networks. Disasters are often compounded by cascading effects (e.g., East Japan's earthquake-tsunami-nuclear reactor failure). In this statement, we will use the term "disasters" for all of these cases. While some disasters (such as droughts, epidemics, or sinking terrain) may develop gradually, here we focus on disasters that occur on short time scales.

The timing of most disasters cannot be precisely predicted. However, careful scientific study, modeling, and monitoring can improve our understanding of the hazards and exposure, and can often provide valuable early warning. Even for events such as earthquakes, and associated tsunamis, warning of a few minutes can save lives. It is important to reexamine periodically risk exposure. For example, extreme weather events (storms, heat waves, wild fire) may become more frequent and intense as a result of climate and other change, and new geophysical and other data may reveal hazards that were previously unrecognized.

COST OF DISASTERS

Losses and costs of disasters have been increasing. For the first time, global annual losses from natural disasters exceeded $200 billion in 2005, 2008, and 2011. Data on loss of life, on the other hand, has no clear trend—but has been much lower in developed countries, which indicates the value of resilience measures.

The rising cost of disasters is due in part to the continued growth of population and infrastructure in vulnerable locations, aging or compromised infrastructure, and the deferral of needed institutional arrangements and investments in warning and protective systems. Sea-level rise and climate change in the future may also increase risks and impacts from disasters. In many cases, natural systems such as coastal mangroves that buffer disasters have been degraded. Society is increasingly dependent on interacting infrastructures that supply energy, food, health care, information, transportation, and finance. Breakdown in one of these can affect many other services.

Coping with disasters can in many cases exceed the capacity of individual countries, and multiple countries may be impacted.

RESILIENCE TO DISASTERS

Resilience can be defined as the ability of a system and its component parts to anticipate, absorb, accommodate or recover from the effects of a major shock in a timely and efficient manner. Capacity for resilience should be developed in institutions at all levels and sectors of society. In many cases, strengthened resilience has multiple benefits: helping to mitigate immediate deaths, injuries, and economic losses from relatively frequent emergencies, while building resilience to future disasters. Elements of building resilience include:

- Systematic assessment and monitoring of disaster risks, continued research to improve understanding of the underlying causes, improved warning systems, and awareness of risks by the public and all levels of governments.
- Establishment of a culture and incentives that lead to the acceptance of responsibility by communities, including private sector and civil organizations, for planning and cooperation in preparation, response, and recovery.
- Long-term planning, investment, and enforcement of mitigating or preventive measures, such as land-use and other zoning and building codes.
- International cooperation in advanced planning and rapid response, as well as research and evaluation on risk factors.

COMPONENTS OF BUILDING RESILIENCE

Important work is underway within the international community, in particular within the Global Platform for Disaster Risk Reduction and the 10-year Hyogo Framework for Action, adopted by 168 countries in 2005. ICSU (the International Council for Science) launched in 2010 a 10-year program of Integrated Research on Disaster Risk. The UN International Strategy for Disaster Reduction is presently consulting on a post-2015 framework. Such efforts produce a wide range of valuable results and recommendations which deserve sustained attention and implementation.

The adoption of a systems approach and the identification of multi-dimensional solutions are key elements to building resilience. We suggest that particular attention be devoted to these five dimensions, and ask governments to engage the national and international scientific community in this effort:

1. **Repeated Risk Surveillance and Capacity Building for Regular Assessment**. It is hard to prepare for disasters that have not been imagined. Individual regions, nations, and the international community must develop strategies to regularly identify and assess the disaster risks they face and reduce their exposure. Continued monitoring is critical in this regard.

2. **Improvement of Public Health Systems.** Even when an initiating event does not involve public health, large social disruptions can quickly lead to multiple hazards including epidemics. Public health systems must be strengthened and sustained, both to avoid disaster, and to respond when disasters occur. Capacity to respond to health impacts of disasters, especially for vulnerable populations, should be an integral part of (and an additional incentive for) building strong public health systems. The same considerations apply to crop and animal health systems, with their huge impacts on food security and economies. Governments should regularly assess the adequacy of regional, national and international public health preparedness.

3. **Applications of Advanced Information Technology (IT).** Information technologies, including geospatial, are important, both to monitor, identify and warn of pending disasters, and to assess the location, nature and extent of damage, deaths and injuries and dispatch, coordinate and allocate relief efforts. Nations should assess the potential advantages of dedicated IT systems for emergency response versus shared systems that serve multiple roles. Either way, systematic practice (emergency response gaming) with all key players, as well as active programs of public involvement and education, are critical to the effective use of these systems.

4. **Planning, Engineering and Implementation of Standards to Minimize Vulnerability.** Losses from disasters can be significantly decreased by improved standards for buildings, roads, electrical systems, water systems, and other infrastructure, and by zoning to reduce vulnerability. In addition to planning the protection of populations and modern infrastructure, cultural and natural heritage sites require protection, as their loss is irreversible. Continued research on innovative design, engineering and materials and dissemination of information about available techniques and materials are essential. To be effective, governments must see that standards are enforced.

5. **Integration of Resilience Capacity into Development Assistance Programs.** Development assistance programs can help countries build their own capacity for resilience, at both local and national levels. For this to be effective, assistance must reach those most in need so that future vulnerability is reduced. Public education and engagement, drawing lessons from past disasters, and communications capacities are especially important for vulnerable populations and areas. Development assistance, even in crisis situations, should involve institutions and individuals of the afflicted country, to build local experience and capacity.

Our academies of science are committed to working together with over 100 science, engineering, and medicine counterpart organizations around the world to continue the process of better understanding the causes of disasters, finding ways to make society more resilient, making that information widely available, and helping to implement the many actions needed.

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Energy and Water Linkage: Challenge to a Sustainable Future

OVERVIEW

Needs for affordable and clean energy, for water in adequate quantity and quality, and for food security will increasingly be the central challenges for humanity: these needs are strongly linked. In some regions, the increasing demands for water in support of energy development and use pose challenges to its availability for food and other human needs and for important ecological systems. It is critically important that planning and investment in energy and water infrastructure and associated policies take into account the deep interaction between water and energy. A systems approach based on specific regional circumstances and long-term planning is essential. Viewing each factor separately will lead to inefficiencies, added stress on water availability for food production and for critical ecosystems, and a higher risk of major failures or shortages in energy supply. In almost all regions of the world, innovative ways of achieving higher efficiency in use of energy and water will be the key factors that determine whether these linked challenges can be met.

BACKGROUND

There is widely shared concern over the looming challenge of adequate food for a world population that has grown from 6 to 7 billion in the past 12 years and that will approach 9 billion within 30 years. This concern is based on current and projected needs that will require almost doubling current world food production, and doing so in situations of increasing demands for water resources. It is widely understood that considering water and energy aspects of food security is necessary, because agriculture is by far the largest user of water in most parts of the world and has enormous energy demands. A key effort in meeting the central challenge of food security will be improving efficiency and reducing waste in energy inputs to agriculture, in agricultural water use, and in post-harvest losses.

However, the direct interaction between meeting energy needs and assuring water availability and quality is less widely recognized. Major stresses on availability of energy and water are already being felt in many countries and regions and more are foreseeable. There are widespread deficiencies in existing water energy infrastructure. Continuing population growth and changes in human diets and life styles will increase demand for both energy and water (even apart from demands related to basic nutritional and household water needs). And changes in regional hydrological cycles due to climate change will add to the potential for human development crises.

ENERGY REQUIRES WATER

Energy runs modern society. In most of the world electrical energy depends on large generating plants burning fossil fuel, to a lesser degree on nuclear power, or on hydropower. Fossil-fired and nuclear power plants and solar-thermal systems, as currently operating, require large water withdrawals and some water consumption. Depending on the type of cooling system, these requirements can vary by large amounts. Energy from some renewable sources such as photovoltaic solar and wind, on the other hand, requires very little water.

Fossil fuels provide some 80% of the worlds current energy needs, including most transportation systems. Some fossil fuel sources, including increasingly important "unconventional" sources, such as tar sands, gas hydrates, and gas and oil in tight formations, have substantial implications for quantity and quality of water. Producing alternative transportation fuels, in particular biofuels, depending on the specific applications, can involve substantial impacts on water resources and water quality.

WATER REQUIRES ENERGY

Providing water quantity and quality requires, in some cases, large amounts of energy. In many countries or regions, where water must be moved long distances from sources to users, considerable energy is used to pump this water. Where water is available but contamination is extensive, the solutions for improving water quality, including waste- water treatment, depend on energy. The extreme case is desalination, which requires large energy inputs.

WATER STRESS AND SCARCITY

Water quantity and quality issues carry serious implications for human welfare, health, and for ecosystems. Current data and a range of projections of demand over the coming few decades (population, demand for water-intensive foods, standards of living, sources of energy and end-uses) indicate that a growing number of areas of the world will be in situations of water stress or scarcity, or will not be self-sufficient in food production. Regional-scale projections for the continuation and acceleration of climate changes and impacts on the hydrological cycle indicate intensified water stress and scarcity in some parts of the world, and uncertainty as to exactly where that will occur. While much of the world depends on precipitation, surface water, and rechargeable aquifers, the extensive dependence of some areas on non-renewable ancient aquifers, or on withdrawals that are much greater than recharge rates on other aquifers, presents a special case of foreseeable serious increase in water stress and scarcity.

RECOMMENDATIONS

Water in a sense is both a regional and a global challenge: each country or region has its own specific situation with regard to water quantity and quality, current uses and needs, future projections, and uncertainties in those projections. Food security and water supply for human consumption are local, but also regional and global challenges. The extensively globalized market for food, energy, and other goods constitutes large trade in "virtual water", which globally alleviates but can locally increase, water stresses. For many, food security alternatives, and better water management and technological alternatives are necessary. Regional water cooperation is, in many cases, essential.

Energy options are a complex mix of local resources (if any), global supply, and available/affordable technological options. The wide range of local circumstances means that the world needs a wide range of clean energy technology options, whose impacts on water need to be well understood and taken into account in the decision processes.

Thus, we Leaders of Academies of Sciences, recommend that governments:

- Ensure that programs in energy and water are fully integrated and that solutions are developed with a systems approach that takes into account their interdependencies. Especially important will be energy efficiency, water efficiency and recycle, and demand management for both. This integration must also successfully deal with the close linkages to food production and sustainability in land use and maintenance of ecosystems.

- Invest in integrated scientific research and innovation in energy optimization and the sustainable use of water, and in further development of systems analysis approaches for dealing with these challenges.

- Establish effective governance structures and clear policies to facilitate the integrated management of energy, water, and agriculture systems. This may require explicit estimation of indirect costs of energy programs, including consumption or degradation of water, and the reflection of these costs in prices.

- Develop systems, which monitor and make freely available key basic data on water and energy.

Each of these actions requires building local and regional human and institutional capacity for the necessary research, data-gathering, evaluation, planning, governance, technology adaptation, and long-term maintenance. This capacity must be built on a public recognition of the need for long-term planning and the importance of efficiency and conservation. Global cooperation will be essential, including development assistance to many of the most vulnerable countries, building capacity to plan and implement integrated national energy and water programs.

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Improving Knowledge of Emissions and Sinks of Greenhouse Gases

BACKGROUND

Most countries have made commitments to limit human-caused emissions of greenhouse gases. To determine the success of these efforts, we need to use standardized methods that accurately estimate natural and human caused sources and sinks of greenhouse gases—including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)—at a national level. Such estimates are needed to verify an international climate treaty as well as to detect changes in natural greenhouse gas emissions (such as, large-scale release from methane hydrates) or sinks. Also, better understanding of the global distribution of black carbon (which is soot, rather than a greenhouse gas) would both improve our ability to manage its impact on human health and allow better assessment of its contribution to climate change.

METHODS FOR ESTIMATING GREENHOUSE GAS EMISSIONS

There are three primary methods for estimating emissions of greenhouse gases, all of which could be improved to reduce uncertainties in emission estimates, by implementing the Recommendations presented in the last section below.

1. National inventories of emissions and sinks. Countries report emissions to the United Nations Framework Convention on Climate Change using methods developed by the Intergovernmental Panel on Climate Change. Emissions are estimated by measuring a human activity (e.g., tons of coal burned) and multiplying by an emissions factor (e.g., CO_2 emissions per ton). This method can be applied to achieve different levels of accuracy. Relatively accurate estimates are based on country-specific emissions factors and sophisticated models of emission sources. This method is capable of producing reasonably accurate estimates of fossil-fuel CO_2 emissions and sinks, but with larger uncertainties for most other greenhouse gases.

2. Atmospheric methods. The net sum of human and natural sources and sinks can be estimated using atmospheric and/or oceanic measurements (including remote sensing from satellites) of the gases and state-of-the-art mathematical models of air and water flow. These methods offer an opportunity to provide an independent check on inventory estimates. However, they cannot yet be used to estimate greenhouse gas emissions and sinks with sufficient accuracy at the national level, because of: transport error; large and incompletely understood background fluctuations of natural emissions; and the small number and uneven geographic distribution of sampling stations. For example, current atmospheric sampling grids largely avoid major emitters like cities, making it difficult to interpret satellite observations. Moreover, air samples are not analyzed for all isotopes of interest: for example, measurements of radiocarbon [^{14}C] would enable fossil-fuel CO_2 emissions to be separated from non-fossil-fuel sources and sinks).

Black carbon, which also influences atmospheric temperatures, is generally monitored as part of air pollution programs.

3. Direct inventories for land use. Sources and sinks of CO_2 can be estimated using time series of measurements at or near ground level (e.g., above- and below-ground change in carbon content of an ecosystem), and satellite measurements of deforestation and reforestation. If all sources and sinks were measured, CO_2 from ecosystems could be estimated with sufficient accuracy. Estimates of some greenhouse gas emissions are reasonably good (e.g., methane emissions from cattle), but estimates of other greenhouse gases and sources are poor. N_2O emissions vary over space and time, depending on how the land is used (particularly the application of nitrogen fertilizer) and on the local climate, topography, and soil and vegetation properties. Improved fundamental understanding is required before accurate estimates of N_2O can be made.

RECOMMENDATIONS

The ability to accurately estimate greenhouse gas sources and sinks is a prerequisite for international agreements or national emission reduction programs to be effective. This ability depends on improved knowledge and understanding of the sources and sinks of greenhouse gases; the coordinated observation of sources and sinks from surface, airborne, and space-based systems; and open access to information from all countries. Key gaps in knowledge could be filled within a few years by refocusing existing measurement programs on greenhouse gas sources and sinks that are important in each country or region. Implementing the first two steps below would yield the capability to accurately estimate and independently verify emissions of CO_2 from fossil-fuel use and deforestation, which are responsible for about three-quarters of emissions covered under the UNFCCC. Implementing the third step would improve fundamental understanding of the carbon cycle.

1. Annual measurement and report by all countries of the greenhouse gas emissions and sinks that currently can be estimated accurately, including CO_2 emissions from fossil fuel burning and from land use and CH_4 emissions from industrial and biogenic sources. The international science community should assist some countries to build the capacity needed to create accurate inventories of these emissions and sinks.

2. International coordination and cooperation to improve the technology and methods for estimating greenhouse gas emissions and sinks and to adopt appropriate new approaches or technologies as they emerge. A concerted effort for sharing state-of-art technologies, deploying cost-effective measurement instruments around the world and in space, and collaborations for combining and analyzing ground and satellite data would speed results and also build science capacity. Such an effort requires exchanges of measurement and analysis methods and established standards for assessing data quality and estimating uncertainty.

3. International and multidisciplinary research programs should be established or enhanced to focus on understanding the possibility of changes resulting in major and/or rapid increases in atmospheric greenhouse gases. The largest risks include the potential release of CO_2 and/or CH_4 from high latitudes, ocean sediments, changes in ocean biogeochemistry and circulation, and changes in the rain forest carbon budget. It is important to analyze those greenhouse gas fluxes in the framework of global biogeochemical cycles.

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