Reg Environ Change
DOI 10.1007/s10113-008-0047-7

ORIGINAL ARTICLE

A stakeholder dialogue on European vulnerability

Anne C. de la Vega-Leinert · Dagmar Schröter · Rik Leemans · Uta Fritsch · Jacomijn Pluimers

Received: 8 February 2008 / Accepted: 8 February 2008

Abstract A stakeholder dialogue was embedded in the ATEAM project to facilitate the development and dissemination of its European-wide vulnerability assessment of global change impacts. Participating stakeholders were primarily ecosystem managers and policy advisers interested in potential impacts on 'Agriculture', 'Forestry', 'Water', 'Carbon storage', 'Biodiversity' and 'Mountain environments' sectors. First, stakeholder dialogue approaches to integrated assessment are introduced. Methodological considerations on stakeholder selection and dialogue implementation and evaluation follow. The dialogue content and process are evaluated from the perspectives of stakeholders and scientists. Its usefulness in the research process and the relevance of outcomes for stakeholders are particularly considered. The challenging compromises required to perform innovative research, which seeks to achieve both peer scientific credibility and societal relevance, are emphasized. Effective stakeholder dialogues play a substantial role in raising the visibility and meaningfulness of vulnerability assessments as critical means to improve awareness on global change and its potential worrying impacts on society. They further provide scientists with critical information on ecosystem management and sectoral adaptive capacity. These processes of mutual learning and knowledge exchange moreover foster a better understanding of the potential and limits of global change modelling and vulnerability assessment for policy and ecosystem management.

Keywords Global change · Ecosystem service provision · Stakeholder dialogue · Participative integrated assessment · Vulnerability · Adaptation · Europe

A. C. de la Vega-Leinert · D. Schröter · U. Fritsch
Potsdam Institute for Climate Impact Research, Potsdam, Germany

R. Leemans · J. Pluimers
Wageningen University, Wageningen, The Netherlands

A. C. de la Vega-Leinert (✉)
Institute of Geography and Geology, Ernst-Moritz-Arndt-University of Greifswald, Friedrich-Ludwig-Jahn-Str. 16, 17487 Greifswald, Germany
e-mail: ac.delavega@gmail.com

Present Address:
D. Schröter
Umweltbundesamt GmbH, Vienna, Austria and George Perkins Marsh Institute, Clark University, 950 Main Street, Worcester, MA 01610-1477, USA

Present Address:
R. Leemans
Environmental Systems Analysis Group, Wageningen, PO Box 47, 6700, AA, Wageningen, The Netherlands

Present Address:
U. Fritsch
Claudia di Medici 19, 39100 Bolzano, Italy

Present Address:
J. Pluimers
The Netherlands Society for Nature and Environment, PO Box 1578, 3500 BN Utrecht, The Netherlands

Introduction

The overarching goal of the ATEAM (Advanced Terrestrial Ecosystem Assessment and Modelling) project was to produce an innovative assessment of European vulnerability to global change, explicitly conceived and implemented with policy makers and environmental managers in mind (Schröter et al. 2005a; Metzger et al. 2008). To this end a stakeholder dialogue initiative was embedded in the research

process. This experience has profoundly affected the way participating scientists designed and performed their work and constitutes a milestone in integrated ecological modelling research for the purposes of global change impact and vulnerability assessments. The underlying broad hypothesis of this initiative was that stakeholder dialogue, and participative methods in general, played a valuable role in the elaboration and evaluation of complex global change models, and in combining scientific credibility with social relevance. More specifically, it was hoped that by incorporating this activity within the overall project, scientists would have access to important sources of expertise on ecosystem management and sectoral adaptive capacity. This would act as a reality check for the vulnerability assessment to be produced.

This paper describes the stakeholder involvement in ATEAM. We aim to provide first hand information on the process and experiences in order to assess the value of such a dialogue process. First, this initiative is placed in the wider context of participatory integrated assessment research. Second, the specific goals and activities of the ATEAM stakeholder dialogue are presented. The stakeholders targeted within the project are discussed with consideration of biases in the selection process and participating group. Third, the dialogue outcomes and process are evaluated and discussed in terms of their relevance for participating stakeholders and scientists. Finally, challenging compromises required to perform innovative research, which seeks to achieve both peer scientific credibility and societal relevance, are emphasized.

Participatory integrated assessments (PIAs)

Sustainability science centres on the interactions between complex co-evolutive natural and human systems. It focuses on possible causes of global change and its impacts on biophysical and socio-economic processes, the provision of ecosystem services and the human populations they support. It also explores plausible future paths to inform and guide society into a sustainable transition. This is performed through the elaboration of integrated assessments (IAs) (Toth and Hizsnyik 1998; Tol and Vellinga 1998; Füssel and Klein 2006) and analytical tools such as coupled computer models of different levels of complexity (Muetzelfeldt 2003). Scenario and model assumptions were originally based on expert scientific knowledge. As the visibility of models increased, their outputs became intensively debated by scientists and within society. Used as tools in political processes, modelling results became politicised themselves and the object of increasing public scrutiny (e.g. Meadows et al. 1972; Alcamo et al. 1996; McCarthy et al. 2001). In this context participatory approaches have been advocated as means to improve research relevance and legitimacy, as well as the social credibility and accountability of researchers (e.g. Renn et al. 1995; Kasemir et al. 2003; Schröter et al. 2005b). There is a wide range of valuable participatory methods and tools to engage society into IAs (Rotmans 1998; Toth 2001), which differ from other participatory processes (Welp et al. 2006a).

PIAs are diverse, and should therefore be designed and implemented on a case-by-case basis. All approaches, however, seek to create opportunities for confrontation and discussion of different worldviews and perceptions. Mutual learning and effective collaboration are key, and thus adequate time and resources are needed to develop trust and commitment over time. If the research is aimed at being of direct use to stakeholders, the system of underlying normative values in which the assessment is to be produced needs to be relevant and acceptable to both scientists and stakeholders (Glicken 2000; Reynolds et al. 2007). Indeed, best expert guesses and underlying value judgements (e.g. on future attitudes towards ecosystem management, lifestyles, energy consumption or risk avoidance) guide the elaboration of many modelling and scenario assumptions. These, therefore, need to be made transparent so that they can be understood and commented upon by stakeholders.

The role of stakeholders in IAs varies largely according to how early they are involved in the thinking, implementation and evaluation of the research. This in turn is closely related to four major dimensions of participation, the 'axes of differentiation' of Berghöfer and Berghöfer (2006, p 90). These include decisions on who participates, in which societal arena, as well as on the nature of the participation exercise and the overall goal of participation. A cross-cutting issue in the design of participative research is, therefore, the degree of power in decision-making that is to be effectively transferred to stakeholders during the process [e.g. see Arnstein's ladder of citizen participation (1969) and Pretty (1995) cited by Oels (2006)].

Science-stakeholder dialogue may fulfil a wide range of purposes within IAs (Welp et al. 2006b). These include: a reality check to the broader, often more abstract assumptions derived from the scientific literature (Welp et al. 2008), stakeholders' evaluation of the relevance of conceptual frameworks, model indicators, or thresholds of change (Walker et al. 2002; Reynolds et al. 2007), or the collective design of plausible scenarios of future change (Berkhout et al. 2002; Shackley and Deanwood 2003; Reid et al. 2005). These scenarios may serve as long-term 'aimed states of the world' for which the necessary steps to get there are identified and discussed in 'backcasting approaches' (e.g. Tuinstra et al. 2003; van de Kerkhof, 2004). Models can be adapted to feed specific policy or climate negotiations needs, as was the case for the global model IMAGE 2 during the Delft process

in the Netherlands (van Daalen et al. 1996). The Millennium Ecosystem Assessment[1] and the IPCC[2] process are science-based stakeholder dialogues at their broadest scale, as illustrated by the long negotiations on the exact wording of the IPCC report 'summary for policy-makers'. A further goal of PIAs has been to analyse the perceptions, priorities, information needs and decision-making processes of stakeholders (e.g. Behringer et al. 2000; Patt and Zeckhauser 2002). For example, focus groups discussions within the UK Climate Impact and ULYSSES Projects, directly fed models of potential impacts of climate change on key economic sectors and climate mitigation and adaptation avenues (Shackley and Deanwood 2002; Kasemir et al. 2003). Here the outcomes of the process range from purely qualitative to (semi)-quantitative results, when systematic methods, such as multicriteria analyses or Bayesian Networks are used to explore and/or rank stakeholders' preferences (Harrison and Qureshi 2000; Welp et al. 2006a; Fürstenau et al. 2007).

At best, stakeholders are seen as collaborators in the research process rather than purely 'objects' or 'recipients' of the research (Welp et al. 2006b). Together scientists and stakeholders can identify socially and scientifically relevant research questions and choose the scope and geographical coverage of the research. This collaboration can stimulate societal debate on controversial topics and foster a valuable exchange of opinions and arguments as well as joint research projects with targeted stakeholders, as within the European Climate Forum[3] (e.g. Runge and Reusswig 2003; Welp et al. 2006b, 2008). Multi-stakeholder platforms or experimental citizen panels and assessments explore and debate public perceptions and opinions in a more representative fashion (e.g. Crosby et al. 1986; Renn and Webler 1996; Warner et al. 2002). Their main outcome is qualitative, namely the discourse itself and the process of reflection, learning and sharing the participants go through. In some cases participatory approaches can reap material benefits for stakeholders (e.g. in the form of increased crop harvests), as a recent study of the usefulness of seasonal climate forecasts to subsistence farmers has shown (Patt et al. 2005b).

The aims of the ATEAM stakeholder dialogue

ATEAM incorporated the participatory process of the stakeholder dialogue to adjust the project's results to better suit stakeholders' needs (Fig. 1). From the stage of proposal writing, the project partners recognized that stakeholders were needed from the outset of the project in order to guide the direction of modelling. Stakeholders would then, later in the project, receive the results of the modelling, and be able to comment on their usefulness to them. The specific goals of the entire process thus included:

- identify and evaluate indicators of change in ecosystem services;
- settle useful scales and units at which these indicators should be measured or modelled;
- discuss thresholds for these indicators, beyond which sectoral adaptive capacity could be exceeded;
- develop stakeholders' ability to use information derived from scenario analysis; and
- present and discuss the project results, in terms of their content and format.

ATEAM was not conceived as a joint research project, where stakeholders and scientists would together decide on the scope, goals and methods of the research. Rather the focus of the participative process was threefold: (1) to prompt critical feedback, (2) to satisfy specific data needs for better model developments, and (3) to develop best dissemination strategies for the model outputs. Therefore, following the Arnstein (1969) ladder of citizen participation, the ATEAM dialogue can be presented as a combination of informing and consulting stakeholders, rather than a full partnership, or co-production of knowledge as described by Welp et al. (2006a, b).

Targeted stakeholder groups

The ATEAM assessment approach was structured into sectors and preliminary vulnerability indicators were compiled (Fig. 1). In parallel, potential stakeholders were identified using the snowball approach (see Biernacki and Waldorf 1981), whereby relevant stakeholder contacts were pinpointed in iterative rounds within a progressively increasing network of contacts. An initial informal survey among ATEAM partners and colleagues was extended by widespread Internet searches. To facilitate a systematic stakeholder selection a matrix was designed with relevant sectors vs. geographical scales and stakeholder (organisation) types (Table 1). A vast database and network of potentially interested parties were created. In total 204 stakeholders were identified, 152 were approached and invited to our activities and 58[4] decided to participate in at

[1] Millennium Ecosystem Assessment: http://www.millenniumassessment.org/.

[2] Intergovernmental Panel on Climate Change: http://www.ipcc.ch/.

[3] European Climate Forum: http://www.european-climate-forum.net/.

[4] These numbers strictly refer to the stakeholders identified, approached or participating within the ATEAM dialogue activities reported upon here. Many more stakeholders were less directly involved within ATEAM via: (1) additional dissemination and outreach activities carried out within the project, and (2) parallel stakeholder networks and activities developed within other projects or institutes, within which ATEAMers participated (for a complete report on these see Schröter et al. (2004).

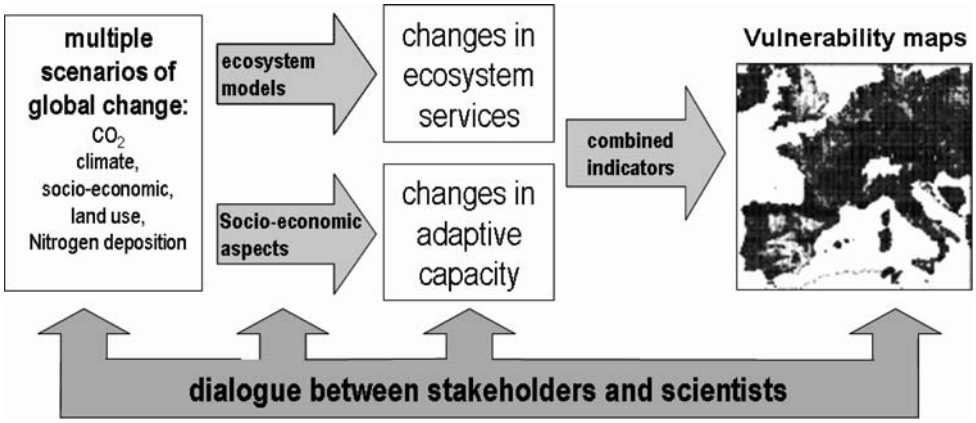

Fig. 1 The structure of the ATEAM project with the specific interactions between scientists and stakeholders (from Schröter et al. 2004)

Table 1 Targeted sectors vs. stakeholder organisational types

	Sectoral consultancy	Sectoral representative	Private business	Public body/ academic	Public body/ advise to policy	Public body/ resource management	NGO	Independent umbrella organisation	Total
'Agriculture'	1 (2)	2 (10)	0 (2)	2 (2)	0 (0)	0 (1)	0 (0)	0 (1)	5 (18)
'Biodiversity and nature conservation'	1 (1)	0 (0)	0 (0)	4 (7)	2 (11)	3 (8)	1 (6)	0 (0)	11 (33)
'Carbon storage'	1 (5)	0 (0)	0 (5)	2 (7)	4 (17)	0 (0)	2 (3)	1 (5)	10 (42)
'Forestry'	2 (3)	7 (19)	0 (6)	3 (5)	4 (7)	2 (2)	1 (2)	0 (1)	19 (47)
'Mountain environments'	0 (0)	0 (1)	1 (3)	0 (2)	1 (1)	1 (1)	0 (0)	2 (10)	5 (18)
'Tourism'	2 (13)	0 (1)	0 (1)	0 (2)	0 (0)	0 (0)	0 (2)	0 (0)	2 (19)
'Water'	1 (5)	0 (0)	2 (6)	1 (2)	0 (5)	0 (0)	0 (0)	0 (1)	4 (19)
'Insurance'	0 (0)	0 (0)	0 (4)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (4)
Media	0 (0)	0 (0)	2 (5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (5)
TOTAL	8 (29)	9 (31)	5 (32)	12 (27)	11 (41)	6 (12)	4 (13)	3 (18)	58 (204)
Total	Private	22 (92)		Public	29 (80)		Independent	7 (31)	

Sectors targeted for the stakeholder dialogue do not correspond exactly to the ATEAM sectors per se which are 'Agriculture', 'Forestry', 'Carbon Storage', 'Water', 'Biodiversity and nature conservation', and 'Mountain environments'. The following organisational types were involved: *Sectoral consultancies*: these can be commercial (e.g.: DHI Water and Environment) or non-profit consultancies (e.g.: Associazione Cultura Turismo Ambiente, ACTA). *Sectoral representatives*: include farmers' unions, cereal growers, land and forest owners, paper-agro industries, etc. *Private business*: from individual farmers to multinational corporations (e.g. IKEA, TETRAPACK, Gerling Reinsurance). *Public organisation, whose main focus is to advise policy*: these are directly involved in policy/decision-making (e.g. Ministries of Environment, European Commission) or in advisory position (e.g. European Environmental Agency). *Public organisations, whose main focuses are academic*: research institutes who were not directly involved in ATEAM. *Public organisations, whose main focuses are environmental resource management*: e.g. forest, water and or natural park management. *Non governmental organisations*: from globally known organisations such as WWF, Greenpeace, to nationally important ones, such as Robinwood (Germany) or the Liga para a Protecção da Natureza (Portugal). *Independent umbrella organisations*: these can be non-profit organisation focusing on awareness raising (e.g. Climate Network Europe, Commission internationale pour la protection des Alpes – CIPRA) to organisation fostering trade (e.g. Organisation for Economic Co-operation and Development – OECD, Association of British Travel Agents). Numbers indicate stakeholders who participated in one or more ATEAM dialogue activities, the total number of stakeholder identified for each category are given in brackets

least one activity (for the full ATEAM stakeholder database see Schröter et al. 2004).

We targeted particularly private agents, sectoral representatives, consultants and private businesses for 'Agriculture', 'Forestry', 'Water' and 'Tourism', since these stakeholders are predominant decision-makers in these sectors. In contrast, for the sectors 'Biodiversity and Nature Conservation', 'Carbon Storage Potential' and 'Mountain Environments', we approached stakeholders from public (academic/advisory/management) or independent sectors (NGOs, umbrella organisations). Here, the associated ecosystem services are often non-marketed (Reid et al. 2005), and are primarily relevant for national or European policy making issues (e.g. climate mitigation,

ecological directives). Government representatives or policy makers per se were not included in the stakeholder matrix. This was a deliberate choice as the project wished to focus on influential participants (e.g. scientific advisers) who were nevertheless free to express their views rather than official policy lines.

Selection bias

Most organisations targeted have a European to global focus of activity, the scales at which the ATEAM results are the most relevant (spatial resolution of ATEAM results: ca. 16 × 16 km) (Table 2). Geographically coherent groups of countries were selected to address regional and national perspectives. The Mediterranean and Alpine regions are best represented, and Scandinavia less so. Although the ATEAM window covers a large part of central and eastern Europe, the formal focus was on the fifteen pre-2004 EU-members, plus Norway and Switzerland (referred to as EU15+). Potential stakeholders in central and in eastern Europe were thus not extensively searched. Large countries like Germany, the UK, and France, were given special attention, and this bias reflects existing networks within the consortium.

The stakeholder selection criteria included: (inter-) sectoral expertise (particularly in public and private environmental resources management), knowledge on climate and environmental issues, general interest for scientific issues and an open, curious and critical mind. Stakeholders' known or presumed views on global change did not, however, constitute a selection criterion, for the sake of encouraging diversity in the debates. Although some of these selection criteria could be assessed through detailed Internet searches (e.g. by targeting the environmental department of a firm), others could only be evaluated through personal contact and experience in cooperation (e.g. personal qualities). Our initiative was not envisaged as a public participation exercise, rather as a focus group approach with selected participants. We therefore did not seek to achieve a representative sample of society. However, we made repetitive attempts to engage with a range of private companies, and specific consumers groups, but interlocutors mostly declined our invitations or cancelled.

Since biases cannot be avoided, reflecting on them and on their influences on the dialogue process and outcomes is an important step in evaluating the dialogue's achievement, as well as planning future exercises. Our selection criteria introduced a 'green' and 'scientific' bias in our stakeholder community, which was reinforced as stakeholders decided to participate or not. Stakeholders needed to be convinced that they would gain significant benefits before they committed any amount of time and effort into extra-professional activities. Communication skills and a strong feeling for how to engage stakeholders and demonstrate the relevance of the dialogue process for their activities certainly helped to gain stakeholder support. However, in some cases the research topic was simply too disconnected from stakeholders interests to secure their participation.

Throughout the ATEAM project three general and three smaller scale sectoral stakeholder workshops were organized. ATEAM scientists participated in 11 further stakeholder events organized within collaborating projects (see Schröter et al. 2004). Multiple informal exchanges between scientists and stakeholders also took place.

Table 2 Main geographical focus of ATEAM stakeholders' activity

Geographical focus	Full database	Participants
Global	10	0
Europe/Global	40	8
Europe	40	9
Alpine	22	8
Central Europe	1	0
Mediterranean	22	7
Scandinavia	12	2
France	7	3
Germany	30	16
UK	20	5
TOTAL	204	58

Global: International organisations (e.g. WWF) *Europe/Global:* European organisations with international outreach/interests (e.g. IKEA, European Environmental Agency) *Europe:* Supranational organisations the activity of which is primarily of European relevance (e.g. CIPRA) *Alpine region:* including Austria, France, Germany, Italy, Liechtenstein, Slovenia, Switzerland *Mediterranean region:* Albania, Croatia, France, Greece, Italy, Malta, Monaco, Portugal, Slovenia, Spain *Scandinavia region:* including Finland, Norway, Sweden

Evaluation of the ATEAM stakeholder dialogue

Methodology

The evaluation of the dialogue was performed in a number of ways. At three events,[5] an evaluation questionnaire on workshop content and format and the project overall was distributed to stakeholders. Less than half of the participating stakeholders provided feedback through the questionnaires, which significantly restricts the representativeness of the trends discussed below. Informal feedback was also collected during conversations with participants as well as personal observations by the dialogue coordinators. External observers were asked to evaluate the

[5] These were the second and third general stakeholder workshop and the Mountain and Biodiversity sectoral stakeholder workshop.

workshops in terms of content and process and to provide recommendations for future events (Jürgens 2001; Vreugdenhil 2003). Finally, formal semi-structured interviews with the project leader and coordinator, and one scientist per modelling sector were performed to gather their views on the outcomes of the stakeholder dialogue and the way it had influenced their research.

The sections below summarize the main points made by participants, observers and scientists. Where appropriate, quantitative results from the evaluation questionnaires are added, although these are indicative only. All numbers quoted below within brackets refer to respondents answering 'Yes' or 'Mostly' to questions out of a total of 22 respondents[6] from the total population of 58 participating stakeholders.

Stakeholders' evaluation of the ATEAM dialogue

Content evaluation

Based on workshops discussion, survey results and informal feedback, it appeared that stakeholders generally found ATEAM's conceptual framework, its implementation in the vulnerability assessment methodology, and the Atlas of European Vulnerability,[7] interesting and innovative. Most questionnaire respondents believed that the ATEAM workshops had been generally relevant to their work (19) and worth their time out of work (18). Most appreciated the workshop contents and the range of topics covered. Participation in itself confirmed that stakeholders had an interest on European vulnerability and adaptation to global change. The presentations were interesting for most stakeholders (21), who believed that they had gained some useful insights on the topics covered (21), and would be able to integrate some of these in their work (19). However, some stakeholders emphasized that too many topics were covered during the events (2), which prevented in-depth discussions (e.g. on sectoral adaptive capacity). The broad nature of the ATEAM assessment prevented local and sector specific interests to be addressed as adequately as some stakeholder wished (e.g. local scale impacts on biodiversity, downstream activities in 'Agriculture' or 'Forestry' sectors).

The temporal and spatial scales of ATEAM analyses were unequally relevant to stakeholders. For some, the ATEAM time slices (1990, 2020, 2050, 2080) were useful. This was the case for stakeholders in the 'Forestry', 'Carbon storage' and 'Biodiversity and nature conservation' sectors, and to a lesser extent in 'Mountains environments' (e.g. the index of snow reliability for the focus on tourism), since management scales in these sectors already considered the long term. However, in the 'Water' and 'Agriculture' sectors stakeholders were more interested in short-term estimates for the next five to ten years. For many stakeholders, especially from regional nature conservations parks, the spatial scale of the assessment (the ATEAM $10' \times 10'$, i.e. ca. 16×16 km grid) was still too coarse, despite its exceptionally fine resolution in comparison to other global change assessments. ATEAM was only able to provide local level of information within the selected Alpine valleys of the 'Mountain environments' sector. Additional local case studies would have been welcomed by stakeholders and scientists alike, but could not be realized due to budget and time constraints. This raises two important points. First, a key effort required in global change modelling lies in bridging the gap between global and local scales, in keeping with the strong downscaling effort developed in the last decades (for a review, see Wilby et al. 2004). Second, it could be argued that the project targeted a too wide range of stakeholders' interests and should have focused on stakeholders, who had a national to European or global focus over decades (e.g. policy advisers).

The identification and assessment of specific ecosystem services, which could be significantly impacted in future, appeared most relevant to stakeholders since this information could form an appropriate basis for exploring adequate adaptation strategies at European to regional levels. In comparison, the aggregated indicators for 'vulnerability' and 'adaptive capacity' *per se* were judged of limited value (Schröter et al. 2005a). This suggests that such concepts and indicators belong more to the realm of academic pursuit than to that of practical environmental management (Patt et al. 2005a). Indeed, stakeholders are acutely aware of the opportunities and barriers to adaptation through management practice in their specific sectors. Sectoral adaptation is often related to the necessity to run an economically viable activity. Stakeholders critically review policies, market fluctuations and environmental changes, which may benefit or endanger their activity. They are continuously re-appraising the vulnerability and adaptive capacity of their activity to changing conditions (albeit without using this terminology). ATEAM's macro-scale, generic index of adaptive capacity does not provide the specific information stakeholders wish and is thus of limited interest to them. For stakeholders, the missing link remained a sector-specific and risk-specific articulation between adaptive capacity and vulnerability. Scientists and stakeholders, therefore, agreed that the components of sectoral adaptive capacity, the interactions between macro

[6] For the full results of the evaluation questionnaires see: de la Vega-Leinert et al. (2004).

[7] See "Communication and dissemination of ATEAM results" for details on the ATEAM Atlas of European Vulnerability. This tool is available from http://www.pik-potsdam.de/ateam/).

and (inter)sectoral adaptive capacities, and between these and vulnerability were key areas for future research.

Within the land use scenarios, specific driving forces were of critical interest to stakeholders but could not be attended to adequately (e.g. consumer preferences). Many stakeholders, especially from the tourism sector, were very interested in extreme events, which were not considered within ATEAM, due to the lack of coherent modelling achievements in this area. Indeed, datasets on extreme events are very restricted and do not cover the required European scale, whereas state-of-the-art climate scenarios cannot produce reliable simulations of extreme events, in particular of the probability of their occurrence. Nevertheless, within the modelling of terrestrial carbon storage, a major change in research orientation was inspired by stakeholders, who prioritised more realistic forest management and land use changes over the improved representation of the nitrogen cycle in dynamic vegetation models originally planned. Stakeholders, moreover, recommended that scenario and model assumptions on critical driving forces such as policy, market trends and sectoral management be elaborated to better represent their key intricate role at European, national and sectoral level. They agreed that it was crucial to clearly point out that scenarios represented alternative choices of society, rather than possible futures that unfold independently from societal and individual decisions.

The significant agreement across modelling results and scenarios contributed to raise stakeholders' confidence in the project results. For example, in the ATEAM assessment tree productivity increases in most scenarios in North European but is limited by water availability in Mediterranean areas. Also, all scenarios and results from all sectors agree on particular regional vulnerabilities, for example that of the Mediterranean and Mountains regions (Schröter et al. 2005a). Stakeholders thus encouraged the development of comparative assessments of impacts of alternative policies across different economic sectors, and believed these would allow decision-makers to better choose between different future pathways.

Broad consensus was nevertheless that ATEAM results, or any vulnerability assessment, would not be sufficient to directly influence decision-making and management behaviour. This is primarily due to the still too large temporal and spatial scales (from the point of view of stakeholders) and associated significant and accumulated uncertainty. For example, one forest management adviser from Catalonia, Spain, that although ATEAM forestry modelling pointed to the regional declining viability of particular tree species, this information would not alone incite forest owners to significantly change the composition of forest plantations. Other factors would be needed, such as repetitive large-scale forest fires, EU regulations, or changing market demand. Thus stakeholders who await predictions or detailed quantified outputs to guide their decision-making will be disappointed by the lack of 'answers' integrated assessments can provide. Consequently, it is important to view integrated assessment results not as potential provider of predictions ('truth machines', see Shackley and Darier 1998), but as compilation of best current knowledge, and as food for thought and debate within a wider social discourse on global change. However, specific modelling tools produced to facilitate decision-making may play an important role, such as decision support and expert systems, particularly targeted at a group of stakeholders (e.g. the products developed by the Project Virtualis—http://www.virtualis-eu.com/). Within ATEAM, one effort in this direction was the design of a tool for natural reserve selection that takes into account economic and ecological considerations (Araújo et al. 2002). Further investigations included a comparison of the effectiveness of different reserve selection tools under climate change (Araújo et al. 2004).

Finally, stakeholders attached great importance to information on the economic cost and benefits of a specific policy (e.g. does it make economic sense to switch to biomass energy crops?). Thus linking ATEAM's vast information pool to economic valuation could have been one way to increase the meaningfulness of the project's results for stakeholders. The coupling of environmental and economic models, such as being currently undertaken within the Community Integrated Assessment Model project (CIAM^n—see http://ecf.pik-potsdam.de/ciam), is a development that goes in this direction (Jaeger et al. 2002).

Process evaluation

Regarding the quality of the interactions, most stakeholders felt comfortable enough to express their opinions (21) and that these had been adequately valued by all participants (19). Although ATEAM was not explicitly a forum, stakeholders valued the opportunity to network with peers and scientists as a way to encourage synergies and collaboration. In general, stakeholders believed that fellow participants were relevant to their own activity, and many considered keeping in touch with some of them independently from follow-up events (12). Most respondents had been sufficiently interested in ATEAM to consider participating in follow-up activities (17). They thereby wished to obtain more information on potential European vulnerability, on sectoral adaptive capacity and adaptation measures, and the opportunity for closer collaboration and networking. Many would prefer to take part in a future sector specific event (7), although most had no preference on this (11). Eventually eleven out of fifty-eight stakeholders participated in at least two of the ATEAM dialogue activities. All respondents wished to receive further information on the project and its final results, and many had

already talked about ATEAM to colleagues (18). These answers suggest that ATEAM has successfully engaged participants, raised interest in its research and provided a dynamic and stimulating discussion and dissemination platform. An atmosphere of trust and friendliness was aimed at, in which questioning comments and constructive criticism were encouraged and valued. Stakeholders or ATEAMers acted as moderators, and encouraged speakers to participate actively, although some stakeholders emphasized the need for unbiased moderation to guarantee that all parties were adequately heard.

The main criticisms on the dialogue process were the infrequence of the events, the long time between each event and the lack of regular and transparent feedback in between activities, especially on information on how stakeholders' comments had been taken into account. During workshops when some stakeholders had the feeling that their concerns had not been addressed, they reiterated them and expressed some frustration in not having their comments adequately taken on board. This suggests that there was a mismatch in stakeholders' and scientists' understanding of the conceptualisation of the goals and degree of participation desired. If some stakeholders envisaged their role as full partner or adviser (or as partners in co-production of knowledge), scientists viewed them primarily as providers of data and critical feedback. ATEAM, moreover, did not sufficiently clarify its margin of manoeuvre in addressing stakeholders' comments in view of the tight research plan and set list of deliverables it had committed itself to produce. However, some important stakeholders' concerns did find their way into current research with time (e.g. a case study on adaptive capacity of the 'Agriculture' sector—see below), or at least they confirmed that significant model developments were needed in order to address these concerns adequately (e.g. bridging gaps between global modelling scales and local management needs).

Relevance and dissemination of ATEAM results

Throughout the dialogue activities, stakeholders emphasised that they found important that the scientific community should phrase questions relevant to society, regarding the causes and impacts of global change, and possible mitigation and adaptation options. They generally believed that ATEAM had succeeded in formulating strong messages on European vulnerability to global change, which provided some guidance in policy and decision-making for a range of stakeholder groups (including landowners' and farmers' organisations, forestry and biodiversity managers, and environmental NGOs), and contributed to raising societal awareness on global change issues.

Both stakeholders and scientists agreed that the way results were framed, interpreted and communicated should be carefully considered, as this would play a major role in bringing potential users to consult and use them in an informed manner. Nevertheless views on the best approaches to do so differed. For scientists the response to demands on clarity and comprehensiveness was to produce the ATEAM Atlas (Metzger et al. 2004; Metzger and Schröter 2006). Although stakeholders praised this initiative, some would have preferred meaningful user-targeted syntheses and policy recommendations, based on key mapped outputs. In trying to meet this request a delicate balance has to be found between honesty about the uncertainty of the results and clarity of the message conveyed.

Evaluation from the perspective of the scientists

The present evaluation is primarily based on semi-structured interviews of specific ATEAM scientists, interventions during workshops discussions, informal feedback and observation.

Influence of stakeholders

Overall, interviewed scientists believed that stakeholders had had a significant influence on the ATEAM research. No attempt was made to evaluate this impact quantitatively or systematically across the whole ATEAM consortium. Instead, statements of scientists are synthesised and discussed in this section.

The wish to define and produce stakeholder-relevant results continuously steered the consortium's work, thereby giving the project leadership a powerful coordination tool. Stakeholders provided thought-provoking perspectives and opinions on ATEAM research framework. They commented on near final results, the meaningfulness of these for their activities, and ways to improve result communication/dissemination. They contributed to the elaboration of further research questions, some of which are currently being addressed. Practically, stakeholders gave useful comments on the research plan. They reviewed and evaluated the methodologies and assumptions used in developing the land use scenarios and each modelling sector (Table 3), as well as the temporal and spatial scales of the results. In particular, the indicators of ecosystem services used in the assessment framework were chosen together with stakeholders from the list of indicators that the ecosystem models were able to produce. Mostly this choice was straightforward, such as choosing the indicator 'wood production' for the 'Forestry' sector, and 'run-off quantity and seasonality' for the 'Water' sector. However, in some cases scientists experienced surprises. For example, many stakeholders from the 'Agriculture' sector were less interested in crop yield estimates than they were in estimates of future agricultural area

Table 3 Examples of stakeholders' impacts on ATEAM's research

Research teams	Stakeholder impact
Land use scenarios	Evaluation and discussion of basic assumptions, sectoral drivers of change and of the decision rules guiding land use prioritisation
'Agriculture'	Reality check (e.g. importance of food quality vs. quantity in the European context)
	Supported the farmers' viability assessment (e.g. the future amount of land available for agriculture was more interesting than indicators for crop production)
	Supported and informed a detailed study of bioenergy crop suitability
'Biodiversity and nature conservation'	Discussed the choice of indicator species
	Supported the research team's preference for habitat vs. the more commonly accepted species diversity and richness indicators
'Carbon Storage'	Research topic prioritisation (e.g. a realistic land management rather than the originally planned nitrogen deposition module)
	Initiated a biomass energy case study not originally on the ATEAM task list (see above)
'Forestry'	Reality check on forest management and adaptation measures (e.g. time scales of planning in forestry; the importance of ownership and national and EU directives)
'Mountain environments'	Reality check on priorities in the tourism sector (e.g. infrastructure/accessibility are more important aspects than aesthetics; links between characteristic species or landscapes and traditional local craft are highly attractive)
	Diverse perspectives on results for different mountain stakeholders (e.g. changes in water storage peak will affect differently the hydroelectric and agricultural sectors)
'Water'	Discussion of scale issues. The ATEAM grid provides valuable information for national and supranational scales of decision-making, but is not very useful for local and regional water managers who need information at catchment level (as provided in Alpine case studies)

and income ('farmer livelihood'). Furthermore, stakeholders provided ATEAM with inspiration and support for specific case studies (e.g. biomass energy, alpine catchment studies), for which additional indicators were elaborated. Moreover, since stakeholders encouraged sector specific assessment of adaptive capacity, an exploratory study into agricultural adaptive capacity was initiated. This is on going and will feed future modelling developments (Reidsma et al. 2007).

Content evaluation

Through the dialogue scientists developed a better understanding on how ecosystem services were recognised and managed by the participating stakeholders, who provided invaluable information on the multiple facets and challenges of sectoral management practice and adaptation. Although ATEAM was predominantly grounded in the natural sciences, much effort was made to include ecosystem management in the vulnerability assessment. For example, decision-making in a socio-economic and policy context enters the assessment via the land use scenarios and via ecosystem models that take into account agricultural and forest management. Nevertheless, a recurring theme during the dialogue was to learn just how complex human–environment interactions are in a context of EU, national and regional policies and under socio-economic constraints, and to reflect on ways to better address this complexity in future modelling. To give one example, the diversity of forest ownership and forest use in terms of area owned, financial relevance relative to other income sources and management goals was even greater than anticipated. Forest owners can rely on forest ecosystem services for almost all or next to none of their income, sometimes independent of the area of forest owned. Forests are managed to optimise many outcomes, ranging from commercial and recreational uses to conservation purposes. Here, ATEAM's choice of indicators (i.e. wood production, carbon stored in vegetation and soil, species turnover, tree species distribution) fell short of the information needs of all possible stakeholders. These complexities were discussed during stakeholder interactions and explored especially in the land use modelling work.

Process evaluation

This section summarises and analyses the way scientists perceived the dialogue process. Initially scientists' attitudes regarding the stakeholder dialogue and its meaningfulness in serving the set research plan were mixed. Enthusiasm and interest about developing significant elements of applied and participative research met scepticism on whether this activity would add substantially to the research in view of the costs involved (i.e. time, effort, resources, which could have been spent on the modelling itself). There was also anxiety about the potential failure to provide stakeholders the information they were after.

The project had chosen to step out of the known paths of fundamental ecological modelling research and there was

some uncertainty on whether this was a valid choice from the scientific point of view, and on how to perform this well. In the peer community some viewed this initiative 'at best' as a marketing trick to attract funding or 'at worst' as a 'non scientific' goal, which would discredit the overall project's scientific credibility. The project leadership thus took a significant risk and had to dedicate much time in convincing some project members and peers that it would be worth the effort. The latter was achieved by not compromising in core parts of the research plan (e.g. the detailed modelling developments and the benchmarking exercise—See Morales et al. 2005), which were not presented to stakeholders. These formed the main scientific achievements per se of the project, and guaranteed scientific credibility in the ecological modelling peer community. As consensus was forged on the originality and feasibility of the overall methodology, including the generic adaptive capacity index, and of the importance of the stakeholder dialogue component, the project achieved scientific recognition in the interdisciplinary global change assessment community.

All interviewed scientists clearly took the need for consultation and transfer of scientific information to stakeholders seriously. They expected however to obtain valuable feedback from stakeholders on specific issues (e.g. on thresholds of change in ecosystem provision beyond which sectoral adaptive capacity would be endangered). This was not always the case, and some scientists felt somewhat frustrated at having invested substantial efforts into the dialogue for apparently little return. Like stakeholders, most scientists believed that the dialogue had been too fragmented. In terms of timing moreover, the first workshops were simply too early for some scientists, who felt they had not had the time to become sufficiently familiar with new models, or to develop them to their satisfaction.

These critiques relate to the way the dialogue was designed and implemented: i.e. few, far-apart, content-rich workshops. Essentially, each workshop first presented the overall methodology, then the developments and results obtained by each modelling group. By opening to a certain extent the black box of modelling, tedious but necessary clarifications were needed to make explicit the range of analyses the models could perform, and the associated limitations due to data restrictions or the strict research plan. Scientists had to accept that stakeholders had a steep learning curve to overcome before they could adequately provide the information scientists desired. For example some forestry stakeholders launched a long discussion on carbon storage in wood products as they felt that this was not adequately covered within ATEAM. Scientists viewed this mechanism as almost irrelevant, due to its very restricted time-span and sought to move the discussion away from this point. The controversy was only settled when scientists took the time to explain in detail that the range of carbon reservoirs considered within the model indeed included temporary carbon storage such as wood products. Therefore, the chosen interaction format effectively reduced the time available to explore some pertinent questions scientists and stakeholders had. Scientists and stakeholders alike would have welcomed more frequent, focused meetings, and to move away from the general 'presentation-feedback' mode, to a 'working group' approach. Some scientists thus pursued in-depth interactions with some stakeholders outside the official dialogue activities.

Scientists generally felt comfortable during the dialogue interactions, since all stakeholders were science-literate and sympathetic to, or even experienced in ecological and/or global change modelling. Scientists found it easier to communicate with stakeholders who had a clear agenda (e.g. managers, scientific advisers, NGOs), than with some, who systematically focused on, or lobbied for, their own interests (e.g. a few private managers and consultants). A common language was aimed at, which occasionally required long discussions to adjust the terminology to better suit stakeholders' opinions. For example, the term 'unprotected land' was renamed 'undesignated land' in the land use scenarios, after some stakeholders insisted that all land management included some degree of protection. Even if terminology discussion took time and appeared tedious or frustrating, they were in fact necessary negotiation processes, which contributed to develop a broad consensus.

Scientists generally felt understanding, curiosity and interest from the stakeholders, and wondered whether the lack of 'cultural shock' did not imply that the project had failed to target 'real' stakeholders. At the same time, when some stakeholders insisted repetitively on their own specific interests and failed to appreciate that these played a minor role in the wider scope of the project, some scientists experienced them as 'pushy' or 'narrow-minded'. This illustrates just how complicated the selection of the appropriate stakeholders for a given project can be. Within ATEAM, stakeholders had to be able to understand the basic science, while being able to detach themselves sufficiently from their particular interests to contribute to a collective discussion. Since each stakeholder group influenced the orientation of the exchange in a different manner, the dialogue organisers had to continuously steer the discussion back on the issues to be covered during a particular session, whether these were set with the stakeholders, or internally.

Communication and dissemination of ATEAM results

Some scientists emphasised the challenges involved in communicating the usefulness of abstract, long-term exploratory research, for example via the use of scenarios. Stakeholders appeared to be primarily interested in obtaining

'relatively certain' information on what could happen in their own region and sector over the near future. These seemingly irreconcilable expectations may again have been prompted by the format chosen. Stakeholders were confronted with scenarios already largely developed, the assumptions and related value judgments of which, they were asked to comment upon. Initially, stakeholders reacted by pointing out driving forces that were critical for them, only to hear that these were or could not be included at this stage (e.g. on the role of the agro-industry). The black box of scenario making was explicitly opened to allow stakeholders to evaluate it. Implicitly however, stakeholders were asked to accept and trust that the scenarios produced were as best as could be within the project constrains. The aims of this activity were therefore ambivalent and resulted in different understandings on the nature and purpose of the discussion and on the role of stakeholders. This could explain the apparent mismatch in scientists and stakeholders' interests and expectations. Effectively most stakeholders have to deal with uncertainty in their decision-making and to develop their own mental models and scenarios to perform their work (although they may not use this terminology). It is precisely these abilities that are funnelled into stakeholder-led scenario-making processes. In these activities, stakeholders are given free reign to identify key driving forces and to elaborate narratives, which are then formalised and quantified by scientists (Shackley and Deanwood 2003).

Half way into the project it became clear that a digital compilation of the project's most salient results would be a useful communication tool for interested stakeholders. This led to the development of the ATEAM Atlas of European Vulnerability[8] (Metzger et al. 2004; Metzger and Schröter 2006). The tool allows users to select indicators of impact and vulnerability, using the socio-economic, climate and land use scenarios they are most interested in. The maps are placed in a fact sheet, which provides succinct information on the models and scenarios used, the main assumptions made, the indicators themselves and additional references. Whenever aggregated or relative indicators are shown, users can decompose the results into their components or choose to view absolute data. Furthermore, users can perform simple queries, as well as focus in on specific environmental regions or countries. During final dialogue activities, stakeholders viewed early versions of the tool and commented on ways to improve it.

Evaluation from external observers

Two external observers noted that stakeholders had little possibility to set the agenda of the meetings, to take an active part in the overall decisions on the research programme and outputs, or to be adequately informed on how their comments were incorporated within the research (Jürgens 2001; Vreugdenhil 2003). These are valid critiques. Indeed, more flexibility could have been built in to allow decisions and discussions to be steered more substantially by stakeholders. However, since the research plan was already largely set and agreed with the funding agencies, long before the first stakeholders were contacted, the methodology for modelling and scenario design and its implementation was only marginally influenced by interactions with stakeholders. Nevertheless the Work Package on Synthesis was left relatively open at the beginning of the project. Here, there was sufficient flexibility and resources to explore methods and tools in a learning-by-doing approach to best compile and communicate the results of the project and to adjust substantially to stakeholders' comments. It is within this part of the project that the ATEAM Atlas was developed (Metzger et al. 2004; Metzger and Schröter 2006). The digital atlas was however also a solution proposed and developed by scientists with little contribution of stakeholders, apart from the feedback they provided during the final general workshop (see "Relevance and dissemination of ATEAM results").

Discussion

A paradox in global change assessment research?

Global change models are increasingly being coupled to combine the insights of both biophysical and socio-economic disciplines (Muetzelfeldt 2003). More comprehensive results are thus produced, which help to uncover clear trends and/or a range of possible outcomes, while computer tools allow representing them in ever-finer resolutions (McCarthy et al. 2001; Metzger et al. 2005). These results are, however, based on broad or generic assumptions, and even the finest models produce considerable uncertainty (Reilly et al. 2001). At the same time global change models such as those used in ATEAM, produce large amounts of interesting results, and browsing through them requires much dedication. For example the ATEAM vulnerability atlas is a compilation of over 3,000 maps, and many more summarising charts (Metzger et al. 2004; Metzger and Schröter 2006). Despite the considerable achievement of producing these valuable scientific results, there seems to be a paradox in presenting vast amounts of uncertain results in a format that implies a high level of accuracy. A non-informed user will intuitively zoom at the region/sector he or she is more interested in and overlook the broad simplifications and uncertainties attached to them. The potential for misunderstanding and

[8] The ATEAM Atlas of European Vulnerability is available to download at: http://www.pik-potsdam.de/ateam/.

misinterpretation of the results is thus large. ATEAM dealt with this serious issue by embedding all maps in succinct fact sheets. However, although clear flags can be inbuilt to draw attentions to limits of modelling, these demand the users to commit the time and effort to understand them.

One way to tackle this paradox is to research methods to better assess and manage uncertainty in global change models (e.g. Rotmans and van Asselt 2001). Another, preferred by stakeholders, is to produce targeted lay syntheses, with specific modelling outputs. This could be understood as the responsibility of scientists, since they would effectively take control of the whole process from scientific knowledge production, integration to communication. However, few scientists are keen to perform all these tasks, while those who do are often considered 'interpreters' or 'communicators' of science, rather than scientists per se. In ATEAM a further way was explored: to take the initiative and the risk and to dedicate substantial resources to collaborate with stakeholders and to open with them the black box of modelling. If stakeholders did not obtain the precise results they were after, the dialogue gave them the opportunity to debate not only the possible implications of global change, but also to better understand global change modelling itself and the attached uncertainty.

Transparency as a basis for open negotiation

Participatory research is about creating the opportunity for confrontation and discussion of different worldviews and perceptions. By opening a window for interactions, scientists are inviting stakeholders to have a say on the research process and content, and are thus opening themselves to critique as well as praise. This feedback is extremely valuable, but can be difficult to accept if it does not correspond to the expectations scientists have. Different participants have different expectations about what the dialogue and research should be about. The scope, boundaries and desired outcomes of the research and the dialogue exercise should be either collectively discussed and agreed upon, or at least clearly stated so that stakeholders understand what is expected from them, and what they can expect from participating in the process. Indeed, participants, whether scientist or stakeholder, have an implicit and explicit agenda in engaging in a dialogue process. Explicitly, scientists may for example want to evaluate with stakeholders their research, implicitly however they may also seek their endorsement to push their method and results forward. Explicitly stakeholders may want to obtain more information and implicitly steer scientific research in specific directions suited to their particular needs. There is nothing wrong about these objectives if they are made transparent, so that participants, scientists and stakeholders alike, are aware of the diverse motivations at hand, and so that conflicting interests may be addressed in open negotiations.

The scientists involved in ATEAM feel a strong responsibility in supporting a transition to sustainability by producing meaningful information for European policy and decision makers. To improve the societal relevance of ATEAM's results was an explicit aim of the project. At the same time the project desired to improve the state-of-the-art of ecological modelling per se. Another explicit goal was thus to achieve scientific credibility and recognition among the scientific peer community. These two explicit aims were not incompatible but raised different, sometimes conflicting priorities: for example, on how to adapt the planned research programme to best tackle stakeholders' needs. Moreover, scientists faced substantial restrictions in terms of data availability and quality. Even if resources would have been unlimited, many interesting scientific approaches and stakeholders' suggestions could not have been addressed for simple want of appropriate data. The many, sometimes mutually exclusive research avenues possible needed to be prioritised. In this process, stakeholders provided valuable input to better balance purely scientific and socially relevant research questions, as illustrated above in Table 3.

Reconciling scientists' and stakeholders' expectations in sustainability science

The potential of numerical modelling as a guide for policy making primarily relies on its scientific credibility at disciplinary and interdisciplinary level, but also on the degree of societal relevance, albeit acceptance, models achieve among policy and decision makers. Both are to a certain extent a negotiated social and political process rather than purely a scientific exercise (Van den Hove 2007). This is one of the fundamental challenges integrated assessments face, namely to achieve an acceptable level of simplification and associated uncertainty while at the same time still encompassing the key complexity of the systems simulated.

In tackling this challenge vulnerability assessment research is being pulled by two opposing forces related to different interpretations of the role of scientific inquiry. Van den Hove (2007, p 12) thus distinguished issue-driven 'science for action' from curiosity-driven 'science for science'. The former fosters a user-orientated discipline focused on satisfying stakeholders' short-term information needs (where scientists may become commissioned consultants or advisers). The latter prefers a discipline, where the definition of research problems, priorities and methodologies remain primarily in the hands of scientists and where stakeholders play a peripheral role. A compromise between these visions thus needs to be found in vulnerability assessments research,

so that societal relevance does not take precedence over scientific excellence and credibility, and vice versa. This compromise will have to be negotiated on a case-by-case basis from the design to the implementation and evaluation stages. To this end, innovative approaches to move away from the perception of science as top–down production of expert answers to one of science as collective exploration of the plausible are required.

If global change research is to overcome the discrepancies between stakeholders' expectations from science and current capability to fulfil these, further and stronger bridges are needed to reinforce dialogue and collaboration between science, policy and society. To raise the visibility and meaningfulness of vulnerability assessments as critical means to better understand global change and its potential worrying impacts on society, two trends are being followed, the common denominators of which are science-based stakeholder dialogues. On the one hand uncertainty has emerged in the last decade as a major issue in global change modelling and in the vaster context of the so-called 'post-normal science' paradigm[9] (Funtowicz and Ravetz 1993). Key issues identified here are how to better communicate scientific uncertainty to policy makers and society, and more generally how to facilitate decision-making in face of uncertainty. These lines of reflection have fostered the development of a rich discourse bringing together representatives of science, policy and society to contribute to a better understanding of modelling opportunities and limits (e.g. Dessai and Hulme 2004). Science-stakeholder dialogue processes dedicated to debating uncertainty as perceived by scientists and lay people could help solving significant misunderstandings about the potential and limits of modelling. This would provide valuable opportunities to reflect on constructive manners to communicate uncertainty, and to incorporate it in decision-making. The ATEAM dialogue process can be understood as a further step in this direction.

On the other hand some assessments seek to explicitly target specific policy-and management orientated questions at higher spatial resolution, in close consultation with interested stakeholders. The aimed products here are smaller, dedicated models, clear and targeted result syntheses, and self-explanatory information tools, which consider national and subnational scales. Both avenues can feed each other, for greater benefits, in particular in bridging the gap in temporal and spatial scales relevant for scientists and stakeholders, and to create a more dynamic scientific agenda, better suited to the rapidly changing policy agenda. The ATEAM analysis has also a role to play in this second area of research. It has for example already served as a broad basis for downscaled assessments (Zebisch et al. 2005). The vulnerability atlas and the tool for natural reserve selection developed within ATEAM are, moreover, valuable initiatives towards a better communication of global assessment results (Araújo et al. 2002, 2004; Metzger et al. 2004; Metzger and Schröter 2006; Costanza et al. 2007).

Nevertheless, we believe that stakeholders need to understand the roles and limits of scientific enquiry and modelling performances. Scientists cannot provide predictions of future global change impacts and vulnerability. Stakeholders should not expect that such a task be feasible, as large uncertainty is unavoidable since society is continuously shaping its future in a complex unpredictable manner. Similarly, scientists should be cautious when committing themselves to produce results that are socially relevant over the short term or stakeholder-targeted products. To achieve these scientists may need to yield a substantial part of their decision power over to the targeted stakeholders, or at least to negotiate openly with them the main lines of the proposed research. At the same time scientists may need to accept the challenge of better communicating their research in the formats preferred by stakeholders, or to have to dedicate more time still to 'educate' stakeholders to understand and use scientific results.

Conclusions

So, was the stakeholder dialogue in ATEAM worth the effort? Will it have long-term influence on either the stakeholders or the scientists? How can we assess its influence? These are difficult questions to answer, since though the costs for both stakeholders and scientists in terms of involvement and resources are readily measured in terms of what could have been done instead, the benefits remain often intangible. Certainly this experience allowed all participants to confront themselves with the mental models, and value systems of others. Each party tried at first to convince the other that their views were legitimate, well thought-out and relevant, but gradually opened up in most cases to those of others. This is when mutual learning starts to occur and when a real exchange takes place.

The ATEAM stakeholder dialogue has been in itself an important part of the project's results. The project collaborated with an expanding stakeholder network and its assessment approach was reviewed and improved in view of the dialogue outcomes. If the original research plan and

[9] For Funtowicz and Ravetz (1993) 'normal', positivist science, based on objective, deducible or observable phenomena fails to address the challenges poses by co-evolving natural and human systems. For example global change and related policy issues are characterised by large uncertainty, complex ethical dilemmas and a plurality of perspectives and value systems. To deal with these important aspects the authors promote a re-evaluation of scientific inquiry, its goals and methods. In particular, science should be developed in dialogue with society to better address key environmental, social and ethical challenges.

the ecosystem modelling per se were not fundamentally changed by stakeholders, these provided healthy and constructive 'outsiders' views on the project research questions and desired results. Scientists further gained valuable insights into stakeholders' perceptions on ecosystem services and global change, as well as on ecosystem management and sectoral adaptive capacity. It therefore appears that the stakeholder dialogue within ATEAM at least partly fulfilled the original goals of obtaining from stakeholders a valuable reality check and critical feedback on the overall project methodology, its outputs, their meaningfulness and ways to disseminate them efficiently. Moreover, through this experience scientists considerably adjusted their thinking and work. Together scientists and stakeholders contributed to developing bridges between the generators of scientific knowledge and their users.

Regarding the influence of the dialogue on the stakeholders, less is known. Policy advisers commissioned a study on German vulnerability, which is inspired by, and based on, ATEAM (Zebisch et al. 2005). However, one could say that it is at the end of the project that the conditions for a successful tight collaboration had been met. Perhaps what will remain for scientists and stakeholders alike are the impressions (positive or negative) they had during the workshops, the surprises and curiosity they experienced at hearing something new or controversial, a key question or two that formed in their mind.

Acknowledgments The authors are in debt with all stakeholders who offered their time and valuable comments during the course of the project. We would also like to thank particularly the project leader, Prof. Wolfgang Cramer and all ATEAMers for their continuous support. Additional thanks go to Professors Martin Welp and Carlo Jaeger for their valuable advice and to the European Commission, who funded the ATEAM Project (Project No. EVK2-2000-00075) under the 5th Research Programme 'Energy, Environment and Sustainable Development.

References

Alcamo J, Kreilemann E, Leemans R (1996) Global models meet global policy. Glob Environ Change 6(4):255–259

Araújo MB, Williams PH, Turner A (2002) A sequential approach to minimize threats within selected conservation areas. Biodivers Conserv 11:1011–1024

Araújo MB, Cabeza M, Thuiller W, Hannah L, Williams PH (2004) Would climate change drive species out of reserves? An assessment of existing reserve-selection methods. Glob Chang Biol 10:1618–1626

Arnstein SR (1969) A ladder of citizen participation. J Am Inst Plann 35(4):216–224

Behringer J, Buerki R, Fuhrer J (2000) Participatory integrated assessment of adaptation to climate change in Alpine tourism and mountain agriculture. Integr Assess 1(4):331–338

Berghöfer U, Berghöfer A (2006) 'Participation' in development thinking—coming to grips with a truism and its critiques. In: Stoll-Kleemann S, Welp M (eds) Stakeholder involvement in environmental management, policy making and research: theory and practice. Springer, Cambridge, pp 79–116

Berkhout F, Hertin J, Jordan A (2002) Socio-economic futures in climate change impacts assessment: using scenarios as "learning machines". Glob Environ Change 12(2):83–96

Biernacki P, Waldorf D (1981) Snowball sampling. Problems and techniques of chain referral sampling. Sociol Methods Res 10(2):141–163

Costanza R, Graumlich L Steffen W, Crumley C, Dearing J, Hibbard K, Leemans R, Redman C, Schimel D (2007) Sustainability or collapse: what can we learn from integrating the history of humans and the rest of nature? Ambio 36:522–527

Crosby N, Kelly JM, Schaefer P (1986) Citizen panels: a new approach to citizen participation. Public Adm Rev 46:170–178

de la Vega-Leinert AC, Schröter D, Fritsch U, Zierl B (2004) Results of the stakeholder evaluation questionnaires. ATEAM report. Potsdam Institute for Climate Impact Research (PIK), Germany. Available from the corresponding author

Dessai S, Hulme M (2004) Does climate adaptation policy need probabilities? Clim Policy 4:107–128

Funtowicz SO, Ravetz JR (1993) Science for a post-normal age. Futures 25:739–755

Fürstenau C, Badeck FW, Lasch P, Lexer MJ, Lindner M, Mohr P, Suckow F (2007) Multiple-use forest management in consideration of climate change and the interests of stakeholder groups. Eur J For Res 126(2):225–239

Füssel H-M, Klein RJT (2006) Climate change vulnerability assessments: an evolution of conceptual thinking. Clim Change 75(3):301–329

Glicken J (2000) Getting stakeholder participation 'right': a discussion of participatory processes and possible pitfalls. Environ Sci Policy 3:305–310

Harrison S, Qureshi ME (2000) Choice of stakeholder groups and members in multicriteria decision models. Nat Resour Forum 24:11–19

Jaeger C, Leimbach M, Carraro C, Hasselmann K, Hourcade JC, Keeler A, Klein R (2002) Community integrated assessment: Modules for cooperation. Nota di Lavoro. Milano, Italia. FEEM, PIK/PIK Publications. Potsdam Institute for Climate Impact Research, Potsdam, Germany

Jürgens I (2001) Climate change and the communication between scientists and stakeholders. Towards a participatory notion of communication. Unpublished MSc. thesis, Lund University, Lund, Sweden

Kasemir B, Gardner M, Jäger J, Jaeger CC (eds) (2003) Public participation in sustainability science. Cambridge University Press, Cambridge

McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS (eds) (2001) Climate change 2001: impacts, adaptation and vulnerability. Contribution of working group II to the third assessment report of the intergovernmental panel on climate change (IPCC). Cambridge University Press, Cambridge

Meadows DH, Meadows DL, Randers J, Behrens WW III (1972) The limits to growth: a report for the Club of Rome's project on the predicament of mankind, 2nd edn. 1974. Signet: New American Library, New York

Metzger MJ, Schröter D (2006) Towards a spatially explicit and quantitative vulnerability assessment of environmental change in Europe. Reg Environ Change 6(4):201–216. doi: 10.1007/s10113-006-0020-2

Metzger MJ, Leemans R, Schröter D, Cramer W, ATEAM Consortium (2004) The ATEAM vulnerability mapping tool. Office C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC), Wageningen, The Netherlands. CD-ROM Publication No. 27. Available at: http://www.pik-potsdam.de/ateam

Metzger MJ, Leemans R, Schröter D (2005) A multidisciplinary multi-scale framework for assessing vulnerabilities to global change. Int J Appl Earth Observation Geoinformation 7:253–267

Metzger MJ, Schröter D, Leemans R, Cramer W (2008) A spatially explicit and quantitative vulnerability assessment of ecosystem service change in Europe. Reg Environ Change. doi: 10.1007/s10113-008-0044-x

Morales P, Sykes MT, Prentice C, Smith P, Smith B, Bugmann H, Zierl B, Friedlingstein P, Viovy N, Sabaté S, Sánchez A, Pla E, Gracia CA, Sitch S, Arneth A, Ogee J (2005) Comparing and evaluating process-based ecosystem model predictions of carbon and water fluxes in major European forest biomes. Glob Chang Biol 11(12):2211

Muetzelfeldt R (2003) Declarative modelling in ecological and environmental research. AVEC Papers—Available at: http://www.pik-potsdam.de/avec/decmod_final8.pdf

Oels A (2006) Evaluating stakeholder dialogues. In: Stoll-Kleemann S, Welp M (eds) Stakeholder involvement in environmental management, policy making and research: theory and practice. Springer, Cambridge, pp 117–147

Patt A, Zeckhauser R (2002) Behavioral perceptions and policies toward the environment. In: Gowda R, Fox J (eds) Judgments, decisions, and public policy, Cambridge University Press, Cambridge, pp 265–302

Patt A, Suarez P, Gwata C (2005a) Effects of seasonal climate forecasts and participatory workshops among subsistence farmers in Zimbabwe. Proc Natl Acad Sci USA 102:12673–12678

Patt T, Klein RJT, de la Vega-Leinert AC (2005b) Taking the uncertainty in climate change vulnerability assessment seriously. C.R. Geoscience 337:411–424

Pretty JN (1995) Participatory learning for sustainable agriculture. World Dev 23(8):1247–1263

Reid WV, Mooney HA, Cropper A, Capistrano D, Carpenter SR, Chopra K, Dasgupta P, Dietz T, Duraiappah AK, Hassan R, Kasperson R, Leemans R, May RM, McMichael TAJ, Pingali P, Samper C, Scholes R, Watson RT, Zakri AH, Shidong Z, Ash NJ, Bennett E, Kumar P, Lee MJ, Raudsepp-Hearne C, Simons H, Thonell J, Zurek MB (2005) Ecosystems and human well-being. Millennium Ecosystem Assessment Synthesis Report. Island Press, Washington

Reidsma P, Ewert F, Oude Lansink A (2007) Analysis of farm performance in Europe under different climatic and management conditions to improve understanding of adaptive capacity. Clim Change 84:403–422

Reilly J, Stone PH, Forest C, Webster MD, Jacoby HD, Prinn R (2001) Climate change: uncertainty and climate change assessments. Science 293(5529):430–433

Renn O, Webler T (1996) Der kooperative Diskurs: Grundkonzeption und Fallbeispiel. Analyse und Kritik 18:175–207

Renn O, Webler T, Wiedemann P (eds) (1995) Fairness and competence in citizen participation: evaluating models for environmental discourse. Kluwer Academic Publishers, Boston

Reynolds JF, Smith DMS, Lambin EF, Turner BL, Mortimore M, Batterbury SPJ, Downing TE, Dowlatabadi H, Fernandez RJ, Herrick JE, Huber-Sannwald E, Jiang H, Leemans R, Lynam T, Maestre FT, Ayarza M, Walker B (2007) Global desertification: building a science for dryland development. Science 316:847–851

Rotmans J (1998) Methods for IA: the challenges and opportunities ahead. Environ Modell Assess 3(3):155–179

Rotmans J, van Asselt MBA (2001) Uncertainty management in integrated assessment modelling: towards a pluralistic approach. Environ Monit Assess 69(2):101–130

Runge D, Reusswig F (2003) Substitution von Geschäftsreisen durch Videokonferenzen. Wege zur Ausschöpfung der Potentiale zur Reduktion von Emissionen aus dem Geschäftsreiseverkehr. Zusammenfassung des Endberichts von Dezember 2003. Potsdam Institute für Klimafolgenforschung e.V.—Deutsche Telekom—European Climate Forum. Available at: http://www.european-climate-forum.net/pdf/Zusammenfassung%20ECF.pdf

Schröter D, The ATEAM Consortium, 2004. Final ATEAM report 2004. Section 5 and 6. Potsdam Institute for Climate Impact Research, Potsdam, Germany. Available at: http://www.pik-potsdam.de/ateam/ateam_final_report_sections_5_to_6.pdf

Schröter D, Cramer W, Leemans R, Prentice CI, Araújo, Arnell NW, Bondeau A, Bugmann H, Carter TR, Gracia CA, de la Vega-Leinert AC, Erhard M, Ewert F, Glendinning M, House JI, Kankaanpää S., Klein RJT, Lavorel S, Lindner M, Metzger MJ, Meyer M, Mitchell T, Reginster I, Rounsevell M, Sabaté S, Sitch S, Smith B, Smith J, Smith P, Sykes MT, Thonicke K, Thuiller W, Tuck G, Zaehle S, Zierl B (2005a) Ecosystem service supply and vulnerability to global change in Europe. Science 310:1333–1337

Schröter D, Polsky C, Patt AG (2005b) Assessing vulnerabilities to the effects of global change: an eight step approach. Mitigation and Adaptation Strategies for Global Change 10(4):573–595

Shackley S, Darier E (1998) Seduction of the Sirens: global climate change and modelling. Sci Public Policy 25(5):313–326

Shackley S, Deanwood R (2002) Stakeholder perceptions of climate change impacts at the regional scale: implications for the effectiveness of regional and local responses. J Environ Plann Manage 45(3):381–402

Shackley S, Deanwood R (2003) Constructing social futures for climate change impacts and response studies: building qualitative and quantitative scenarios with the participation of stakeholders. Clim Res 24(1):71–90

Tol RSJ, Vellinga P (1998) The European Forum on Integrated Environmental Assessment. Environ Modell Assess 3:181–191

Toth FL (2001) Participatory integrated assessment methods. An assessment of their usefulness to the European Environmental Agency. Technical Report 64, European Environmental Agency, Copenhagen, Denmark

Toth FL, Hizsnyik E (1998) Integrated environmental assessment methods: Evolution and applications. Environ Modell Assess 3:193–207

Tuinstra W, van der Kerkhof M, Hisschmöller M, Mol A (2003) COOL: exploring options for carbon dioxide-reduction in a participatory mode. In: Kasemir B, Jäger J, Jaeger CC, Gardner MT (eds) Public participation in sustainability Science. A handbook. Cambridge University Press, Cambridge, pp 176–186

Van den Hove S (2007) A rationale for science–policy interface. Futures. doi:10.1016/j.futures.2006.12.004

van de Kerkhof M (2004) Debating climate change. A study on stakeholder participation in an integrated assessment of long-term climate policy in The Netherlands. Lemma Publishing, Utrecht

van Daalen CE, Thissen WAH, Berk MM (1996) The delft process: experiences with a dialogue between policy makers and global modellers. Glob Environ Change 6(4):267–285

Vreugdenhil JJ (2003) Stakeholder, scientists, scenarios and the skills of shaping dialogue. Evaluation of the scenario development and the stakeholder dialogue in the ATEAM project. Unpublished Msc Thesis, Wageningen University, Wageningen, The Netherlands

Walker B, Carpenter S, Anderies J, Abel N, Cumming GS, Janssen M, Lebel L, Norberg J, Peterson GD, Pritchard R (2002) Resilience management in social–ecological systems: a working hypothesis for a participatory approach. Conserv Ecol 6(1):14. [online at: http://www.consecol.org/vol6/iss1/art14]

Warner JP Waalewijn P, Hilhorst D (2002) Public participation for disaster-prone watersheds: time for multi-stakeholder platforms?

Water and Climate Dialogue Thematic Paper/Disaster Sites No.6, Wageningen University

Welp M de la Vega-Leinert A, Stoll-Kleemann S, Jaeger CC (2006a) Theoretical approaches for science-based stakeholder dialogues. Glob Environ Change 16(2):115–234

Welp M de la Vega-Leinert A, Stoll-Kleemann S, Fürstenau C (2006b) Science-based stakeholder dialogues in climate change research. In: Stoll-Kleemann S, Welp M (eds) Stakeholder involvement in environmental management, policy making and research: theory and practice. Springer, Cambridge, pp 213–240

Welp M, Battaglini A, Jaeger C (2008) Social relevance of vulnerability assessments: role of stakeholder dialogue in defining dangerous levels of climate change. In: Patt A, Schröter D, Klein RJT, de la Vega-Leinert AC (eds) Environmental vulnerability assessments for policy and decision making. Earthscan (accepted)

Wilby RL, Charles SP, Zorita E, Timbal B, Whetton P, Mearns LO (2004) Guidelines for use of climate scenarios developed from statistical downscaling methods. Intergovernmental panel on climate change—http://www.ipcc-data.org/guidelines/dgm_no2_v1_09_2004.pdf

Zebisch M, Grothmann T, Schröter, D., Haße, C., Fritsch U, Cramer W (2005) Climate change in Germany—vulnerability and adaptation of climate sensitive sectors. Report commissioned by the Federal Environmental Agency, Germany (UFOPLAN 201 41 253). Potsdam Institute of Climate Impact Research, Potsdam, Germany. Report in German and English available at: http://www.umweltbundesamt.de/index-e.htm