

## Research Plan 2006–2010

# Risk and Vulnerability Program

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## Abstract

The long-term aim of the IIASA Program on Risk and Vulnerability (RAV) is to conduct conceptual and applied analyses that contribute to decreasing the risk and vulnerability of societies and ecosystems, and promoting their adaptation and resilience, to stresses imposed or aggravated by global change phenomena. The research will be relevant mainly, but not exclusively, to developing countries. By addressing the social, economic and ecological system, and considering multiple stresses and system resilience, vulnerability as a research-organizing concept is more complex than risk. Addressing this complexity is the fundamental challenge of this research program. The specific goals of the program are fourfold: to advance the conceptual and methodological development of risk and vulnerability research; to carry out selected risk and vulnerability assessments; to carry out integrative stakeholder-led case studies; and to develop interactive tools that can provide training on vulnerability and adaptation. In support of these strategic goals, seven projects are planned for 2006. The program will build on the methodologies, activities and experience gained from the previous IIASA Risk, Modeling and Society (RMS) Program, will integrate across other IIASA programs (including the Greenhouse Gas Initiative) and will link closely with the vulnerability/resilience research communities.

## Introduction

Global trends in population, urbanization, land and water use, mobility, trade and climate (among others) are imposing stresses and risks on societies and their environments worldwide; yet, the impacts differentially affect people – their livelihoods, health, institutions and ecosystems. Over 400 million people, mainly in developing countries, face water scarcity, and nearly two billion people suffer from hunger and chronic nutrient deficiencies. Among the major food security threats on the horizon are climate change, the altering of nutrient and water cycles, the loss of diversity of plant and animal species and the rise of food borne illnesses (Steffen *et al.*, 2004). Climate change, and more importantly urbanization and land use, are also expected to contribute to the growing human and economic toll of weather-related disasters. In the past decade, some 96 percent of deaths from floods and other weather extremes occurred in developing countries (Freeman *et al.*, 2002). Vulnerability to food and water shortages, and the vagaries of weather, is intensified by disease. Several known diseases have re-emerged or spread geographically, and many new ones have been identified over the last three decades, again disproportionately affecting the poor.

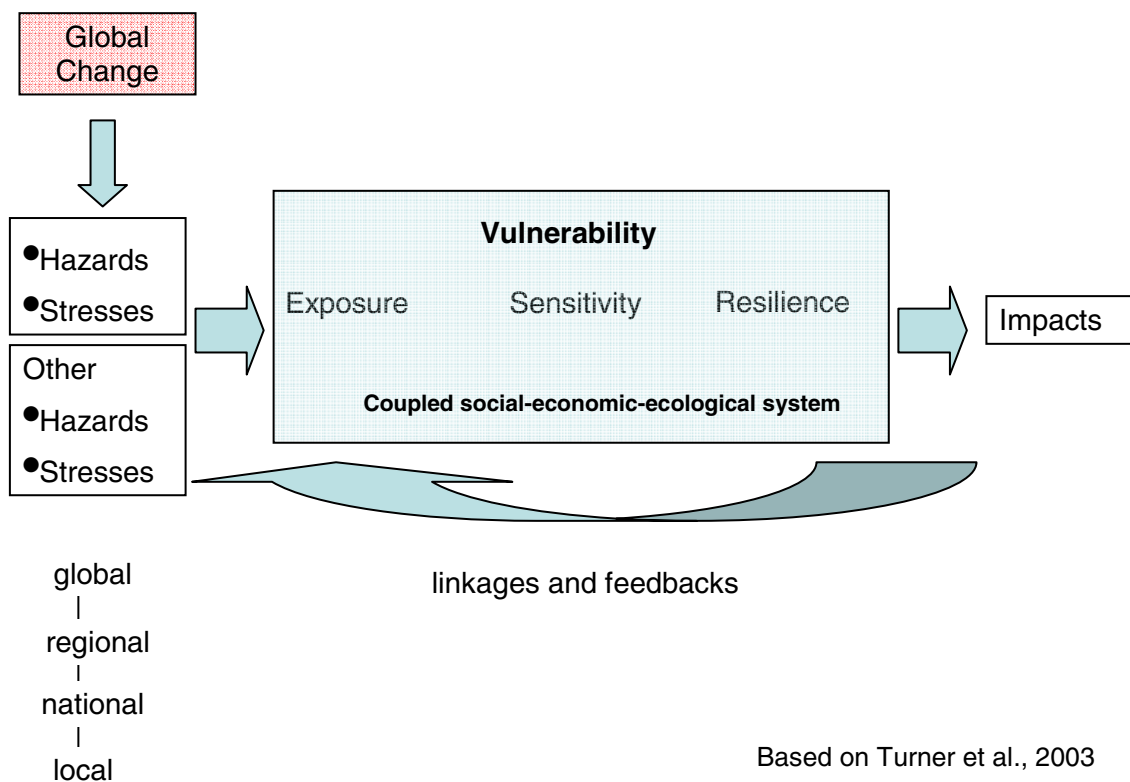
Research addressing risk and vulnerability is motivated by the differential needs of people and their environments, and also by the emergence of these concerns on international, national and local policy agendas. Within the climate-change policy context, the UN Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol call on developed countries to assist developing countries that are particularly vulnerable to the adverse effects of climate change in meeting the costs of adaptation. Composite information on relative and differential vulnerability, possibly informed by “vulnerability indicators”, can help determine eligibility for adaptation funds. Beyond assisting adaptation, understanding risks and vulnerability, as well as the opportunities, constraints and costs of adaptation, are essential for addressing the commitments of subsequent protocols. Perhaps the most critical question for the post-2012

negotiations, and for integrated assessments, such as IIASA's Greenhouse Gas Initiative, is the relative benefit of investing in mitigation and adaptation, a question which can only be answered with a conceptual and empirical understanding of vulnerability.

Risk and vulnerability research has applications far beyond the issues facing the climate-change community. Policy makers at all scales will increasingly address hazards and stresses, including topical issues like earthquakes-tsunamis, infectious diseases, and loss of biodiversity, that are aggravated by global trends in population, land use, mobility and urbanization, to name a few. Risk and vulnerability assessments that take account of the multiple and interlinked stresses on societies and their supporting ecosystems can potentially assist public and private policy actors in developing appropriate responses. At the very least, attention to vulnerability will raise awareness of today's global hazards and the differential toll they take on people and their environments. Vulnerability assessments linked to sustainability can also serve international initiatives, such as the IHDP, IGBP and the Millennium Ecosystem Assessment.

## Background

As an analytical term, vulnerability has been used in a confusing array of disciplinary contexts, including geography, risk and hazard, anthropology, engineering and ecology. Vulnerability as commonly defined in the context of climate change (e.g., IPCC, 2001) is a function of both potential impacts and society's capacity to adapt to these impacts. A narrower definition that focuses only on the impacted system is common in the risk/hazards and vulnerability communities. Turner *et al.* (2003) define vulnerability as the degree to which a system or subsystem is likely to experience harm due to exposure to a hazard, either as a perturbation or stressor. Based on Turner *et al.*, a framework for characterizing vulnerability is shown in Figure 1. In this framework, multiple hazards can be caused or aggravated by global change



**Figure 1:** Vulnerability to global change.

phenomena, where vulnerability is a function of the exposure, sensitivity and resilience of the system in question. Risk, alternatively, is a function of the hazard (likelihood and severity) and its potential consequences (exposure, sensitivity), but usually stops short of considering the coping capacity and resilience of the exposed system.

Risk and vulnerability are thus complementary concepts. By some accounts, risk research focuses on the hazard and vulnerability research on the victims; however, these simple characterizations do not capture the full distinctions in the framing and scope of risk and vulnerability research. The single most important distinction of vulnerability research is its focus on the coupled social/economic and ecological system. Unlike risk in its traditional usage, vulnerability must be understood in the context of a human and environmental view of the world; efforts to reduce vulnerability will fail if they do not enhance ecological life-support systems (Clark *et al.*, 2002). A second distinguishing characteristic of vulnerability research is the inclusion of multiple stresses, some, such as nutrient loading or infrastructure development, accumulating over time scales longer than conventional frames used for management. Whereas risk research developed in the often contentious context of introducing hazards into society (for example, toxic chemicals or hazardous technologies), vulnerability research originated with concerns about the ability of communities to deal with hazards or perturbations for which they have little control (for example, climate change impacts or currency exchange rates). By focusing on the recipient, vulnerability analysis is not limited to a single hazard or stressor, but encompasses multiple, interacting perturbations, as well as the capacity of the system (at different nested scales) to cope or respond. Unlike risk in its traditional usage, vulnerability to long-term global phenomena is thus fundamentally linked with sustainable development. Moreover, since systems continually adapt to the stresses to which they are exposed, vulnerability must be understood as adaptive and dynamic.

A key concept in vulnerability research is resilience, which refers to the capacity of the system to absorb disturbances and reorganize while undergoing change so as to retain essentially the same function, structure and identity (Walker *et al.*, 2002). Ecosystem resilience has been examined as it relates to productivity and population density (Carpenter and Cottingham, 2002), functional redundancy within similar scales (Peterson *et al.*, 1998, Sendzimir *et al.*, 2002), systemic structure (Sendzimir *et al.*, 2005) and catastrophic shifts (Scheffer *et al.*, 2001). Not so dissimilarly, previous work within IIASA's RMS Program examined economic resilience to shocks as it relates to macroeconomic stability, fiscal soundness and diversification (Mechler *et al.*, 2005).

Vulnerability as a research-organizing concept is thus more complex than risk, and this complexity is both its strength and its weakness. Its strength lies in its integration across multiple stresses, recipients (human and environmental) and temporal/spatial scales. Its weakness lies in the difficulty of carrying out empirical case study research at this level of complexity, and vulnerability assessments have generally lacked the empirical rigor of risk assessments. Indeed, few, if any, have met the ambitious aspirations of the vulnerability community (Kelly and Adger, 2000; Smit *et al.*, 1999). A second drawback is the mismatch between the vulnerability concept and the policy process (Kasperson and Kasperson, 2001), since few policy makers have a mandate broad enough to address issues at this scope (there are no "vulnerability managers"). The challenge for IIASA's RAV Program is thus to build on the rigor of (more narrowly focused) risk assessments and contribute to the complex science, institutions and policy processes necessary for effectively assessing and reducing vulnerability of coupled human-environmental systems.

Since concepts of risk and vulnerability are part and parcel of complex adaptive systems, IIASA is well suited to carry out this research. The Program will build on IIASA's traditions of systems analysis (for example, the early work of Howard Raiffa, and others, on policy and negotiations under uncertainty, as well as work by C. Holling, and others, on resilience and

adaptive management). IIASA's current strengths and needs strongly support establishing such an interdisciplinary program on vulnerability at the Institute. Specifically, RAV will build on:

- IIASA's expertise on global scenarios, energy, technology land use, forestry, population, climate change, health and negotiations;
- RMS's track record of interdisciplinary, methodological and social science research on risk, vulnerability and governance; and
- IIASA's Greenhouse Gas Initiative, which will benefit from the RAV Program for its modeling framework and policy assessment of adaptation measures.

The RAV Program has strong synergies with other IIASA Programs, and RAV is already engaged in collaborative discussions with the World Population Program (POP) and the planned Health and Global Change project.

## Strategic Goal and Objectives

The overall strategic goal of the RAV Program is to advance scientific inquiry and assist the development of policy strategies that promote adaptation and resilience of societies and ecosystems to stresses imposed or aggravated by global change phenomena. The emphasis will be on moving beyond frameworks and diagnoses and contributing to the design and implementation of adaptation policies. This emphasis on the *science-policy interface* will be a distinguishing feature of the RAV Program. Interdisciplinary research will concentrate mainly, but not exclusively, on developing countries. Four strategic goals will advance these objectives

- **Conceptual and methodological:** Building on the risk/hazards research area, to transfer and develop concepts and methodologies for the purpose of addressing the complexity of social-economic-ecological systems and advancing vulnerability frameworks and research;
- **Assessment:** To develop and carry out studies that characterize (e.g., through indices) risk, vulnerability and resilience in ways that are useful for policy negotiations, processes and decisions;
- **Integrative case studies:** To design and implement policy tools and stakeholder processes on a case basis (e.g., China's Dongting area) that support the assessment and reduction of vulnerability of social-economic-ecological systems in ways that are considered fair, legitimate and economically sound by those affected (governance).
- **Capacity building:** To carry out analyses and develop interactive tools that can provide insights and training on vulnerability and adaptation for the purpose of assisting national efforts (e.g., government risk management schemes), international efforts (e.g., donor assistance) and international negotiations (e.g., Article 4.8 of the UNFCCC) aimed at reducing risk and vulnerability.

The strategic goals are ambitious in terms of both their scope and complexity. The possible interdisciplinary studies cover many regions of the world with different physical and cultural characteristics, as well as multiple policy contexts. Clearly, priorities must be set that bound the RAV Program agenda. For this purpose, RAV will choose assessments and cases according to the following strategic criteria:

- During the early research stages it will be important to build extensively on the past accomplishments and expertise of the IIASA RMS Program, and yet allow exploratory work on addressing the complexity presented by the vulnerability framework;

- At later stages, cases will be selected that more explicitly couple the social, economic, and ecological systems;
- Priority will be placed on timely and topical research that addresses the science-policy interface and that provides potentially useful information to the policy process;
- Cases will be selected to represent a portfolio of locations, sectors and issues, and case methodologies developed that permit generalizations where appropriate, with the primary purpose of creating prototypes that can inform research in this emerging field (with an eye to young scientists in developing countries);
- Priority will be given to cases that promote in-house collaboration and contribute to the Greenhouse Gas Initiative.

## Research Framework

The general framework of RAV will be based on four topics of research:

- (1) Conceptual and methodological development;
- (2) Assessing risk, vulnerability and adaptive capacity;
- (3) Integrative case studies of vulnerability and governance; and
- (4) Building capacity at the local, national and international levels.

Seven projects will address specific problem areas in these topics that promote the overall Program objectives. The objectives and background of the topics and projects, as well as the 2006 work plan, are discussed below. A summary of topics, projects, funding sources and collaborators can be found in *Table 1*.

## Research Projects

### Conceptual and Methodological Development

The objective of this theme is to transfer theory and practice from the risk/hazards areas, as well as develop new concepts and methodologies, for the purpose of addressing the vulnerability of complex social-economic-ecological systems

The appeal of vulnerability research is its underlying systems concept: integration across stresses, recipients (social-economic-ecological) and temporal/spatial scales. Vulnerability rests largely within the conditions and dynamics of the coupled human-environment system exposed to hazards, and vulnerability assessments must be comprehensive, treating not only the system in question but also its many and varied linkages. Risk research, in contrast, has a narrower focus on reducing the hazard or stress and its consequences, with relatively less attention to the capacity of the recipients to cope. More importantly, the risk community has given far less attention to the relation between human and ecological risks, and the imperative to view them as an integrated system. For example, IIASA's RMS study on flood risk management on the Tisza River addressed both the economics of flood losses and the ecological problems in a region with decades of structurally engineered flood measures. Two questions on the Hungarian policy agenda arose: how to reduce and transfer the economic losses from floods?, and whether to choose pilot regions for removing the levees and creating natural reservoirs? The IIASA simulation model illustrated the economic consequences of policy options addressing both issues, but fell short of incorporating the ecological considerations beyond the economic gains from creating natural reservoirs. This raises a hugely important methodological challenge: how

to incorporate the range of social, economic and ecological dimensions into vulnerability analyses and maintain their usefulness in stakeholder-led policy processes? Insights from the vulnerability community, especially scenario-driven participatory processes, will be helpful in addressing this challenge.

The challenge also exists in the other direction – furthering the concepts and practices of vulnerability analysis by building on the long-standing methodological and applied research from the risk/hazards communities. RAV is well positioned to further this cross fertilization with its expertise on, among other concepts, probabilistic methods, pro-active disaster risk management, risk transfer, adaptive management, model-based stakeholder processes and system dynamics modeling. The Tisza flood policy model, to continue the example, took account of complexities often absent in vulnerability studies: large spatial scales, probabilistic distributions with “fat tails”, endogenous uncertainties, interdependencies, non-linear interactions, and plural perceptions of the problems and their solutions. At the same time, RMS models fail to account for multiple stresses, long-term time scales that include climate and other global changes, nor explicitly frame the problem in the context of the coupled social-economic-ecological system. Expanding the scope of the assessments while retaining the probabilistic approach is a methodological challenge that RAV will necessarily confront.

The methodological challenges go beyond model development to designing stakeholder-led policy processes. RAV can build on a long tradition of collaborative work on social complexity, which has addressed the multiple, conflicting and dynamic worldviews of the social actors and their corresponding risk perceptions and myths of nature (Verweij and Thompson, forthcoming; Douglas, 1982). A central thesis of RAV is that when dealing with complex policy issues there is inherent value in engaging the broadest possible array of interests and voices in active debate (see, e.g., Dryzek, 2000; Sabatier and Jenkins-Smith, 1993, Kasemir *et al.*, 2003). The complexity of social systems is mirrored in the environment. Simon Levin describes the biosphere (the Earth’s atmosphere, physical and chemical fabric, and its biological essence) as a prototypical complex adaptive system. As with social systems, understanding the essential features of the biosphere’s internal organization is fundamental to developing effective strategies for sustaining the environment (Levin, 1999). Integrating social, economic and ecological complexity into research that supports policy processes is RAV’s ultimate challenge.

In meeting this challenge, RAV will rely extensively on (integrated) case-based analyses in assessing and reducing risk/vulnerability. Since general conclusions cannot be drawn from case studies that focus on a single location, sector or other risk recipient (for example, the public-private insurance system emerging from the Hungarian Tisza study cannot be transplanted to other countries), it is vitally important to develop general purpose research approaches and tools (for example, the Tisza methodology and approach are being revised and applied in Japan, China and Argentina). Throughout its research agenda, RAV will carry out a cross-cutting project for this purpose.

### ***Cross-cutting Conceptual and Methodological Research Project***

RAV’s conceptual/methodological challenges will be addressed as they cut across the range of RAV’s research topics and projects. The purpose is to develop new concepts and methodologies that can address the complexity of social-economic-ecological systems and advance vulnerability/resilience frameworks and research. The project will be selective over a range of methodological issues, a few of which are listed below:

- What methods could be useful in integrating social, economic and ecological aspects of vulnerability?, or in addressing the spatial and temporal aspects of vulnerability assessments (for example, downscaling from the global climate models)?

- How can probabilistic analyses be integrated into vulnerability studies that rely on deterministic scenarios, for example, the IIASA's scenarios for global human induced climate change?
- What statistical analyses can help identify sectors of biodiversity that are functionally significant, thereby contributing to assessing the ecological components of vulnerability and resilience?
- How can case studies be designed that allow generalizations to different social, economic and ecological contexts?

Selected cross-cutting methodological issues will be tackled in close collaboration with IIASA's programs on Integrated Modeling Environment and Dynamic Systems, and a special effort will be made to engage with the vulnerability and resilience research communities. At this early stage, five specific initiatives can be mentioned:

- Three workshops have or will take place with IHDP-UNU on integrating risk/hazards and vulnerability research;
- RAV will contribute its expertise to IIASA's Methodology Forum, which will address the topic of probabilistic scenario generation;
- In collaboration with ecologists at the University of Umea, RAV is organizing a workshop on advanced statistical methods for detecting functional groups of animal species, e.g. groups that perform the same or similar ecological function over the same space/time scales (ecological redundancy).
- Discussions are on-going with collaborators at Oxford University and the ROKKAN Centre (Bergen), as well as with IIASA's program on Dynamic Systems, to develop and apply agent-based modeling for gaining a better understanding of the dynamics of vulnerable communities; and
- A proposal is in preparation for surveying and developing the vulnerability concept for application to later stages of IIASA's Greenhouse Gas Initiative. This proposal will provide information on feedback loops on greenhouse gas emissions (for example, how might extreme events set back economic development and thus effect GHG emissions?), and, most importantly, input vulnerability assessment into the policy case studies.

In 2006, the work plan in this area foresees RAV contributing at least one paper to the proceedings of the IHDP/UNU workshops addressing risk and vulnerability (a paper in preparation titled "Assessing Financial Vulnerability and Coping Capacity: The IIASA CATSIM Model" will be published in a collection of papers by the United Nations University Press). This paper is the first to directly assess economic vulnerability to extreme events, and it will be of significant interest to vulnerability researchers. A paper is also in preparation for the Umea workshop. In addition, RAV plans early in 2006 to deliver a collaborative proposal (with LUC, FOR and POP) to the GGI on vulnerability research at IIASA. A plan of action for agent-based modeling (ABM) is also envisaged for 2006, and this work will be of general interest to other IIASA programs, many of which are planning ABM applications.

## **Assessing Risk, Vulnerability and Adaptive Capacity**

The objective of this theme is to develop and carry out studies that characterize risk, vulnerability and adaptive capacity in ways that are useful for policy negotiations, processes and decisions

In essence, a risk assessment focuses on a particular hazard or stress (e.g., a toxic chemical, dangerous technology or windstorm) and seeks to assess its probability and consequences, usually to human lives and property. A vulnerability analysis, alternatively, selects a particular

unit of concern (e.g., landless farmers or a forest ecosystem) and seeks to determine adverse outcomes in the face of a variety of stresses. The focus is on exposure, sensitivity and resilience. Each type of analysis serves a different purpose. Risk assessments are helpful in designing regulations and other interventions to reduce the hazard and its consequences. A typical question (and one that RMS is investigating) is: What are the costs and benefits of implementing a large scale polder system for protection against El Nino induced floods in Northern Peru? Vulnerability assessments, alternatively, are more suited for designing interventions that build the capacity of the system to cope or adapt to the stress or hazard. Typical questions (also addressed by RMS) are: How can Mexican rural farmers, who are facing natural hazard risks and (after NAFTA) crop-price fluctuations, make their livelihoods more resilient? How can the GEF prioritize funds for reducing developing country vulnerability to climate change?

As these policy questions suggest, risk and vulnerability assessments – *depending on their purpose* – can be carried out:

- at different nested spatial scales, including local/community, regional, national and international;
- focusing on different sectors or societal segments, e.g., agriculture, public infrastructure, women;
- taking account of selected multiple stresses;
- emphasizing different types of impacts, e.g., economic, health, institutional, and/or ecological; and
- presented in different ways, e.g., there is a current obsession with vulnerability indicators and maps (Morse, 2004), which can be useful for single objective decisions, but that may give a false sense of precision in multi-objective settings.

Ideally, vulnerability assessments are integrated, that is, not segmented according to scale, type of stress, sector or impact; however, in practice it will be necessary to bound the problem and frame the analyses in ways that are empirically manageable and match the relevant policy agenda (Olsson and Sjöstedt, 2004). The challenge for RAV is to adopt a frame broad enough to encompass the systems underlying global change and sustainable development, yet narrow enough to provide insight to the relevant stakeholders and policy process. Priorities must be set in choosing what to assess, and RAV's choices will be driven by the criteria discussed above.

Two projects that advance the topic objectives are planned for 2006: (1) *Vulnerability and adaptation to weather extremes in Europe*, which will be carried out as part of RAV's extensive involvement in the EU integrated project, Mitigation and Adaptation to Climate Change (ADAM), and (2) *Assessing social, economic and financial vulnerability to disasters in megacities*, which will be carried out in collaboration with the Centre for Disaster Information and Technology (CEDIM) run jointly by the University of Karlsruhe and Geoforschungszentrum Potsdam. The challenge is to expand the scope of these projects, which focus on vulnerability to extreme events. It is envisaged that selected future cases (2007 and beyond) will be broader in scope, for instance, focusing more explicitly on ecological or health aspects of vulnerability.

### ***Vulnerability and Adaptation to Weather Extremes in Europe Project***

This research project, which runs from 2006 to 2009, will be part of an EU integrative project on Mitigation and Adaptation to Climate Change (ADAM)<sup>1</sup> RAV will have responsibility for

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<sup>1</sup> The ADAM project is now in contract negotiation stage.

the work package “Coping with Extremes”, which involves seven European collaborators, as well as a policy case study on rethinking development assistance. This work package will quantify weather-related extreme-event risks in Europe and identify high-risk areas (“hot spots”); project these risks to 2025 and 2100; specify present-day economic vulnerability to the risks; identify innovative technologies and social institutions for reducing and transferring extreme-event risks (adaptation); and craft strategic options for mainstreaming and restructuring EU development assistance and humanitarian aid to promote climate-change mitigation and adaptation (and their synergies) in developing countries.

A fundamental question underlying the post-2012 negotiations is: What will be the economic costs of adapting to climate change (e.g., to a 5-degree change in climate versus a 2-degree change)? By quantifying current and future risks of extreme weather in the EU, and identifying the costs of structural/technological and other paths for adapting to extremes (retreat and living with the risks being other paths), the ADAM collaborative project will provide an important piece of the puzzle underlying this post-2012 question.

A great deal of knowledge exists on the risks from extreme weather. The reinsurance industry (e.g., Munich Re), consulting firms (e.g., Risk Management Solutions), multi-lateral financial institutions (e.g., the World Bank), and NGOs (e.g. German Watch) have worked together with RMS in estimating natural disaster risks and devising policy strategies for their reduction. Moreover, a number of EU research projects (MICE, ESPON, MARS, ENSEMBLES) have focused on weather-related risks in Europe. With important exceptions there has been less research on social and economic vulnerability.

This research will assess risks of extreme weather, vulnerabilities and adaptive capacity in Europe, and propose strategies for increasing the resilience of EU member states to climate-related disasters. The research will extend beyond Europe to craft strategic options for mainstreaming and restructuring EU development assistance and humanitarian aid to promote climate-change mitigation and adaptation (and their synergies) in developing countries. The problems with development and humanitarian assistance will not, however, be solved only by mainstreaming climate-change mitigation and adaptation policies into existing programs, although this is an important route to pursue. There is concern, even within the donor community, that development assistance has not been effective in reducing poverty, let alone promoting sustainable development and the Millennium Development Goals. Recent studies have raised the possibility of far-reaching unintended consequences of aid (Sharma *et al.*, 2004). Concern with unintended consequences is especially pronounced in the disaster community, where reactive disaster assistance is increasingly viewed as contributing to disaster risks (UNISDR, 2005). A challenge is to develop innovative stakeholder-led strategic options that take account of multiple voices and development paths.

In 2006, specific deliverables (for which RAV shares responsibility) for the first 18 months of this project are:

- Focusing only on flood risks, a characterization and quantification of public- and private-sector economic vulnerability for selected regions/sectors;
- A report on interviews and design of survey instrument for preparing a catalogue of existing and innovative options for extreme-event adaptation, noting costs, benefits and environmental/social consequences.
- Report on identified developing country regions (in South Asia) and characterization of risk profiles for restructuring the EU’s development and humanitarian assistance to promote adaptation and mitigation through disaster prevention and risk transfer. This will include reporting on

- EU policies that have direct or indirect effects on developing countries, e.g., trade, energy, agriculture, climate change, and an assessment of their consequences for climate mitigation and adaptation; and
- EU development assistance and humanitarian aid policies, and their contribution to climate goals.

The deliverables are the first stage of the final reports of the 3-year ADAM project, and as such they will contribute mainly to the collaborative research agenda of the study partners. The final reports of this EU research will be of great interest to EU policy makers, and also to all parties involved in the post-Kyoto climate negotiations. Moreover, the methodologies developed for the European case can contribute to vulnerability assessments in other countries, including the developing world, as well as to IIASA's Greenhouse Gas Initiative. Thus, outputs of this research are keenly and strategically important to the goals of the RAV research agenda.

### ***Assessing Social and Economic Vulnerability of Disasters in Megacities Project***

The long-term indirect effects of disasters to societies, economic agents and sectors as a consequence of limited coping capacity, and the resulting aggregate macro-economic effects, are not well understood. Research at IIASA (Freeman *et al.*, 2004; Mechler, 2004) has shown that indirect effects can seriously impede the development of developing and emerging economies. A key focus and challenge of this research is to characterize and assess the indirect social and economic consequences of disasters in the highly dynamical context of mega-cities, many of which are experiencing rapid increases in exposure to hazards as well as changing and differential vulnerabilities to those hazards. Begun in 2005 this project foresees completion in 2008.

Istanbul has been selected as the first case study. This mega-city is probably the most severe seismic hot spot world-wide with an estimated 0.41 probability of a severe earthquake, and possible tsunami, occurring over the next thirty years (Parsons, 2004). Policy measures include seismic retrofitting of the housing structure and restricted development in high-risk areas, but the benefits for these costly policies depend on the full social, economic and ecological costs of seismic events. Following Istanbul, it is planned to continue with other case studies in mega-cities exposed to severe natural hazards in India and China.

In 2006, RAV will be responsible for the following deliverables.

- Estimation of human/economic risks in Istanbul in terms of indirect and macroeconomic damages as a function of hazard, vulnerability and assets exposed, taking account of future scenarios of development;
- Qualitative assessment of social and institutional vulnerability; and
- Background paper on current status of Turkish Catastrophe Insurance Pool and stakeholder views on the difficulties in passing the necessary legislation.

The deliverables will be in the form of collaborative reports. A main audience will be Turkish policy makers, who will make use of this information in regulations for seismic retrofitting and premiums on the public-private earthquake insurance. By developing a methodology for assessing indirect impacts, this project is strategically important for RAV's overall aims of integrating social and economic considerations. Papers will be submitted to peer reviewed journals.

## **Integrative Case Studies of Vulnerability and Governance**

The objective of this theme is to design and implement science-based stakeholder processes that further the assessment and reduction of vulnerability of social-economic-ecological systems in ways that are considered fair, legitimate and economically sound by those affected.

Case (and place)-based vulnerability assessments and policy processes are motivated by questions, such as: Who and what are vulnerable to the multiple environmental and human changes taking place at different spatial/temporal scales? What can be done to reduce vulnerability in ways that are cost-effective, fair and credible to those affected? Answers to these questions will require a research agenda that addresses governance, develops methodologies for supporting stakeholder processes, and that focuses on the coupled human-environmental systems.

RAV will inherit the experience and on-going work of the 2004 START/IIASA Vulnerability Institute that brought 20 young researchers from developing countries to IIASA for three weeks to develop their skills in carrying out research on vulnerability. These scholars have subsequently embarked on case studies in their countries, many of whom are developing stakeholder approaches for reducing vulnerability. Five of these researchers are supervised by RMS, and the ambition of RAV is to develop its own distinct case approach that can serve as a prototype for use by developing country (and other) researchers.

RMS's model-based, stakeholder case of flood risk management in the Upper Tisza area (the Tisza study) will provide a useful point of entry. Yet, the Tisza study did not fully incorporate the factors necessary for an integrated case study on vulnerability and governance. To broaden the issues, and especially to integrate the ecological concerns, the research team will incorporate recent, and closely related, research on "resilience analysis", specifically the work by Brian Walker and his colleagues (e.g., Walker *et al.*, 2002). This work is based on a shared skepticism of optimization tools for addressing policy issues characterized by massive uncertainties in the probabilities and outcomes, possible thresholds, and multiple decision makers. Instead of finding the "best solution", the emphasis is on maintaining the capacity of the system to cope with whatever the future brings (note that this approach cannot apply to infrequent, very high consequence risks). Emphasis is on adaptive capacity, which is an aspect of resilience reflecting learning, flexibility to experiment and adopt novel solutions. Moreover, for effective implementation the coping strategies must be considered legitimate and fair by the stakeholders. In the words of Walker and his colleagues: "Expert solutions may maximize something, but they rarely maximize legitimacy" (p. 31). Borrowing from experience with adaptive management, the authors suggest a four-step resilience analysis for social-ecological systems (SES) that is conceptually quite similar to the Tisza approach:

- Describe the historical development of the SES system;
- Explore visions, create scenarios with stakeholders;
- Develop models and reflexivity for analysis; and
- Evaluate policy and management options with stakeholder involvement.

In two important aspects, the Tisza project extended beyond the work of Walker and his colleagues by (1) recognizing the multiple perceptions, world views and ideas of fairness that stakeholders bring to the policy process and (2) by developing probabilistic model scenarios. The "multiple perspective" research will form a part of the conceptual foundation of RAV's integrated case studies. Details can be found in a forthcoming collaborative book with Oxford University, titled *In All Fairness* (J. Linnerooth-Bayer, M. Thompson, and R. Ervik, editors).

The challenge of the approach by Walker *et al.* (2002), which cannot be repeated often enough, is coupling the human and environmental systems. In the early stages of the Program, this challenge will be taken up in two integrated case study projects: In collaboration with Beijing Normal University, the first project will assess and reduce the vulnerability of social-economic-ecological systems in the Dongting Lake area of China. The second case, which will take place within the EU integrated project NeWater, will focus on European river basins, including the Tisza, and explore different transition paths from currently prevailing regimes of river basin water management into more adaptive future regimes. Both projects are integrative and systems oriented in the sense of coupling human and ecological concerns, incorporating science with stakeholder-led processes and framing the problems over broad temporal and spatial scales.

Before describing these two projects, it should be noted that RAV is already considering further case studies. Proposals have been submitted for (a) Adaptation to Climatic Variability and Change in the Middle East and (b) Adaptation and Livelihood Resilience in South Asia (with ISET, Oxford University and the ROKKAN Centre). In collaboration with IIASA's World Population Program, discussions are ongoing to examine risk and vulnerability of the Nicobar Islands after the tragic tsunami disaster of 2004. Negotiations are also underway on a World Bank funded case study on risk and vulnerability of the Philippines. Finally, very preliminary discussions are taking place with the International Centre for Theoretical Physics for a workshop/study on several possible topics, including the risks/vulnerabilities of coastal fishing communities to ocean upwelling.

### ***Assessing and Reducing Vulnerability in China's Dongting River Basin Project***

China's huge Dongting Lake, which is fed by five rivers including the Yangtze, is one of the most serious flood risk areas in China, and the risks are further aggravated by dire ecological problems in the region (lake shrinkage, pollution and over fishing). Flooding can lead to a "spiral of poverty", where farmers lose harvests due to floods and are forced into deeper debt to survive. China has understandably pursued engineered structural measures to reduce the flood hazard, but recent evidence throughout the world reveals ecological consequences from high dams, levees and other control structures. The Chinese government has recently taken both structural and non-structural measures to reduce the flood risks in the Dongting area (the Three Gorges dam project and the relocation of people and crops out of the highly exposed reclaimed land, dredging the lake, and reforesting large areas of cropland upstream). Still severe flooding can be expected, as well as continuing environmental deterioration, and the government would like to increase the resilience of the region. There is high-level interest in a public-private system for transferring risks (insurance) and sharing losses (solidarity) that, at the same time, provides incentives for loss-reduction measures. An acceptable and workable system will require knowledge of the risks and input from the stakeholders, including the residents of this area, Chinese and foreign insurers, and local/national government officials. True to the vulnerability framework, the development of an insurance system must be fully integrated into measures for promoting the sustainability of the region.

The Dongting collaborative research project, with a duration through to 2007, will encompass the following tasks:

- Model flood exposure and potential losses in the Dongting area with a focus on the Xiang river;
- Characterize the vulnerability of the households, businesses and governments of the region to flood risks and ecological deterioration;
- Examine the institutional setting, constraints and potential development of a public-private insurance system that is integrated with incentives for loss reduction and sustainable development;

- Conduct interviews with the stakeholders to assess their views on loss reduction, risk-transfer arrangements and sustainable development of the region;
- Based on the model and interviews, develop policy options (with stakeholders) for reducing risks and promoting sustainable development.

In 2006, RAV will supervise the Chinese (mainly students) carrying out this research project. Beginning already in summer 2005, a BNU student will join the YSSP to begin this research. In 2006, it is envisaged that RAV will interactively develop the stakeholder interview guidelines, as well as a questionnaire for assessing the institutional setting, constraints and potential development of an incentive-compatible public-private insurance program. This initial work is critically important for the success of the project, especially in integrating the economic with the social/ecological objectives of the research. The design of the interview protocol and questionnaire prototype will be of substantial relevance to other RAV case studies. Depending on the selection of the GGI case studies, the Dongting case could be an early start on a China case.

### ***Case Studies on Developing Adaptive River Management Regimes Project***

Technical solutions are no longer sufficient to tackle rising complexity in water management. Scaling issues need to be explored to understand the complex dynamics of institutional resource regimes and to improve the match between biophysical and actor based scales. Equally important are issues of good governance, with the human dimension in a prominent place. The strong tradition of local and regional water resources management has to be combined with integrative river basin approaches by embedding them in a perspective of change at multiple scales. This necessitates linking research areas heretofore developed rather independently with little exchange among them.

The purpose of the EU integrated project, NeWater, is to explore different transition paths from currently prevailing regimes of river basin water management into more adaptive future regimes. While integrated water resource management (IWRM) is widely accepted as the appropriate framework to deal with complex water resources management issues, the current IWRM concept does not elaborate on water management under uncertainties, nor does it fully develop approaches and methods towards adaptive water management strategies. Adaptive management is a key concept in the resilience literature and practice. It seeks to aggressively use management intervention as a tool to strategically probe the functioning of a social or ecosystem. This approach is very different from a typical management approach of 'informed trial-and-error' which uses the best available knowledge to generate a risk-averse, 'best guess' management strategy.

RAV is leading a work package of the NeWater project with the purpose of identifying and modeling key elements of current water management systems and the transition of these elements to adaptive IWRM. The project will examine a number of river basin cases, including the Amudarya in Uzbekistan and the Hungarian Tisza river (building on earlier RMS research). RAV staff will collaborate with colleagues from, among others, Wageningen University, the University of Osnabrück, Stockholm Environment Institute and the Potsdam Institute for Climate Impact Research.

In 2006, the expected results of RAV's work on this project are:

- A report on methods applied in the Rapid Vulnerability Appraisal of the Tisza and Amudarya river basins, including indicators of resilience and adaptive capacity;
- Prototype systems-dynamics and agent-based models of interacting factors that influence resilience and adaptive capacity of the river basins; and

- A report on the integrated conceptual framework and protocol for evaluation tools for the transition to adaptive management in river basins.

These reports/models will be essential for meeting the ultimate goal of NeWater, which is to identify key typical elements of current water management systems and ways to transition these elements to adaptive IWRM. This project goal, in turn, serves the strategic goals of RAV by contributing research informed by stakeholder processes, which ultimately promotes adaptation and resilience of societies and ecosystems. Most importantly, the NeWater will contribute to the methodology of model-based, stakeholder case studies. The audience, therefore, extends beyond the European Commission to researchers and practitioners. It is envisaged that the results of NeWater will be published in a book with accompanying journal articles.

## **Building Capacity at the Local, National and International Levels**

The objective of this theme is to carry out analyses and develop interactive tools that can provide insights and training on vulnerability/adaptation for assisting local, national and international efforts/negotiations aimed at reducing risk and vulnerability to global change.

At the international level, RAV will continue to develop strategies for implementation of Article 4.8 of the UNFCCC, which calls upon developed countries to consider actions, including those related to insurance, to meet the specific needs and concerns of developing countries with respect to the adverse impacts of climate change. RMS has published extensively and participated in the UNFCCC Conference of the Parties (COP) capacity building workshops for the purpose of developing financial strategies that will increase the resiliency of developing countries to weather-related extremes (Linnerooth-Bayer *et al.*, 2004). International support for financial adaptation strategies could take many forms, including provision of: (1) a backup for public-private insurance systems (e.g., like that developed by the Tisza study); (2) for micro-insurance and other low transaction cost disaster hedges; (3) subsidies for risk-transfer instruments (e.g., catastrophe bonds) for asset losses at the national and regional levels.

The RAV Program's contribution to building the capacity of negotiators and policy makers will not be limited to implementation of Article 4.8 of the UNFCCC. Moving from the international level, RAV will undertake research that develops tools for building capacity at the local and national level policy levels. The research will build on the interactive CATSIM tool (CATastrophe SIMulation model), which simulates catastrophic risks at the country level and illustrates the costs and benefits of financial tools for reducing and transferring these risks (Mechler *et al.*, 2005). This tool has already been successfully tested at an IIASA workshop that brought policy makers from five developing countries, and the World Bank is planning to fund a study and workshop addressing disaster vulnerability in the Philippines.

Two projects are initially planned for this topic, including the *Munich Initiative on insurance-related instruments* and *Interactive tools for supporting adaptation*.

### ***The Munich Initiative on Insurance-related Instruments Project***

In 2002, RMS contributed the background paper to a meeting convened to examine the possibilities for implementing Article 4.8 of the UNFCCC (In collaboration with the PIN Program, this paper is being further developed). Later, IIASA's ideas were presented at the 2005 Kobe World Conference on Disaster Reduction. At the initiative of RMS, Munich Re organized a recent follow-up meeting that brought together researchers, NGOs and practitioners interested in implementing insurance-related products. From this meeting a group of collaborators have established the "Munich Initiative" with the purpose of building the capacity of negotiators in addressing Article 4.8 of the UNFCCC, which calls upon developed countries to consider insurance-related instruments for reducing the vulnerability of developing countries to climate-change impacts.

The questions RAV will address in this project are: How can developed countries support insurance-related climate instruments to render them affordable to poor households, businesses and governments in highly exposed developing countries? How can these instruments be coupled (e.g., through incentives) with risk reduction and sustainable development? These questions raise a host of related issues that will be addressed by the Munich Initiative, including

- Which regions will be most affected by risks increasing due to climate change?
- What types of insurance-related instruments should be considered?
- How can the developed countries support these instruments/partnerships?
- How can these instruments/partnerships be coupled with a reduction of physical and ecological losses?
- What are the political barriers (e.g., the role of OPEC countries, the coupling of insurance with liability)?

In 2006, RAV will work closely with the Munich Initiative in addressing these questions and, generally, building capacity of the negotiating community on this issue. Specifically, RAV will take the lead on a “think piece” addressing “Options for an international insurance related mechanism”, which will be the basis for discussions at a capacity building side event planned for the forthcoming COP11 in Montreal.

### ***Interactive Tools for Supporting Vulnerability Reduction Project***

According to the well-known Arrow-Lind theorem, the public sector can be considered risk neutral with respect to its financial planning for rare but extremely costly events (Arrow and Lind, 1970). Since the government’s post-disaster expenses can be spread over a large base of taxpayers, public authorities are not risk averse and therefore should not purchase insurance or other financial hedging instruments. Disaster risks and other stochastic shocks to public budgets can thus be ignored in public planning and budgeting decisions. Recent research undertaken by RMS, however, has shown that this theorem does not hold for hazard-prone developing countries if their tax base is too weak to sufficiently spread the risk and if the pool of publicly owned assets is too narrow for sufficient diversification (Mechler, 2004). In other words, it will not hold if the state is not resilient to the economic losses from disasters.

The RAV Program’s research on financial vulnerability to stochastic extreme events is based on an RMS study carried out for the Regional Policy Dialogue of the Inter-American Development Bank (Freeman *et al.*, 2002). For the first time, an approach was developed and applied to identify countries that are financially vulnerable to extreme events, that is, countries where disasters have the potential to swamp the government’s ability to finance the recovery process. The approach has subsequently led to the interactive CATSIM tool, which was successfully tested at an IIASA/World Bank workshop with representatives from five developing countries. The participants agreed that CATSIM has significant practical application for building the capacity of policy makers to evaluate ex-ante financial instruments, including insurance, catastrophe bonds, contingent credit arrangements and other disaster hedges, and compare their benefits with investments in loss reduction.

In 2006, the RAV Program will build on the success of CATSIM by further adapting the tool for the needs of highly exposed developing countries. With financial assistance from the Austrian National Bank, in 2006 the CATSIM methodology will be improved to yield an optimal mix of ex-ante and ex-post measures by solving a multi-stage stochastic optimization problem. In addition, the model will be developed to better incorporate changes in land use and climate. It is anticipated that in 2006, CATSIM will be the basis of a World Bank funded study and workshop addressing disaster vulnerability in the Philippines. RAV will provide the study and preparatory work for the workshop.

## Networking and Collaboration

Table 1 summarizes the funding sources and main collaborators for the seven research projects planned for 2006. In addition to these projects, RAV will continue its Joint IIASA-DPRI Annual Meeting on Integrated Disaster Risk Management (sponsored by Beijing Normal University in 2005, and Bogazici University in Istanbul in 2006). Most importantly, RAV will continue in-house collaboration. Foremost on this list, RAV will take the lead in developing a proposal on vulnerability for the Greenhouse Gas Initiative, in collaboration with IIASA programs on World Population (POP), Land-Use Change (LUC), and Forestry (FOR), and possibly other projects. RAV is also discussing possible collaboration with the planned IIASA project on Health and Global Change in identifying case studies of vulnerability to infectious diseases. A case on the Nicobar Islands might also be undertaken jointly with the POP Program.

**Table 1:** Topics, projects, funding and collaboration (2006).

Topics	Projects	Relevant Externally Funded Project	Funder	Selected Collaborators
<b>Conceptual and Methodological Development</b>	Conceptual and methodological development			Barbara Goebel (IHDP) Janos Bogardi (UNU-EHS) Joern Birkmann (UNU-EHS)
<b>Assessment of Risk and Vulnerability</b>	Vulnerability and adaptation to weather extremes in Europe	Adaptation and Mitigation Strategies: Supporting European Climate Policy (ADAM)	European Commission	Mike Hulme (Tyndall Centre) Richard Klein (PIK) Joyeeta Gupta (IVM) Other partners include: JRC, CICERO, Univ. of Maastricht, Wageningen Univ., Polish Acad. of Sciences, Univ. of Florence
	Assessing social and economic vulnerability of disasters in mega-cities	Assessing indirect socioeconomic impacts of a future earthquake in Istanbul	Center for Disaster Management and Risk Reduction Technology (CEDIM, Karlsruhe)	Ute Werner (Karlsruhe U.) Jochen Zschau (GFZ-Potsdam)
<b>Integrative case studies</b>	Assessing and reducing vulnerability in China's Dongting river basin (2005–2007)	Vulnerability in Dongting Lake Basin of China	National Natural Science Foundation of China	Peijun Shi (BNU) and students
	Case studies on developing adaptive river management regimes	New Approaches to Adaptive Water Management under Uncertainty (NEWATER)	European Commission	Thomas Downing (SEI) Claudia Pahl-Woestl (U. Osnabrueck)
<b>Capacity building</b>	The Munich Initiative on insurance-related instruments	Munich Initiative	None	Peter Hoeppe (Munich Re) Ian Burton (formerly Environment Canada)
	Interactive tools for supporting vulnerability reduction	Public Sector Financing of Disaster Risk	Austrian National Bank; World Bank (tentative)	

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