Global Environmental Change 20 (2010) 266–277

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

Barriers in the science-policy-practice interface: Toward a knowledge-action-system in global environmental change research

Juergen Weichselgartner [a,*], Roger Kasperson [b,1]

[a] Institute for Coastal Research, GKSS Research Center, Max-Planck-Strasse 1, 21502 Geesthacht, Germany
[b] George Perkins Marsh Institute, Clark University, Worcester, MA 01610-1477, USA

ARTICLE INFO

Article history:
Received 16 May 2009
Received in revised form 17 November 2009
Accepted 18 November 2009

Keywords:
Knowledge systems
Science-practice interface
Vulnerability
Global environmental change
Disaster mitigation
Hazard research

ABSTRACT

This paper presents the results of a case study analysis from the knowledge domains of vulnerability and resilience. We analyzed 20 scientific assessments to provide empirical evidence for successes and failures in collaborative knowledge production, i.e., the joint creation of assessments reports by researchers and decision makers in policy and practice. It became clear that the latter typically use insufficiently the research-based knowledge available and researchers typically produce insufficiently knowledge that is directly usable. We found a number of functional, structural, and social factors inhibiting a joint problem identification and framing of knowledge producers and potential users: divergent objectives, needs, scope, and priorities; different institutional settings and standards, as well as differing cultural values, understanding, and mistrust. Combining understanding from multiple sources and providing mechanisms for linking solutions proposed by research with articulated needs and problems of practitioners would reduce the discrepancies in activities of different actors and result in more timely and context-appropriate solutions. In the concluding section we argue for a more locally embedded and socially contingent production of actionable knowledge and make suggestions about ways to enhance effectiveness of research-based knowledge.

1. Introduction

Coupled human–environment systems are undergoing rapid changes and therefore are committed to adapting to changing conditions. This makes the understanding of response mechanisms – and hence the state of vulnerability and resilience – one of the most important issues for society in general, and for science in particular. In recent years, natural risk management has increasingly included scientists and practitioners from various fields, special research programs and institutes, numerous journals, advanced technology, private companies, and NGOs; in short, it includes a huge variety of knowledge systems and resources (Weichselgartner, 2006). At the same time, great natural disasters set new records each decade, and the trend towards higher and higher losses continues (Munich Re, 2006). This paradox of concurrent increases in economic loss and in disaster-related research, precisely described by White et al. (2001) as "*knowing better and losing even more*", brings the production and use of knowledge in the disaster-related domains to the foreground. Is the knowledge base inadequate despite the increasing research effort, or is it that existing knowledge is not applied or not used in an effective way? This in turn raises the possibility that existing research-based knowledge is being blocked by fundamental barriers, in addition to increasing vulnerability to global change processes.

White et al. (2001) illuminated the gaps between what is known about natural hazards and disaster mitigation, on the one hand, and how research findings are translated into policies and programs, on the other hand, and offer two concluding observations: (1) better appraisal is needed of the actual results at community and other levels of applying the best available knowledge in the best possible way and (2) there is a need to build upon past achievements in creating more understanding of natural hazards, by better integration of the knowledge into the wider efforts directed at sustainable development. Complementing these findings, Weichselgartner and Obersteiner (2002) have argued that the increase of disaster losses is also a consequence of unsatisfactory transformation of existing knowledge, i.e., converting theoretical research findings into concrete actions in practical disaster management. Moreover, complex cognitive processes, such as perception, learning, and communication, are strongly linked to the management of global environmental risks (The Social Learning Group, 2001) and "insufficient" knowledge is an important part of the hazard problem (Weichselgartner, 2006).

* Corresponding author. Tel.: +49 4152 871542; fax: +49 4152 872040.
E-mail addresses: juergen.weichselgartner@gmail.com (J. Weichselgartner), rkasperson@clarku.edu (R. Kasperson).
[1] Tel.: +1 508 751 4607.

0959-3780/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.gloenvcha.2009.11.006

Given the situation that less effort has been made to improve the existing gap between scientists (the knowledge producers) and decision makers in policy and practice (the knowledge users), we were interested in the influence of scientific assessments on decision making in the practical disaster mitigation arena and the barriers that inhibit the involvement of users in the design of assessments. The domains of vulnerability and resilience are context but not focus of our study (for definition and underlying theories see Janssen and Ostrom, 2006; Birkmann, 2006). Vogel et al. (2007) have pointed to persisting problems that hinder the use of vulnerability and resilience 'knowledge' including the difficulties of developing consensus on the methodologies used by different stakeholders; slow delivery of products that could enhance resilience to change, and the time-consuming process of coming to a negotiated understanding in science-practice interactions. We believe that co-producing knowledge – i.e., the joint production of assessments reports by experts and decision makers – better integrates different viewpoints and is more robust to maintain identity across producers and potential assessment user groups and thus develops reciprocal understandings of what salient, credible, and legitimate mean to the others involved (see Cash et al., 2003; Jasanoff, 2004). Moreover, we support Nowotny's appeal for a "*need for socially robust knowledge*" (Nowotny, 1999; Nowotny et al., 2001). In her opinion, a 21st century view of science must embrace not only the wider societal context, but be prepared for the context to begin to talk back. Reliable knowledge will no longer suffice, at least in those cases, where the consensuality reached within the scientific community will fail to impress those outside. We believe that particularly research on global environmental change (GEC) requires a shift towards a more extended notion of scientific knowledge, namely a shift towards socially robust or context-sensitive knowledge.

We consider the collaborative production of knowledge as a systematic and emergent inquiry process, embedded in a collaborative partnership between scientists, policy makers, and practitioners for the purpose of generating actionable scientific knowledge. Recently, Hurricane Katrina showed that there is a deficit in the application of existing knowledge and a clear need to consider human security concerns, which are shaping the potential and trajectory for cooperative approaches to global environmental governance. Katrina was known to be headed into New Orleans a few days in advance, and the potential damage was known and understood years ahead of time (Travis, 2005). Not surprisingly, investigation of prevention and response processes characterized the event as "a failure of initiative" rather than "a failure of knowledge" (Select Bipartisan Committee, 2006). But there is, of course, a nexus between the two. Both knowledge and initiative require good information and a coordinated process for sharing it.

Here we present a case study analysis of 20 scientific assessments from the knowledge domains of vulnerability and resilience to provide some empirical evidence for gaps and bridges in the science-policy-practice interface (SPPI). The next section gives a brief rationale concerning the study design (for a more detailed description see Weichselgartner, 2007). Thereafter, main characteristics of the assessments are analyzed and key findings of the questionnaire survey are presented. Barriers and bridges in the disaster-related SPPI are examined in the following section. Last but not least, we make suggestions that may be usefully considered by those concerned with improving linkages between research-based knowledge and action to move toward a knowledge-action system in global change research.

Objectives of the study were to identify (i) information sources used by scientists and decision makers, (ii) the influence of scientific assessments on decision makers, (iii) how decision makers evaluate scientific assessments in terms of saliency, credibility, and legitimacy, and (iv) conflicts among actors and arenas at the SPPI. Note that the study should be considered as exploratory, certainly not as exhaustive and definitive. On the basis of a small sample, the investigation attempts to grasp how scientific assessments are carried out and to uncover what limits the collaborative production of knowledge. Both the literature review and questionnaire sample are restricted. We therefore suggest a more comprehensive study that analyzes the full range and quality of linkages between determinants of vulnerability and determinants of the specific assessment, as well as the influencing factors that are responsible for failure and success in bridging the SPPI.

2. Study design and data collection

Ideally, the analysis of the influence of vulnerability assessments should take into account all determinants of a larger social process, ranging from vulnerability-determining factors to the assessment process and its impacts on disaster mitigation practice. As illustrated in the conceptual framework elaborated (Fig. 1), an analysis of vulnerability assessments and their influence is a challenging endeavor, requiring a great amount of resources. However, this said, the authors' intension is neither to specify factors for conducting vulnerability analyses nor to critique nor promote specific frameworks or methods. Rather, their premise is that analyzing case study results can bring some light to the clouded interpretation of barriers and bridges in the SPPI and thus support collaboration between scientists and practitioners in the field of GEC.

Given the availability of time and work force for the study, the work focuses on the identification of potential linkages between specific vulnerability and assessment determinants and failure and success in bridging the SPPI. The vulnerability framework developed by Clark University and the Stockholm Environment Institute (Turner et al., 2003) serves as a basis for the determinants of vulnerability. In determining factors of knowledge transfer and influence, this study builds on research undertaken by the Science, Environment and Development Group at Harvard University's Center for International Development (Cash et al., 2003; Mitchell et al., 2006). Of particular interest for this study is the finding that saliency, credibility, and legitimacy are critical attributes of an assessment about which audiences make judgments, and which determine whether they will change their thoughts, decisions, and behavior.

2.1. Case study search

The overall goal of the study is to investigate the interface between the science developed in vulnerability/resilience assessments and the actions put into practice by those people in positions to implement that research-based knowledge in mitigating natural disasters. Consequently, assessment selection was made on breadth rather than on depth so as not to limit the study to a bias from a particular subset of assessments, whether by region, hazard type, or publication method.

Most research results in the knowledge domains of vulnerability and resilience are published in journals. The *Hollis Catalog* of the Harvard University Libraries, *Google Scholar* and the *Social Science Citation Index* (SSCI) were used to identify published material for the meta-analysis. The latter is provided by the Institute of Scientific Information; the *Hollis Catalog* contains over nine million records for more than 15 million publications in all kind of formats. Identification of literature was based on a keyword-based search across these databases. Keywords that were combined with vulnerability and resilience used to retrieve papers for the two knowledge domains included: natural hazard, hazards, assessment, assessing, evaluation, coping, response, case study, and

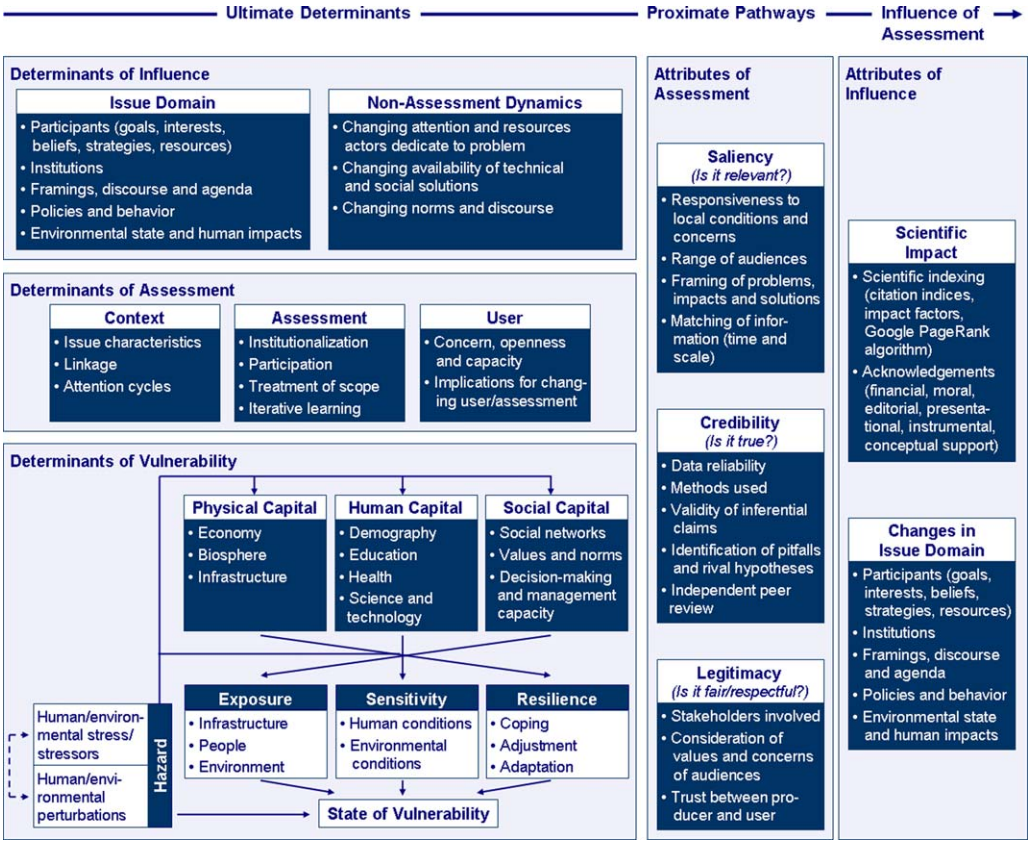

Fig. 1. Conceptual framework for analyzing the influence of vulnerability assessments.

disaster. Seminal papers that are referred to frequently by key scholars publishing on vulnerability and resilience complemented the keyword-based search.

The acquired dataset has a number of potential shortcomings that introduce bias for particular streams of research. Most significantly, the non-English literature is largely excluded due to the database and keywords used for the literature search. Since the database covers mostly journal papers, particular book chapters and reports might have been missed as they are not included in the SSCI. Moreover, the concepts of vulnerability and resilience have developed over time, and have been used in various ways. As a result, relevant documents are sometimes published in a "non-scientific" form and/or medium or for internal use only. Such documents were not retrieved, nor were ones that did not contain or use the keywords. Additionally, interesting and valuable studies were excluded because their assessment was carried out in locations where identification and contact of potential knowledge users was considered difficult (e.g., extreme rural areas and regions with restricted information available in the Internet). The limitation of these factors was partly balanced by including certain documents in place of others to broaden the set of case studies.

2.2. Case study selection

To provide scope to this research exploration, given the potentially huge database, a number of limiting decisions were made. Each document that was retrieved by keyword-based search was checked manually regarding its suitability for the study. Criteria for the initial selection were publication date, hazard type, and assessment mode and scale. A second criterion was that the paper refers to natural hazards. Studies that focused exclusively on ecological vulnerability or resilience (e.g., animals and plants) or on infrastructure (e.g., buildings and facilities) were excluded. For the remaining publications in the area of natural hazards, a third criterion was that a somewhat concrete assessment was carried out (no theoretical papers). Fourth, it was expected that assessments on local and regional levels would provide more valuable information concerning the identification of successes and failures in the SPPI and therefore, with one exception, national and global assessments were excluded.

The final selection was made to obtain a set of case studies with a broad range across geographic location, hazard type, and recognition of the publication. Recognition was measured by means of the *Social Science Citation Index* (SSCI) recording the number of times the given report was cited; wider public impact was evaluated by the number of *Google* hits each exactly cited publication title earned. Using *Google* English, measurement took place between 19 and 21 May, 2006. In total, 20 case studies were chosen for meeting the criteria of breadth, time, and source of publication, and the potential for relevance to practitioners.

To evaluate the influence of the case studies, two questionnaires were designed: one for case study producers and one for potential users of the case study. Both questionnaires start with a question regarding the use of information sources and are followed by more specific questions concerning the assessment. The questionnaire for the case study authors was designed to ask questions regarding the research process, the intended audience, dissemination of findings, and the SPPI. The questions were followed by multiple choice answers in order to quantify better the responses, but space was left for elaboration and comments, and several questions were open ended. The questionnaire for potential users included questions about the usefulness, scope, and real or future impact of the case study publication. As with the producer questionnaire, questions are a combination of multiple choice and open ended questions, with an emphasis on probing

into the underlying bases of response. In total, 64 people authored the 20 case studies selected. Forty-seven authors were contacted and forty of them participated in the study (85.1% response rate).

Identifying and contacting potential users of each assessment were more difficult. A case study user was defined as a person in a position to put the ideas and knowledge in each report into practice, whether in the context of the government, a non-governmental organization, or a private company. Depending on the results of the assessment, for each case study a strong effort was made to identify potential users whose responsibilities are in the range of the assessment's topic and to select a variety of users from different levels of government, non-governmental institutions, and other areas. Once identified, potential users were contacted first by telephone, and if they agreed to participate in the study, an email was sent with a cover letter containing details on the study, together with the relevant scientific publication and the questionnaire. After reading the publication, the potential users filled out and returned the questionnaire (42.3% response rate). In total, 40 case study producers (14 female) and 52 potential users (12 female) participated in the survey.

2.3. Case study characteristics

In total, 20 case studies were analyzed, which were authored by 64 people (Table 1). Publication dates range from 1998 to 2005 with one unpublished book chapter that was to be published in early 2007. This publication was excluded in the measurement of recognition. Regarding wider public impact as measured by the number of *Google* hits each publication earned, results range from no hits to 10,800. Concerning scientific recognition, SSCI varies from 0 to 64. On the basis of these two factors, publications were grouped in three recognition classes with four assessments in the highly recognized group, six in the medium, and nine in the low-recognition class.

Using the World Bank's country classification which is based on Gross National Income per capita in 2005, 12 case studies are in high-income countries, five in middle-income (both lower and upper middle), and three in low-income countries. Regarding hazard type, 12 case studies refer to a single-hazard and eight to multiple-hazards. Altogether, the case study sample includes fourteen local assessments, five regional, and one national assessment. Another characteristic analyzed is the assessment's capability to integrate multiple-scale, science-practice, and social-physical aspects. When grouped according to the degree of integration, four case studies are considered to highly integrate these factors (at least two out of the three factors), ten assessments did it partly (at least one and the others partly), and six case studies showed little integration (only one or less out of three).

3. Study findings

Table 2 shows some general findings of the questionnaire survey (all percentage rounded). By grouping the answers from assessment producers and potential users, cross-covariance between factors illuminates interesting results and patterns that are discussed below.

3.1. Sources and matching of information

When comparing single and multi-authored studies it appears that single-authored publications mainly draw on scientific literature (71% compared with 39% of multi-authored publications) and use significantly less data and models as information sources (14% compared with 55%). Moreover, the regular use of non-governmental information sources is three times higher for

Table 1
Assessment characteristics.

Date	Journal/Publisher	No. of authors	Hazard type	Location of assessment	Country's income status	Scale of assessment	Recognition of -assessment	Integration of assessment
1999	World Development	1	Climate change, storm	Vietnam	Low	Local	High	Medium
2005	Mitigation and Adaptation Strategies for Global Change	2	Tropical cyclones, storm surges	Australia	High	Local	Medium	Low
1999	Disasters	2	Flood	Canada	High	Local	Medium	Low
2002	Environmental Hazards	2	Earthquake	USA	High	Local	Low	Low
1998	Mitigation and Adaptation Strategies for Global Change	10	Storm, flood	USA	High	Local	Medium	Medium
2005	Environmental Hazards	1	Fire	USA	High	Local	Low	Medium
2000	Annals of the Association of American Geographers	3	Multiple	USA	High	Regional	Medium	Medium
1999	Environmental Monitoring and Assessment	4	Sea level rise	Egypt	Medium	Local	Medium	Low
2004	Cities	1	Fire	Australia	High	Local	Low	Medium
2002	Natural Hazards Review	1	Earthquake	Peru	Medium	Regional	Low	Low
2004	Marine Policy	3	Sea level rise	East Caribbean Islands	Medium	Regional	Low	Medium
2003	Global Environmental Change	5	Climate change, market fluctuations	Mexico	Medium	Local	High	Medium
2003	Environmental Hazards	1	Flood	Pakistan	Low	Local	Low	Medium
2004	Global Environmental Change	11	Climate change, globalization	India	Low	Local	High	High
2002	Natural Hazards Review	1	Multiple	USA	High	Regional	Low	Medium
2004	Coastal Management	2	Earthquake, tsunami	USA	High	Local	Low	High
2002	Mitigation and Adaptation Strategies for Global Change	1	Flood	Philippines	Medium	Local	Low	Low
2003	German Committee for Disaster Reduction	9	Flood	Germany	High	Regional	Medium	High
1999	Joseph Henry Press	1	Multiple	USA	High	National	High	High
2007	Elsevier	3	Sea level rise, flood, surges	USA	High	Regional	N.A.	Medium

Table 2
General findings of the questionnaire survey (percentage rounded).

Knowledge producers
48% formulate their research questions without input from internal or external colleagues
Regularly use scientific (93%), governmental (58%), and non-governmental (43%) information sources
66% consider policy makers and practitioners, 58% science, and 25% non-governmental, public and private organizations as the intended audience for the assessment
35% would change their assessment to include the application of theory and clear recommendations if the purpose of the assessment would have been an action plan for practitioner use
18% consider the involvement of stakeholders as a way to increase the practical use of the assessment
63% disseminate the research in form of reports, 50% through scientific papers, 40% through symposia and meetings, and 20% use the media, Internet, public material, and lectures
63% believe that their assessment addresses the needs of users
45% are not aware of any impact whereas 55% believe that it caused changes
48% believe that their study had impact on science but not on practice
48% believe that differences in objectives, needs, scope and priorities are the main sources of conflict at the SPPI
58% believe that the best way to improve the SPPI would be through more collaboration, trust, and/or outreach.
Knowledge users
Most frequently use governmental (71%) and internal (65%) information sources
50% consider media and governmental sources, 42% non-scientific literature, and 39% scientific sources as most influential and critical information sources
52% did not know at all about the specific assessment
14% were aware of both assessment and publication and 6% were involved in the assessment
48% did or will consider the findings of the assessment in the future
25% believe that the assessment's findings did or will not influence their actions
46% believe that the assessment addresses some of their needs
79% consider the assessment as accurate and technically sound
83% consider the assessment as respectful of stakeholders and unbiased
57% recommend improving data and/or information sources to improve legitimacy of the assessment.

authors of multi-authored assessments than for single-authored ones. The latter also disseminated their findings to a higher degree only through the publication analyzed (29% compared with 3%). It is less surprising that authors of assessments with a high degree of integration of multiple-scale, science-practice, and social-physical aspects, use a variety of information sources, whereas less integrated assessments use primarily one specific source. When asked about the most influential and critical information sources for the assessment, half of the producers refer to surveys, fieldwork and communication, 48% to statistics, census and maps, and 45% to scientific literature. In contrast, half of the potential users responded that media and governmental sources are most important—two sources of information that the case study producers never mentioned (Table 3).

Considerable differences are visible when grouping the case studies according to their recognition. The number of cases in which only the authors prepared the research is significantly higher for low-recognized publications (78% as compared with 55%), for assessments with little integration (67% compared with 47%), and for countries with a low-income status (78% compared with 33%). Moreover, authors of publications that are highly recognized use statistical, graphical, and census data to a higher degree (64%) than the average (48%).

Table 3
Sources and information most influential and critical to the work (percentage rounded).

Information Source	Knowledge producers			Knowledge users		
	All	Male	Female	All	Male	Female
Most frequently used						
Internal	38	32	47	65	71	46
Governmental	58	60	53	71	68	82
Non-governmental	43	36	53	35	29	55
Scientific	93	88	100	50	54	36
Media	28	32	20	44	37	73
Personal communication	33	32	33	48	39	82
Considered as most critical						
Data (statistics, census, maps)	48	44	53	42	24	36
Scientific literature	45	56	27	39	42	27
Non-scientific literature	13	8	20	27	39	55
Survey, fieldwork, communication	50	44	60	19	22	9
Media, government releases	3	4	0	50	46	64

When comparing assessments in developing countries with those undertaken in developed countries, the number of cases in which only the author(s) prepared the research is significantly higher for assessments in countries with a low-income status (78% compared with 33%). Moreover, authors of assessments undertaken in developing countries to a higher degree use internal information sources (67% as compared with 25% of countries with high-income status) and they less often disseminate their findings in the form of public material, offprint, and lectures. In contrast, one-third of the authors of case studies in low-income countries who believe that their assessment addresses the need of users think that their publication addresses the need of science. Only 13% of the authors of publications with assessments in developed countries consider that their study addresses the need of science and no author is aware of procedural changes – i.e., methodology and processes were altered – as a consequence of the assessment (compared with 36% of authors of case studies in developed countries), but 60% are aware of changes of the attitude, i.e., a changed awareness or belief (compared with 21%). Moreover, a vast majority of authors believes that the assessments influenced science and not practice (78% compared with 38%).

Great divergence exists regarding the question of whether or not the assessment addresses the need of users. While 46% of the authors of highly recognized documents believe that their assessment is relevant for science, none of the authors of poorly recognized publications believe so. On the other hand, 78% of the latter consider their assessment as relevant for agencies and practitioners, compared with only 9% of the authors of well-recognized publications. These findings lead to the conclusion that the producers of highly recognized case studies estimate the assessment's scientific quality and relevance somehow appropriate, whereas single authors tend to overestimate the relevance. Only 14% believe that the assessment is not relevant (as compared with 42% of multi-authored assessments), and 86% of those who believe that it is relevant consider agencies and practitioners as the most important users (as compared with 39% of multi-authored assessments). This is supported by the fact that authors of highly integrated assessments consider different audiences as potential

users for their findings, whereas most of the authors of poorly integrated studies believe that their assessment addresses the need of agencies and practitioners (78%) and local governments (89%). None of them thought that it addresses the need of science, the public nor the private sector. The same can be said with regard to authors of poorly integrated assessments: almost all of them believe that their study addresses the need of agencies, practitioners, and local governments.

3.2. Publication date and gender

When grouping the answers of case study producers according to the date of the publication, only a few differences are apparent. While the authors' ranking of regularly used information sources is the same, the use of non-scientific information sources generally increased. Authors of "newer" publications frequently use more internal, governmental, and especially non-governmental sources for their work. They also consider to a higher degree scientific literature and data as most influential and critical for scientific assessments and disseminate their findings more often through reports as compared to authors of "older" publications. Not surprisingly, the latter are more aware of scientific impacts their assessment caused, whereas authors of recently published case studies are more aware of changes in perception due to their research.

Also, little surprising is the finding regarding gender. Male decision makers to a higher degree use internal sources and scientific sources; female users frequently use governmental information sources, personal communication, media sources, and non-governmental sources (Table 3). When asked about the most influential and critical information sources for the assessment, differences not only exist between producers and users, but also between men and women. While 42% of the male decision makers affirmed that scientific sources are most critical to their work, only 27% of the female users did. Moreover, 73% of the men stated that they did or will talk about the assessment within their organization (compared with 55% of the women), but only 37% said that they did or will use the report for their work or to refer to it to convince other people (compared to 64%).

More interesting is the fact that significant gender differences exist concerning the credibility of assessments. 67% of female users did not believe in assessments' findings because of weak methodology and/or insufficient data (compared with 0% of the men), whereas for 43% of the male users the use of too qualitative and/or theoretical approaches were the main reason for a lack of trust in the assessments (compared with only 14% of the women who listed the same reason).

3.3. Working domains of knowledge users

Divergent views exist between decision makers working in the domain of disaster management (e.g., emergency planning and fire department) and those who work is not primary disaster-related (e.g., development planning, health and city council). For example, the former use to a fewer degree internal information sources and consider scientific information as more critical to their work than decision makers in the non-disaster domain (Table 4). It also seems that the assessments are more influential to users in the disaster arena. Almost half of the users whose work is related to disaster management issues consider the assessment's finding as relevant as compared with only 10% of decision makers working in the non-disaster arena. On the contrary, the assessments address to a larger extent the needs of the users not working on disaster management (67% as compared with 32%).

Decision makers in disaster policy consider an assessment as having low credibility if certain aspects were ignored or missed (60% as compared with 20% of decision makers in the non-disaster field), and suggest to a higher degree to improve credibility by providing clear recommendations (18% as compared with 0%). On the other hand, users in the non-disaster arena state more often that the assessment's credibility would be higher if the authors would have chosen more in-area research and/or a different location. Differences with regard to legitimacy are even higher. While for 80% of the disaster-related decision makers the exclusion of stakeholders is the reason for considering an assessment as illegitimate (compared with 0% of the users in the non-disaster arena), the use of weak theory, methodology, and recommendations is the main cause cited by those decision makers who are not working directly in disaster management (compared with 0% of the users in the disaster arena).

Table 4
Information sources and needs with regard to user's working domain (percentage rounded).

	User's working domain		
	All	Disaster protection and management	Social and environmental development
Most frequently used sources			
Internal sources	65	55	81
Governmental sources	71	74	67
Non-governmental sources	35	42	24
Scientific sources	50	55	43
Media sources	44	39	48
Personal communication	48	52	43
Most critical sources			
Data (statistics, census, maps)	27	29	24
Scientific literature	39	45	29
Non-scientific literature	42	39	48
Survey, fieldwork, communication	19	23	14
Media, government releases	50	45	57
User's needs addressed			
No, not at all	10	10	10
No, but I see the strengths	23	26	19
Yes, some of my needs	46	32	67
Yes, but findings are not relevant	2	3	0
Yes, findings are relevant	38	48	10
More relevant and useful if ...			
Clear recommendations	32	25	44
Different/broader/ specific scope	44	44	44
Improved methodology	8	13	0
More information/data sources, new findings	24	31	11

3.4. Impact and influence

When asked for the awareness of impacts of the assessments, 71% of the authors of single-authored papers said that they are not aware of impacts (compared with 39% of authors of multi-authored publications). Nevertheless, 100% of those who are aware of impacts believe that the assessment caused behavioral changes. In contrast, 61% of the authors of multi-authored publications are aware of impacts and only one-fourth of them believe that they caused behavioral changes. 43% of the authors of individual papers evaluate the influence of their assessment as limited both on science and practice, and only 14% of them believe that it had impact on science, but not on practice.

None of the users in the developing countries read the report before nor were involved in the assessment (in developed countries, 16% of the users read the report and 8% were involved). More interesting is the fact that almost the same number of users

from developed countries state that the assessment did or will influence their beliefs (30%) and will not influence their actions (35%), respectively, but none of the users from developing countries marked these statements. They almost exclusively answered that they would talk about the assessment within their organization (71%) and would use it for their work and refer to it to convince other people (57%). Furthermore, differences exist when an assessment is considered to be not salient. While 42% of the users from developed countries suggest clearer recommendations to improve the saliency of the report, none of the users from developing countries did so. In contrast, half of them suggest the use of "better" methodologies, which none of the users from middle-income countries and only 5% from high-income countries recommend. Also when considering legitimacy, it seems that decision makers in developed countries were more concerned about stakeholder involvement than their colleagues in developing countries.

When asking the knowledge producers for changes to the assessment if its purpose was to be an immediately actionable plan for practitioner use, almost half of the authors of highly recognized studies would change the method and/or data basis, but only one-tenth of the authors of less-known publications would make such changes. In contrast, the latter would improve their case studies mostly through the application of theory and clear recommendations (44% compared with 27%). Moreover, these authors disseminated their findings significantly less often by means of reports than authors of well-known case studies (44% compared with 82%). In contrast, almost half of the authors of less-recognized publications claimed influence on both science and practice. Furthermore, only 22% of them have the opinion that their assessment had scientific impact, but no impact on practice.

When grouping the answers of case study users according to the recognition of the assessment report, it becomes evident that highly recognized papers have not only a higher scientific impact (as measured by the SSCI) but are also more influential. 22% of the potential users of well-recognized documents were not aware of the report and assessment, as compared with 61% of users of little-known papers. One-third of the former knew both the report and assessment before they had been contacted, but only 9% of the potential users of lowly recognized papers knew about it. Moreover, all of the users of highly recognized case studies affirmed that they would talk about the assessment's findings within their organization, compared with "only" 61% of the decision makers that evaluated less-recognized reports. Likewise, users of highly integrated assessments stated to a higher degree that they would talk about it within their organization. However, these assessments did or would not influence the actions for almost half of the potential users. Only 13% and 27% of the users of middle and lowly integrated assessments testified that the assessments would have no influence on their behavior. Interestingly, when asked about saliency, also 43% of the users confirmed that the findings of the well-integrated assessments were relevant (compared with only one-fourth for hardly integrated assessments) and no user stated that the assessment did not address needs (compared with 20%).

3.5. Saliency, credibility, and legitimacy

Of particular interest for the study was the saliency of an assessment. When asked "Does the assessment report address your needs?", highly recognized and highly integrated assessments received a high amount of "Yes and the findings are relevant" answers given by decision makers (Table 5). Surprising, however, is the fact that this is also true with regard to the findings of single-authored and single-hazard assessments. A possible explanation is that most of the single-authored papers refer to a single-hazard assessment carried out for a specific local area, resulting in clearer recommendations for the potential decision makers and thus in a higher saliency. An important result is the fact that – independent of the assessment's factors such as recognition, integration, authorship, and hazard type – the users share the opinion that especially a different, broader, and/or more specific scope of the assessment would increase the relevance for them, rather than an improved methodology or more information and new findings. However, particularly methodological aspects and novelty of findings are relevant factors in science due to incentive structures and the reward system for career advancement.

Interesting findings also appear when the answers of producers and users are compared with regard to the same assessment. For instance, assessments that – according to the answers of potential users given in the questionnaire – did or would not influence the actions of the decision makers were in many cases not very well-integrated assessments. Moreover, the authors of such assessments estimated the influence of their report quite properly. Most knowledge producers affirmed that their assessment did not address the need of users and did or would have – at maximum – impact on science but not on practice. On the other hand, authors of well-recognized and highly integrated assessments were pessimistic about the influence of their assessments on practice. Knowing that their report was scientifically highly recognized, they mostly estimated properly the limited influence on practical decision making. This led to the assumption that the case study

Table 5
Producers' intended audience and users' needs compared (percentage rounded).

	Recognition		Authorship		Integration		Hazard		Gender	
	High	Low	Single	Multiple	High	Low	Single	Multiple	Male	Female
Producers intended audience										
Policy makers, practitioners	55	56	43	73	80	78	74	59	68	67
Scientists, researchers	73	56	86	52	40	56	57	59	60	53
Public and private parties, NGOs	9	22	14	27	33	33	30	18	20	33
Users needs addressed										
No, not at all	0	4	6	11	0	20	17	0	10	9
No, but I see the strengths	11	30	24	23	21	20	27	18	24	18
Yes, some of my needs	44	39	24	57	43	47	37	59	49	36
Yes, but findings are not relevant	0	4	6	0	0	0	0	5	2	0
Yes, findings are relevant	44	44	59	20	43	27	37	27	29	46
More relevant and useful if ...										
Clear recommendations	0	30	17	37	20	42	48	0	35	20
Different/broader/specific scope	67	30	33	47	80	42	35	63	45	40
Improved methodology	33	10	33	0	0	0	0	25	5	20
More information/data sources, new findings	0	30	17	26	20	17	24	25	25	20

producers were fairly acquainted with the needs of decision makers in policy and practice. Hence, knowledge producers could estimate more or less accurately the influence of their scientific work and were well-aware of the limiting factors that prevented a higher impact on policy and practice. Moreover, there was a significant relationship between the user's view on credibility and legitimacy. If a potential decision maker considered an assessment not credible, in most cases the same user also regarded it as not legitimate. A negative credibility and legitimacy, however, did not necessarily lead to a low saliency and vice versa.

4. What hinders the collaborative production of knowledge?

A huge variety of influential factors exist to limit the collaborative production of knowledge, comprising such diverse aspects as different needs and objectives, institutional reward systems and incentives for collaboration, language and cultural differences, and divergent standards of credibility and legitimacy. Such barriers contributed to and resulted in failures that typically occur when knowledge is transferred through the traditional pipeline mode in which scientists set the research agenda, do the research, and then transfer the results to potential users, assuming that they diffuse automatically through the practice community.

A first group of factors is of functional nature, such as divergent objectives, needs, scope, and priorities. Responders of the questionnaire survey pointed out that many practical problems are not relevant for or not known to scientists. As one producer pointed out, researchers "often work on some sort of obscure, trivial issue that doesn't impact practical decision making". In other words: researchers do not necessarily pick research questions that make a difference in the lives of those studied, and then take action to implement those research findings. On the contrary, scientific research grants increasingly encourage huge research teams working on extensive, multi-faceted questions that do not translate well to practitioners. Moreover, practical disaster risk assessment is often limited by the available data or the budget for data collection. In contrast, scientific research frequently focuses on methodologies that may not be accurate in the absence of detailed and accurate input data. While science is based on facts, decision making – especially in traditional risk management – is more cost–benefit-oriented, determined by risk–benefit analyses, and often ends up in the domain of finance departments. However, the benefits of mitigation – in the best case the absence of disasters – are hardly measurable in monetary terms. A well-known but still apparent drawback is the fact that both scientists and practitioners often ignore the interrelations between the physical environment, society, and man-made environment when considering natural hazards.

A second group is social factors, such as cultural values, communication, understanding, and mistrust. Scientists are often unable to tolerate the impreciseness of the "big picture" whereas "broad-brush" but with specific recommendations is often more useful to practitioners. As a result, scientists propose solutions that are often unworkable in practice, often due to a poor understanding of the institutional and other constraints to implementing changes in practice. It seems to be important to determine how decision makers can or will use the provided information to develop mitigation programs and measures. This requires an understanding of the socioeconomic and political-administrative context of the hazard planning process, as past studies have shown that scientific information can play no role in such planning processes. On the other hand, community boundaries are based on political-administrative areas for politically decision making processes and administrative convenience. Traditionally, emergency managers consider a community to comprise a group of people that share the same geographically defined area, with the underlying assumption being that the group is relatively homogenous and socially cohesive. In reality, the occupants of a spatially defined area are rarely homogeneous but likely belong to a mosaic of communities that are inter-related and overlapping (Kasperson and Kasperson, 2005; Kasperson, forthcoming). Consequently, effective risk management requires that decision makers understand and respond to the diversity of communities.

Moreover, theoretical and conceptual research-based findings are rarely directly usable by policy makers and practitioners and the language of science is often too complex and intimidating for many practitioners and policy makers. As a result, authorities and scientists mostly interact at the level of data transfer but seldom at the level of equal partners that develop things together. Perhaps the scientific community will need to define the current and increasing risks more clearly, convey them in unison and hence more forcefully, without shying away from pointing out the inherent uncertainties. In particular, risk-related communication between science and its varied audiences is all too often structured on a "deficit model" that assumes that the public simply does not know enough and that information flow should therefore be unidirectional, from knowledgeable experts to the ill-informed public. Mistrust plays an important role in disaster response, and the military-style command-and-control response is especially problematic and ineffective.

Third, structural factors, such as different institutional settings and standards, clearly restrict the collaborative production and transfer of knowledge across boundaries. Scientists and researchers have other timeframes and deadlines than decision makers in policy and practice. Scientists involved in policymaking are constrained by political structure and agendas. Likewise, practitioners involved in scientific activities need to follow scientific standards. In contrast, scientists often do not take the time to fully explain how certain methods were conducted. Articles are written for those who already have a strong background on and expertise in the topic and not for practitioners who have the desire to implement scientific ideas and findings. An important barrier is the reward system for scientists, which is based largely on products for the academic arena. Researchers are rewarded for scientific publications, with little acknowledgement for their work on brochures, reports, and wider dissemination. Or to quote one assessment producer: "we are rewarded for writing to our peers and not to the communities that need us". However, numerous development planners, disaster managers, and emergency responders do not read the majority of academic journals. Decision makers need specific conclusions and clear recommendations that they can act upon, rather than conceptual and theoretical arguments about frameworks and the terminology of disaster or GEC management.

With regard to our questionnaire survey a worthwhile mention is the fact that for more than half of the authors of highly integrated assessments, conflicts at the SPPI are due to different objectives, needs, scope, and priorities as well as institutional settings and standards. In contrast, authors of less integrated assessments hardly cite these factors, but rather point to differences in understanding, language, and mistrust. Also interesting is the fact that one-third of authors of case studies in developing countries suggest intermediary bodies and brokers to improve knowledge transfer at the SPPI, whereas only 4% of the authors of case studies in developed countries do so.

5. Discussion

By analyzing solely the knowledge products (i.e., scientific publications), the coverage of the knowledge systems in the domains of vulnerability and resilience is necessarily incomplete. Knowledge systems are more usefully conceptualized from an

actor- and institution-focus than from the conventional information-focus (Mitchell et al., 2006). Despite the limitations of this study, focusing on generic assessment-related matters identified a number of linkages between specific vulnerability and assessment determinants as well as barriers – functional, structural, and social – that inhibit the collaborative production of used and applied knowledge. It is the quality of these relations that determines the grade of influence of research-based knowledge on action. Hence, the internal relationships of a knowledge-action system can be better understood as arenas of shared responsibility, embedded within larger systems of power and knowledge that evolve and change over time.

The findings of both the case study review and questionnaire survey indicate that divergent institutional settings and standards clearly restrict a cross-border collaborative production of knowledge. Unsurprisingly, decision makers do not always use the most appropriate available scientific information to influence policy decisions and, likewise, scientists often do not consider the needs of decision makers when conducting research. Differences in approach and method in vulnerability and resilience research can often be attributed to the central questions of interest, the disciplinary composition and history of the knowledge production team, and the intended users. Difficulties exist in integrating disciplinary perspectives within the research team as well as between the scientists and the various types of local decision makers. According to this study, scientific assessments which have been designed in "academic isolation" have significantly lower impact than assessments designed with input from internal and external people.

Influential scientific assessments cause changes in issue domains, defined as arenas in which interested actors seek to address an issue of common concern about which they have different beliefs and policy preferences (Fig. 1). It is assumed that adjusting academic standards and settings to more resolution-exploring and problem-solving structures would facilitate behavioral changes, and not just rational ones. Furthermore, faster and more effective transmission of existing and new knowledge to policy and decision makers, as well as better communication of this knowledge to the public can accelerate processes of change. Assuming that both formal and informal institutional settings constrain social learning and change, existing rules, laws, customs, norms, and particularly reward systems for career advancement become focal points of triggering potential change. On individual level, academic researchers need to strike a balance between pushing theoretical boundaries and generating information for practical use.

As a consequence of social barriers of understanding, language, and trust, differences arise from ambiguities in framing problems and in the diverse ways in which the nature of problems are perceived. Divergent views exist regarding the perceptions of the problem character, the need for action, and the type and priority of actions that should be taken. Moreover, differences often result from uncertainties in the factual knowledge base of vulnerability and resilience. Since individual and collective cognitive processes have a strong tendency to maintain internal coherence and resist change, boundary work may be one feasible way to encourage successful dialogue and resolve conflicts between scientists and practitioners. Based on communication, translation and mediation, intermediary bodies can play an important role in the collaborative production of disaster-relevant knowledge, especially in developing countries in which formal networks that provide bi-directional links across scales tend to be less dense and stable. Boundary organizations – i.e., "institutions that straddle the apparent politics/science boundary and, in doing so, internalize the provisional and ambiguous character of that boundary" (Guston, 2000, p. 30) – are often the outcome of the lack of co-producing knowledge in existing structures. Learning can be supported if scientists would more actively engage in activities that enhance self-reflection, e.g., assessing the assessment processes and products.

Assessments vary in the type of influence they have, ranging from no impact to significant attitudinal and behavioral changes. Moreover, the influence of the same assessment varies across potential users. However, there seems to be a relationship between credibility and legitimacy. Users who considered assessments as untrue also, for the most part, considered them as unfair. While publication date and gender are not influential factors with regard to knowledge production, both factors are more influential concerning the potential use of knowledge. Differences exist between male and female decision makers regarding the use of information sources, the information considered to be most important, and the credibility of assessments. Traditional knowledge transfer through the pipeline model requires time, resulting in delayed – and maybe not the most appropriate – use of research-based knowledge. Furthermore, it seems that knowledge produced in the domains of vulnerability and resilience addresses more the needs of decision makers working in the disaster management arena than it does for users dealing with other policy fields. Clearly, the former consider the assessment's findings as more relevant. In short: research-based knowledge in the domains of vulnerability and resilience is considered as highly credible and legitimate by multiple users. It is, moreover, considered as relevant by decision makers – particularly by those working with disaster mitigation and response – but it addresses only to a low degree the needs of these users.

Pettigrew (2003) has comprehensively outlined the challenges of and arguments for co-producing knowledge. Our examinations of knowledge producers and users underpin the reasonable view that science must be considered relevant, true, unbiased, and applicable in order to have impact on decision makers in policy and practice. More in-depth studies are needed to illuminate the rather 'spider webs' of ephemeral linkages than clearly defined routes between scientists, policy makers and practitioners and to clarify under which circumstances existing relationships between research and action become productive sources of creativity and innovation; or stagnant domains of blame-casting and inaction. For instance, it would have been useful to gain more information from the case study users on needs (e.g., evidence or solutions) and types (e.g., instrumental or conceptual) of knowledge. Particular in the domains of vulnerability and resilience, power and equity play a crucial role and knowledge is used by empowered groups to justify pre-existing behaviors and gain further advantage over disempowered ones (Weichselgartner, 2006). Likewise, factors such as data monopolies and media coverage strongly influence the knowledge–power relationship.

Science plays an important role in shaping our understanding of vulnerability and resilience to natural disasters. Generating actions to counteract the problems identified by scientific research has proven to be a more difficult task. Our case study survey provides evidence that assessments of vulnerability and resilience increase their influence – or at least saliency – when they are co-produced for defined socio-ecological systems in specific areas to meet local decision making needs. A clear identification of the assessment's purpose, its unit and scale, and the intended audience followed by specific recommendations is obviously more important for decision makers than addressing theoretical aspects of state-of-the-art methodology. In particular, scale should be a concern of both the unit of scientific analysis and of the administrative decision making to avoid scientific assessments being implemented at geographic scales that are incompatible with the local management units (Cash and Moser, 2000). The goal is to understand systematically the complex process of interactions

within and among societal arenas, spatial and temporal scales, and coupled human–environmental systems and to integrate them into a more comprehensive analysis.

The fact that 12 case studies refer to a single-hazard and eight to multiple-hazards supports the tendency of increasing acceptance that ''single-stressor-single-outcome'' approaches fail to capture the reality of vulnerability and resilience for most socio-ecological systems. However, only 20% of the case studies analyzed attempt to integrate practical elements and consider socioeconomic and geophysical aspects across spatial scales. A shift toward more collaborative productions of knowledge might improve data constraints and modeling capabilities, which still limit the tools for addressing the problem of up- and down-scaling, and thus increase the low number of assessments addressing particular systems in multi-stressor contexts.

While scientific literature and data are considered to be most critical for scientific assessments, there is a trend among knowledge producers not only to use scientific information sources, but also a broad variety of sources, including information provided by governments and NGOs. The fact that particularly authors of recently published documents disseminate their research findings to a higher degree through reports demonstrates that knowledge arenas are not stable but dynamic. This might be related to a relative increase of non-academic funding of scientific research. External sources of research funding increasingly seek evidence of applicability as an important indicator of performance. They expect the delivery of intermediate and final reports, and not of scientific papers. In contrast, the number of producers who particularly produce knowledge for and disseminate it to the general public, non-governmental organizations, and the private sector is still very low.

While the production and quality of knowledge differ considerably, applicable knowledge on disaster mitigation exists to reduce present vulnerabilities to natural disasters. Unsatisfying is the transformation of existing knowledge into practical applications. On the one hand, many scientists set the research agenda and do the research without input from other disciplines and practitioners, and then transfer the findings to potential users. On the other hand, many users make insufficient use of the existing possibilities to obtain research-based information. Both parties, however, are increasingly aware of the problem resulting from the use of limited information sources and distribution channels. The availability of consistent hazard and exposure data and technology to achieve integrated vulnerability assessments is often limited or beyond the resources of local governments.

To what extent do the actors make use of the knowledge available to them? Clearly, actors in policy and practice use insufficiently the research-based knowledge available to them; meanwhile, actors in science and research produce insufficiently knowledge that is useable. The latter still consider scientific literature and data as the most critical information source for scientific assessments; decision makers use primary governmental and internal institutional information sources. It seems that the trickle-down approach – by and by research will be taken up by users without additional effort by the producers – is still the default relationship between disaster-related scientists and decision makers in policy and practice. The practice of bringing research findings into the policy and practice arenas by publishing in peer reviewed journals is deeply embedded in the science system, manifested not only in attitudes, but also in incentive structures that reward publications in media with scientific impact and participation in forums with academic relevance. As a result, knowledge production is mostly ''career driven'' and ''academic driven'' (''publish or perish''). Though often relevant for practitioners, findings are rarely presented in a way that they can easily be used and applied by decision makers.

The main barriers that limit the knowledge transfer are divergent objectives, needs, scopes, priorities, institutional settings and standards. Hence, failures occur in both domains. More important, however, are differences in the ''language'' used, a lack of understanding of the counterpart's ''modes of operation'', and mistrust, all hindering the collaborative production of knowledge. As a result, intermediary bodies and boundary organizations play an important role in ''translating'' and ''coordinating'' knowledge, particularly in developing countries with sparse networks and existing mistrust among actors.

Researchers in the knowledge domains of vulnerability and resilience are constantly confronted with barriers, whether they rise up between the sciences and the humanities, between scientific disciplines, between the functional silos in a faculty, or between the scientist's world of ideas and the practitioner's world of action. Moreover, research grants increasingly encourage large research teams, often located in higher recognized and better equipped institutions. In contrast, institutions with lower recognition and fewer resources are limited with the scope of their research. In addition, most funding schemes and research programs do not allow comprehensive long-term research and are not equipped to deal with GEC studies that will require a generation to take effect. Fragmentation of responsibilities is also a problem for decision makers in policy and practice. Issues related to vulnerability reduction are handled in different arenas within the political-administrative system: separate ministries, departments, programs, budgets, and time horizons, often with minimal relation to each other (Birkmann, 2006). Authorities and responsibilities are highly specialized by function and territory and fragmentation of jurisdictions among federal, state, and local governments hinder inter-agency communication and thus development of comprehensive mitigation plans. Supporting a bibliometric analysis that showed there are few interlinkages among the knowledge domains of resilience, vulnerability and adaptation in terms of co-authorships and citations (Janssen et al., 2006), this case study review suggests that research on ecological and social vulnerability and resilience needs to be better integrated.

Major conflicts result from functional, structural, and social barriers that divide knowledge systems. Depending on the quantity and quality of interactions between actors, conflicts range from a ''knowing better-mentality'' to mistrust and problems in understanding each others language, needs, and standards. Typically, disaster mitigation has to compete with other societal needs, resulting in exclusion in governments' priority lists. The multidimensional and often invisible and infrequent nature of vulnerabilities contrasts with the clear responsibilities and time and financial budgets of authorities. The conflicts are not primary about values and facts, but they are often hidden in the contextual surroundings, such as how much attention is paid to vulnerability, how politically contested it is, and how it is linked with other issues (e.g., security and terrorisms).

Single-disciplinary and single-author knowledge are, by necessity, reductionist in nature and capture only part of the causes, conditions, and impacts of vulnerability and resilience. Particularly in the risk-related domain, the epistemological divide between engineering and the natural sciences, on one side, and the social sciences on the other side, obstructs a more comprehensive picture. Likewise, what interdisciplinary knowledge exists is often generalized rather than specific, and decontextualized rather than locally embedded. Though often claiming to have universal applicability, single-disciplinary and single-author assessments still require exterior inputs from other disciplines in order to address properly the dynamic and multi-layered nature of vulnerability and resilience. Additional input is needed from non-research-based knowledge in order to tackle practical issues

Table 6
Proposals to increase effectiveness of research-based knowledge.

Research in the domains of vulnerability and resilience should . . .
Create dense social networks that provide bi-directional links across scales and mechanisms for early problem identification and framing in concert with practitioners in order to better match the needs of various users.
Involve a variety of actors in setting up the research agenda and establish a shared problem perception within this group of actors.
Combine understanding from multiple sources in order to discover which can be adapted to diverse local contexts and capacities without ignoring impacts across dimensions or people.
Avoid to the extent possible the use of generalizing, decontextualizing and reductionist approaches and strengthen integration of ecological and social approaches and tools.
Engage research end-users early in defining data needs to create a research process more likely to produce salient knowledge.
Include multiple stakeholders to enhance legitimacy by providing end-users with more, and more transparent, access to the research process.
Include multiple types of expertise to increase credibility by ensuring that sources of information and data have expertise (i.e., accurate information is identified) and are trustworthy (i.e., will report that information honestly).
Include mechanisms to facilitate social memory and learning by providing a reservoir of experience from which solutions to new problems can be drawn, as well as an open window for new practices which may be needed under changed contexts.
Study the interrelations between knowledge and action and increasingly contribute to the application of knowledge.
Provide mechanisms for linking solutions proposed by research with articulated needs and problems of practitioners in order to reduce the discrepancies in activities of different actors resulting in more timely and context-appropriate solutions.
Engage both ends of the producer-user spectrum in a dialogue out of which emerges a negotiated and more consensual view of what is both feasible and desirable.
Develop possible scenarios with regard to future states of a vulnerability and resilience and new management approaches.

of suitability and feasibility of concrete mitigation measures for GEC impacts.

Today, there is broad agreement that more integrative assessments are needed. However, less consensus exists on *what* needs to be integrated and *how* that integration should be accomplished. Suggestions range from the integration of scope, research methods, and scale to disciplines and stakeholder involvement. Although it seems that assessments are more effective when they simultaneously integrate scientific, policy, and practical aspects as well as social and geophysical linkages across multiple scales, only a fifth of the case studies analyzed attempt to integrate practical elements and consider socioeconomic and geophysical aspects across spatial scales.

Existing or potentially vulnerable populations are often institutionally and economically invisible but their participation in vulnerability assessments is crucial if these assessments are to be useful for decision makers. Although an increasing number of vulnerability assessments aim to be explicitly stakeholder-driven, however, the subject of social vulnerability, i.e., vulnerable populations, is rather a study object that is assessed than an equal stakeholder that is integrated in the knowledge production process. Interestingly, for the only case study that thoroughly integrated the people into the assessment (interviews, participant observation, group discussions), none of the contacted users returned a questionnaire.

6. How to improve the science-policy-practice interface?

Despite growing synergy among conceptual frameworks and increasing consensus on the issues of importance, research on vulnerability and resilience is still facing theoretical and practical challenges, namely to address concurrently and capture socioeconomic and geophysical factors, multiple and interacting stressors, cross-scalar influences and outcomes, as well as to confront aspects of governance, gender, and social justice (Dikau and Weichselgartner, 2005). Likewise, concepts to link research-based knowledge with action vary regarding their underlying assumptions, scope, and influence, forming a fragmented and often contradictory set of approaches.

By virtue of their multi-faceted and dynamic character, the knowledge domains of vulnerability and resilience inevitably pose difficulties for discipline-based non-collective knowledge production. In both knowledge domains, many facts are uncertain, values often in dispute, and decisions two-edged. Such problems cannot be addressed by incompletely designed tools and programs, which inevitably generalize, decontextualize, and reduce much of what is important about the character of vulnerability and resilience. Forms of knowledge production are necessary which entail making connections not only across discipline boundaries, but also between scholarly inquiry and policy and practice. Hence, knowledge systems are needed that overcome technocratic reductionisms, integrate an extended range of sources and types of information, and engage in the collaborative production of knowledge through the interaction of producers and users, thus enhancing the quality of associated decision making.

Given the rapid changes in coupled human–environment systems and the need to mitigate and adapt to changing conditions, the knowledge domains of socio-ecological systems and knowledge systems are of crucial importance. It is time to interrelate and tie the two domains closer together—in both theoretical and practical terms. Not only GEC management but also knowledge management plays an important role in reducing vulnerability and enhancing resilience. Single-disciplinary concepts based on single-stressor focus, static thinking, and linear causalities are contradictory to the socially divergent, multidimensional, dynamic, interactive, and scale dependent character of vulnerability and resilience; single-technical fixes are not capable to solve multi-layered problems coupled with GEC. More is needed than only "reliable knowledge" (i.e., ensuring robustness through conventional discipline-bound norms) but also being sensitive to a much wider range of social implications to produce "socially robust knowledge" (i.e., a more locally embedded, historically and socially contingent knowledge production). Ultimately, reduction of impacts is only successful if the structures and practices in GEC *and* knowledge management are properly adjusted, taking into account societal and natural conditions.

Needless to say that there is no magic bullet. One feasible way for knowledge producers and users to generate a deeper mutual understanding of each other's needs and constraints is to increase the amount and intensity of face-to-face interaction by creating institutional contexts where both are encouraged to interact. On the basis of the empirical findings emerging from case studies analysis and questionnaire survey, we offer the following propositions on how effective systems should be designed to harness better research-based knowledge and know-how with action (Table 6). Obviously, designing such contexts has major implications for the science system. Co-producing knowledge requires precious resources – temporal, spatial, and financial – and brings greater complexities and transaction costs in the research process.

Acknowledgements

The study at Harvard University's Center for International Development was made possible through a Feodor Lynen Fellowship

from the Alexander von Humboldt Foundation awarded to J. Weichselgartner and matching funds from a core grant (#2004-26318) from the David and Lucile Packard Foundation. The authors are indebted to William Clark, Nancy Dickson, and Laura Jeanty for supporting the study. The whole is more than the sum of its parts.

References

Birkmann, J. (Ed.), 2006. Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies. UNU, Tokyo.

Cash, D.W., Moser, S.C., 2000. Linking global and local scales: designing dynamic assessment and management processes. Global Environmental Change 10 (2), 109–120.

Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., Jäger, J., Mitchell, R.B., 2003. Knowledge systems for sustainable development. PNAS 100 (14), 8086–8091.

Dikau, R., Weichselgartner, J., 2005. Der unruhige Planet: Der Mensch und die Naturgewalten. Wissenschaftliche Buchgesellschaft, Darmstadt.

Guston, D.H., 2000. Between Politics and Science: Assuring the Integrity and Productivity of Research. Cambridge University Press, New York.

Janssen, M.A., Schoon, M.L., Ke, W., Börner, K., 2006. Scholarly networks on resilience, vulnerability and adaptation within the human dimensions of global environmental change. Global Environmental Change 16 (3), 240–252.

Janssen, M.A., Ostrom, E., 2006. Editorial—resilience, vulnerability, and adaptation: a cross-cutting theme of the International Human Dimensions Programme on global environmental change. Global Environmental Change 16 (3), 237–239.

Jasanoff, S. (Ed.), 2004. States of Knowledge: The Co-Production of Science and Social Order. Routledge, London.

Kasperson, J.X., Kasperson, R.E., 2005. The Social Contours of Risk. Earthscan, London.

Mitchell, R.B., Clark, W.C., Cash, D.W., Dickson, N.M. (Eds.), 2006. Global Environmental Assessments: Information and Influence. MIT, Cambridge.

Munich Re, 2006. Topics Geo. Annual Review: Natural Catastrophes 2005. Munich Re Group, Munich.

Nowotny, H., 1999. The need for socially robust knowledge. TA-Datenbank-Nachrichten 3–4 (8), 12–16.

Nowotny, H., Scott, P., Gibbons, M., 2001. Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty. Polity Press, London.

Pettigrew, A.M., 2003. Co-producing knowledge and the challenges of international collaborative research. In: Pettigrew, A., Whittington, R., Melin, L., Sánchez-Runde, C., van den Bosch, F.A.J., Ruigrok, W., Numagami, T. (Eds.), Innovative Forms of Organizing. Sage, London, pp. 352–374.

Select Bipartisan Committee to Investigate the Preparation for and Response to Hurricane Katrina, 2006. A failure of initiative. Final Report of the Select Bipartisan Committee to Investigate the Preparation for and Response to Hurricane Katrina. Washington, DC.

The Social Learning Group, 2001. Learning to Manage Global Environmental Risks—Volume 1: A Comparative History of Social Responses to Climate Change, Ozone Depletion, and Acid Rain. MIT Press, Cambridge.

Travis, J., 2005. Scientists' fears come true as hurricane floods New Orleans. Science 309, 1656–1659.

Turner II, B.L., Kasperson, R.E., Matson, P.A., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Kasperson, J.X., Luers, A., Martello, M.L., Polsky, C., Pulsipher, A., Schiller, A., 2003. A framework for vulnerability analysis in sustainability science. PNAS 100 (14), 8074–8079.

Vogel, C., Moser, S.C., Kasperson, R.E., Dabelko, G.D., 2007. Linking vulnerability, adaptation, and resilience science to practice: pathways, players, and partnerships. Global Environmental Change 17 (3–4), 349–364.

Weichselgartner, J., 2006. Soziale Verwundbarkeit und Wissen. Geographische Zeitschrift 94 (1), 15–26.

Weichselgartner, J., 2007. Integrating science and practice for the mitigation of natural disasters: barriers, bridges, propositions. CID Graduate Student and Postdoctoral Fellow Working Paper No. 21. Center for International Development, Harvard University.

Weichselgartner, J., Obersteiner, M., 2002. Knowing sufficient and applying more: challenges in hazards management. Global Environmental Change Part B: Environmental Hazards 4 (2–3), 73–77.

White, G.F., Kates, R.W., Burton, I., 2001. Knowing better and losing even more: the use of knowledge in hazard management. Global Environmental Change Part B: Environmental Hazards 3 (3–4), 81–92.