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Stakeholder dialogue as a communication and negotiation tool in scientific inquiry

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Abstract

A stakeholder dialogue aimed to facilitate the development and dissemination of the ATEAM European vulnerability assessment of global change impacts. This participative experiment constitutes a milestone in integrated ecological modelling. Participating ecosystem managers, sectoral representatives and policy advisers significantly influenced the research content and process. The usefulness of the projects' outcomes for stakeholders and an evaluation of the dialogue are presented.

Three challenges are highlighted. First, the increasing complexity and uncertainty of global change modelling and the multiplication of its results raise the question of how to best communicate modelling outcomes to society. Second, scientifically credible and socially relevant participative research implies the need for transparency in the research process, so that goals, underlying assumptions and methods of scientific inquiry may be adequately scrutinised and debated. Finally, stakeholder dialogues are valuable processes of negotiation, which may help to reconcile the differing needs of fundamental and applied global change sciences.

Keywords: science-stakeholder dialogue, participative research, ecosystem modelling, global change, vulnerability assessment

1. Introduction

The present paper focuses on communication between scientists and societal actors *during* participatory research on climate change. This includes two main domains: 1) communication on climate change and, 2) communication on the research itself. If the former emphasises the content, the latter focuses on the form and the process the research takes.

Science-stakeholder dialogues have been defined as a 'structured communicative process of linking scientists with selected actors that are relevant for the research problem at hand' (Welp et al., 2006a). This approach, among other participative research methods, has become important in

the last two decades in a range of academic fields. The underlying rationale is closely related to a paradigm-shift in science epistemology, namely the post-normal paradigm (Funtowicz and Ravetz, 1993). For these authors, a scientific domain such as climate change science is characterized by the universal scale of the processes it studies and their long-term impacts, and the intricate interactions between natural and human systems. A typical positivistic, deductive, quantitative approach reaches its limits in such complex issues. *Alone* 'normal' science is unable to bring society critical answers due to: intractable cumulative uncertainty, which makes predictions impossible; critical ethical and political dilemmas, for which a range of valid, often conflicting societal perspectives exist; and finally the high stakes these value-laden issues are associated with, which demand urgent societal debate and decisions. One of the methods of the proposed 'post-normal' science is to involve societal actors in the research process to satisfy a series of goals. These range from data collection methods, where stakeholders are invited to share their knowledge and information, to fully participative exercises, where scientists and stakeholders become partners and jointly decide the research scope (Welp et al., 2006a, b).

This paper presents and discusses insights gained during the science-stakeholder dialogue exercise implemented within ATEAM (Advanced Terrestrial Ecosystem Assessment and Modelling). This EU framework 5 research project officially run from 2001 to 2004 and was coordinated from the Potsdam Institute for Climate Impacts Research, Germany. Its overarching goal was to produce maps of European impacts and vulnerability to global change, explicitly conceived and implemented with policy-makers and environmental managers in mind (Metzger et al., 2008; Schröter et al., 2005). For this purpose a stakeholder dialogue initiative was embedded in the research process. This experience profoundly affected the way participating scientists designed and performed their work and constitutes a milestone in integrated ecological modelling for the purposes of global change impact and vulnerability assessments. The underlying hypothesis is that stakeholder dialogue, and participative methods in general, play a valuable role in the elaboration and evaluation of complex global change models, which may be both scientifically credible and socially relevant.

First, the overall project and the stakeholder dialogue are presented. The stakeholders' selection criteria, including biases, are discussed. Second, stakeholders' influence on the research is summarised. Finally, the dialogue content and process are discussed in terms of their relevance for participating stakeholders and scientists.

2. Overall aims of the ATEAM and the stakeholder dialogue

ATEAM aimed at assessing quantitatively the vulnerability[1] of human sectors (i.e. agriculture, forestry, water, biodiversity, mountain tourism, and carbon-storage potential) to global change.

[1] The degree to which an ecosystem service is sensitive to global change combined with the degree to which the sector that relies on this service is unable to cope with the change.

Since it was primarily an ecosystem modelling project its entry point to vulnerability was through the possible impacts on ecosystem services[2], such as wood production and snow availability.

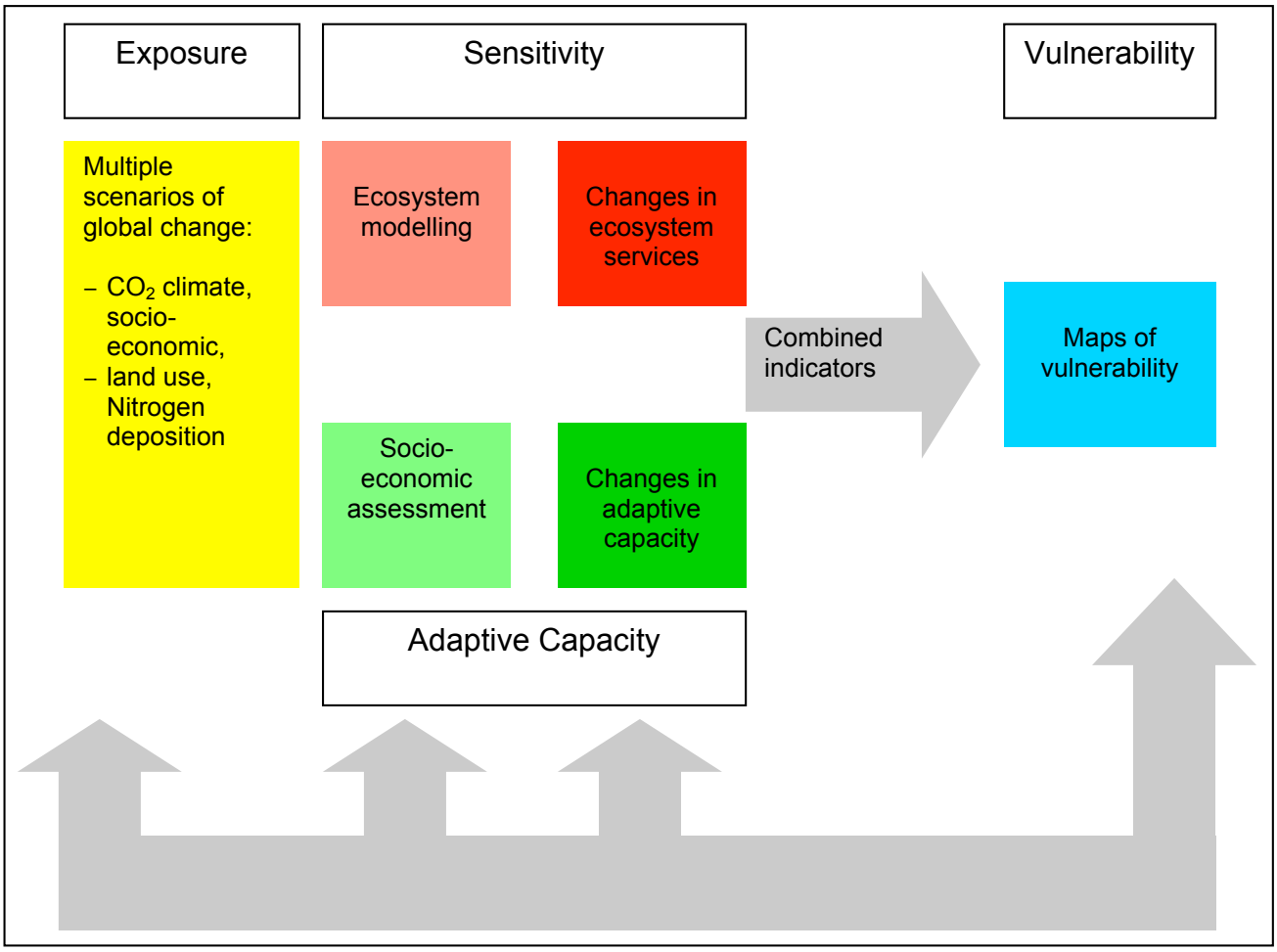

Figure 1. The structure of the ATEAM project with the specific interactions between scientists and stakeholders (from Schröter et al., 2004).

The project methodology is presented in Figure 1[3]. It used a typical deductive, quantitative, natural science approach. Firstly, its umbrella concept, vulnerability, was described and broken down into constitutive elements (i.e. Exposure, Sensitivity, Adaptive Capacity) following established conceptual frameworks. Secondly, driving forces were identified (i.e. climate and land use changes), scenarios were built and proxy indicators were derived and quantified through ecological modelling. Thirdly, a generic, semi-quantitative index for adaptive capacity was derived

[2] Conditions and processes through which ecosystems and the organisations that make them up sustain and fulfil human life.
[3] For the precise description of the methodology and the terminology used, consult Schröter et al. (2004, 2005).

from established socio-economic indicators. Finally, all these indicators were combined to produce an aggregated index of vulnerability expressed on a geographically explicit grid of Europe of 16 km x 16 km.

The stakeholder dialogue aimed at adjusting the project's results to better suit stakeholders' needs with the following goals: identifying and evaluating indicators of change in ecosystem services; determining useful modelling scales (spatial and temporal) and units for these indicators; discussing adequate thresholds for these indicators, beyond which sectoral adaptive capacity could be exceeded; developing stakeholders' ability to use information derived from scenario analysis; and discussing and disseminating the project's results.

Potential stakeholders were identified using the snowball approach (Biernacki and Waldorf, 1981). To complement this a systematic selection matrix was designed based on three main categories: 1) the human activity sectors considered in the overall assessment (e.g. 'Agriculture,'); 2) the type and main interests of stakeholder organisations (e.g. private firm, public management, non-governmental organisations); and 3) the scale of activity of these organisations (i.e. from local to international). The resulting stakeholder database included 204 identified stakeholders, 152 of which were invited to our activities with 58[4] participating in at least one activity.

Sectoral representatives, consultants and private businesses were particularly targeted for the 'Agriculture', 'Forestry', 'Water' and 'Tourism' sectors, since decision-makers and managers in these sectors are often private agents. In contrast, stakeholders from public or independent sectors were approached for the 'Biodiversity and nature conservation', 'Carbon storage' and 'Mountain environments' sectors, since the associated ecosystem services are often non-marketed (Reid et al., 2005), and policy-making occurs at national and/or European levels (e.g. climate mitigation, ecological directives). Policy-makers *per se* were deliberately not included in the stakeholder matrix, since the project targeted stakeholders who though influential could nevertheless express their views freely. In the end, most targeted organisations had a European to global focus of activity, the scales at which the ATEAM results are the most relevant.

The stakeholder selection criteria included: (inter-)sectoral expertise, some 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 to encourage multiple perspectives. Rather than a public participation exercise, we pursued a focus group approach with selected participants. Therefore a

[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).

representative sample of society was not aimed at. Although repetitive attempts were made to engage as many different stakeholders as possible, including private companies and specific consumer/interest groups, most chose not to participate.

Our selection criteria, combined with stakeholders' decision criteria to participate or not, produced a 'green' and 'scientific' bias in the participating group. 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 feel for how to engage stakeholders and demonstrate the relevance of the research project 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 organised. ATEAM scientists participated in 11 further stakeholder events organised within collaborating initiatives (see Schröter et al., 2004). Furthermore, multiple informal exchanges between scientists and stakeholders took place. The primary goal of the formal stakeholder workshops was to facilitate the exchange of information and discussion between scientists, which were involved in modelling development, and stakeholders, who could provide expert knowledge on on-going strategies and practice in natural resource policy and management. Typically, formal workshops gathered an equal number of scientists and stakeholders, with the total number of participants not exceeding 40. Formal events lasted from an afternoon to two days and were organised in a series of plenary and sector-specific working groups. Additional stakeholder events were a series of information side-events, where the ATEAM project, its methodology and results were presented, although here the emphasis was mostly on the unilateral transfer of information from project representatives to potential users, rather than on exchange between scientists and stakeholders.

3. Evaluation of the ATEAM stakeholder dialogue

3.1. Methodology

At main events, stakeholders were asked to complete a questionnaire on the project and workshop content and format. Informal feedback was collected during the events. External observers moreover evaluated the workshops and provided recommendations for future events (Jürgens, 2001; Vreugdenhil, 2003). Finally, semi-structured interviews were carried out with the project leader and coordinator, and one scientist per modelling sector to explore views on the impacts of the stakeholder dialogue on their research. The sections below summarise the main points made by participants, observers and scientists.

3.2. Stakeholders' influence on ATEAM research process and content

If the project's aim to define and produce stakeholder-relevant results was, as such, a powerful coordination tool, which continuously steered the consortium's work, stakeholders themselves had a significant impact on the ATEAM research. This included: 1) thought-provoking perspectives and opinions on the research framework, the near final results and their meaningfulness for stakeholders' activities; 2) suggestions on ways to further improve result communication/dissemination; and 3) contributions to future research agenda.

Practically, stakeholders reviewed and evaluated the methodology and some assumptions used in developing the land use scenarios and specific ecosystem models, as well as the temporal and spatial scales of the results. Stakeholders helped scientists to select and prioritise the indicators of ecosystem services for the assessment framework and to gain insights on how ecosystem services were recognised and managed. They provided invaluable information on the multiple facets and challenges of sectoral management practice and adaptation. They also enthusiastically supported additional exploratory case studies, particularly that on biomass energy potential (Tuck et al., 2006) and agricultural adaptive capacity (Reidsma et al., 2008).

Figure 2. Menu of the ATEAM Atlas of European Vulnerability.

Finally, to ease the presentation, dissemination and analysis of the project results a digital

compilation of the project's most salient results, the ATEAM Atlas of European Vulnerability[5], was developed (Metzger et al., 2004; Metzger and Schröter, 2006) (see Figure 2). This 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, scenarios and indicators used, the main underlying assumptions and additional references. Aggregated resulted can be decomposed and both relative and absolute data can be viewed. Furthermore, simple queries can be performed and users can zoom on specific environmental regions or countries. Early versions of the tool were improved with the help of stakeholders' comments. The final version of the ATEAM Atlas of European Vulnerability is freely available under: http://www.pik-potsdam.de/ateam/ateam.html

3.3. Stakeholders' evaluation

Content evaluation

Stakeholders generally found ATEAM's conceptual framework, the vulnerability assessment methodology, and the Atlas of European Vulnerability interesting and innovative. The temporal and spatial scales of ATEAM analyses were, however, of unequal relevance. The 1990, 2020, 2050, 2080 time slices were useful, for example, for stakeholders in the 'Forestry', 'Carbon storage' and 'Biodiversity and nature conservation' sectors, and to a lesser extent in 'Mountains environments', for which long-term management is key. However, for the 'Water' and 'Agriculture' sectors short-term estimates for the next five to ten years would have been more useful. For many stakeholders the spatial scale of the assessment remained too coarse, despite its exceptionally fine resolution in comparison to other global change assessments.

The identification and assessment of specific ecosystem services, which could be significantly impacted in future, were most relevant for the majority of stakeholders, since this information forms an appropriate basis for exploring adequate adaptation strategies at European to regional levels. In comparison, the aggregated index for 'adaptive capacity' and 'vulnerability' *per se* were judged of limited value (Schröter et al., 2005). Such concepts and indicators therefore seem to have more pertinence as an element for broad scale academic analysis than for practical environmental management (Patt et al., 2005). Stakeholders are generally acutely aware of existing needs and opportunities to adapt to change in their management practice and sectoral adaptation is closely intertwined with economically viability. Stakeholders critically review current policies, market fluctuations and environmental changes, which may benefit or endanger their activity. They are thus 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

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

and is thus of limited interest to them. Scientists and stakeholders however agreed that the components of sectoral adaptive capacity, the interactions between macro and (inter-)sectoral adaptive capacities, and between these and vulnerability were key areas for future research.

Also within the land use scenarios, stakeholders isolated specific driving forces, which they believe should be better taken into account in scenario and model assumptions, in particular policy, market trends, sectoral management, consumer preferences and extreme events. Within the modelling of terrestrial carbon storage, stakeholders inspired a major research re-orientation by prioritising the implementation of more realistic forest management and land use changes over the improved representation of the nitrogen cycle in dynamic vegetation models, which was originally planned. Stakeholders further agreed that in disseminating research results, it should be clearly pointed out that scenarios represent alternative choices of society, rather than possible futures that unfold independently from societal and individual decisions.

Stakeholders' confidence in ATEAM's results was enhanced as significant agreement across modelling results and scenarios was demonstrated. For example, 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., 2005). Consequently, stakeholders particularly encouraged comparative assessments of impacts of alternative policies across different economic sectors, which might allow decision-makers to better choose between different future pathways.

Nevertheless, there was a broad consensus that ATEAM results, or any state-of-the-art vulnerability assessment, would not directly influence decision-making and management behaviour due to the still too large temporal and spatial scales and associated significant cumulative uncertainty. Stakeholders, who await predictions or detailed quantified outputs to guide their decision-making, will be disappointed by the lack of 'answers' from integrated modelling. Integrated assessment results should therefore not be viewed 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 (e.g. decision support systems) may play an important role when targeted at a group of stakeholders. Efforts in this direction included the development of a tool for natural reserve selection that takes into account economic and ecological considerations (Araújo et al., 2002) and 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 be one way to increase the meaningfulness of the project's results for stakeholders in the future, although it might be necessary to overcome a strong resistance from nature scientists to attach monetary values to ecosystem service provision. Environmental and economic model coupling is a development that goes in this direction (Jaeger et al., 2002).

Process evaluation

An evaluation questionnaire was distributed to stakeholders at three events[6]. In total 22 stakeholders out of 58 handed back questionnaires. All numbers quoted below within brackets refer to respondents answering 'Yes' or 'Mostly' to questions out of a total of 22 respondents[7].

Most 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 content and the range of topics covered and found presentations interesting (21). Most gained some useful insights on the topics covered (21), and thought they would be able to integrate some of these in their work (19). For some, too many topics were covered (2), which prevented in-depth discussions on the specific subjects they were interested in (e.g. local scale impacts on biodiversity, downstream activities in 'Agriculture' or 'Forestry' sectors, sectoral adaptive capacity).

Most stakeholders felt comfortable enough to express their opinions (21) and believed that these had been adequately valued by participants (19). Some emphasised the need for unbiased moderation. In later events, stakeholders were offered the possibility to alternate with ATEAMers as moderators. It seems that active participation, constructive criticism and an atmosphere conducive to developing trust and friendliness were achieved. Stakeholders also valued the opportunity to network with peers and scientists as a way to encourage synergies and collaboration. Fellow participants were relevant to many, who envisaged keeping in contact with some of them independently from ATEAM events (12).

Most respondents had been sufficiently interested in ATEAM to envisage participating in follow-up activities (17). Eventually, 11 out of 58 participated in at least two 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). It seems that for respondents, ATEAM had successfully engaged participants, raised interest in its research and provided a dynamic and stimulating discussion and dissemination platform.

The main criticisms on the dialogue process were the infrequence of the events, the long time between events and the lack of regular and transparent feedback in between activities. Some stakeholders expressed some frustration if they felt that their comments had not been adequately

[6] The 2nd and 3rd general stakeholder workshop and the Mountain and Biodiversity sectoral stakeholder workshop.
[7] For the full results of the evaluation questionnaires see: de la Vega-Leinert, A.C. et al. (2004) available from the author.

taken on board. These critiques relate to a key issue in participative research. By asking stakeholders' opinion, ATEAM also raised the expectations that these opinions could and would be fully taken into account. However, the tight research plan and set list of deliverables the project had committed itself to produce meant that the margin of manoeuvre scientists had in addressing stakeholders' comments was significantly narrower than stakeholders thought. Clarifying as early as possible and as repeatedly as necessary how far stakeholders may influence the research programme is thus critical. Important stakeholders' concerns did nevertheless find their way into ATEAM research (e.g. the above mentioned study on agricultural adaptive capacity). Other concerns may only be addressed adequately through fundamental model developments over the long term (e.g. bridging gaps between global modelling scales and local management needs).

Stakeholders encouraged the scientific community to continue raising relevant societal questions, regarding global change impacts and adaptation. They generally believed that ATEAM 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 non-governmental organizations), and contribute to increasing societal awareness.

Both stakeholders and scientists agreed that the way results are framed, interpreted and communicated plays a major role in how modelling outputs are used. Nevertheless, views on the best approaches to foster an informed use of scientific results differed. For scientists the ATEAM Atlas should address issues of data clarity and comprehensiveness. 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.

3.4. Scientists' perception and evaluation of the dialogue

Initially scientists' attitudes regarding the stakeholder dialogue and its meaningfulness in serving the 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 the information stakeholders sought.

The project incorporated elements of qualitative, exploratory, participative social sciences in a framework otherwise centred on fundamental quantitative ecological modelling. There was some uncertainty 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. This represented a significant risk and it required much effort to convince some project members and peers that the dialogue with stakeholders was a valid choice from the scientific point of view. 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 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 to obtain valuable feedback from stakeholders on specific issues (e.g. on thresholds of change in ecosystem service 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 become sufficiently familiar with new models, or had not developed them to their satisfaction. These critiques relate to the way the dialogue was designed and implemented: i.e. few, far-apart, content-rich workshops. This format 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 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 first needed to be established, 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 stakeholders insisted that all land management included some degree of protection. Even if terminology discussions take time and may appear tedious or frustrating, they are in fact necessary negotiation processes, which helps to develop a broad consensus.

Scientists generally experienced stakeholders as understanding, curious and interested and some thus wondered if the lack of a 'cultural shock' did not imply that the project had failed to find 'real' stakeholders. However, when some stakeholders insisted on their own agenda, even if this 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 needed to be able to understand the basic science, while being able to detach themselves sufficiently from their particular interests in order to contribute to a collective discussion.

Some scientists emphasised the challenges involved in communicating the usefulness of abstract, long-term exploratory research (e.g. global change scenarios). Stakeholders appeared to be primarily interested in obtaining 'relatively certain' information on near-future sectoral impacts of global change at local scale. These seemingly irreconcilable expectations may have been prompted by the format chosen. Stakeholders were confronted with scenarios already largely developed, the assumptions and related value judgment of which they were asked to comment upon. Initially stakeholders reacted by pointing out driving forces, which were critical for them, sometimes only to hear that these were or could not be included at this stage (e.g. on the role of the agro-industry). Explicitly, this activity opened the black box of scenario making 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 existing constrains. These ambivalent aims could explain the apparent mismatch in interests and expectations. Effectively most stakeholders deal with uncertainty in their decision-making and 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, within which 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). Unfortunately, the timing and workplan of the project did not allow using this method within ATEAM, since this should have taken place well before the scenarios were actually constructed to give time to scientists to actually devise methods to incorporate stakeholders' ideas.

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. Key stakeholders could theoretically have been brought in as early as the project proposal development stage. However, since the research plan was already largely set and agreed with the funding agencies, 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.

4. Discussion

4.1. 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 uncovering clear trends and/or a range of possible outcomes, while computer tools allow representing them in ever-finer resolutions (McCarthy et al., 2001). 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 3000 maps and many more summarising charts (Metzger et al., 2004; Metzger and Schröter, 2006). Despite the considerable achievement of producing these scientific results, there seems to be a paradox in presenting vast amounts of uncertain results in a format that suggests a high level of accuracy.

It would be interesting to investigate what viewers instinctively take in when observing the maps in Figure 3. How would they combine the message from the text, which points at significant areas of modelling uncertainty, with the detail of the colour contours? Regardless of how much and how precise information one gets on the uncertainty levels involved in the computation of this modelling output, this sort of figures may become a cognitive trap, in that, it is argued, they give contradicting messages on the reliability of these model outputs. If the text invites the viewer to cautious analysis, the level of detail displayed in the figure invites the viewer to associate "precision" for "accuracy" and possibly to take the result for granted. Moreover, a non-informed user will intuitively focus on the region/sector he/she is more interested in and overlook the broad simplifications and uncertainties attached to them. The potential for misunderstanding and 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 built in to draw attentions to limits of modelling, these demand the users to commit the time and effort to understand them.

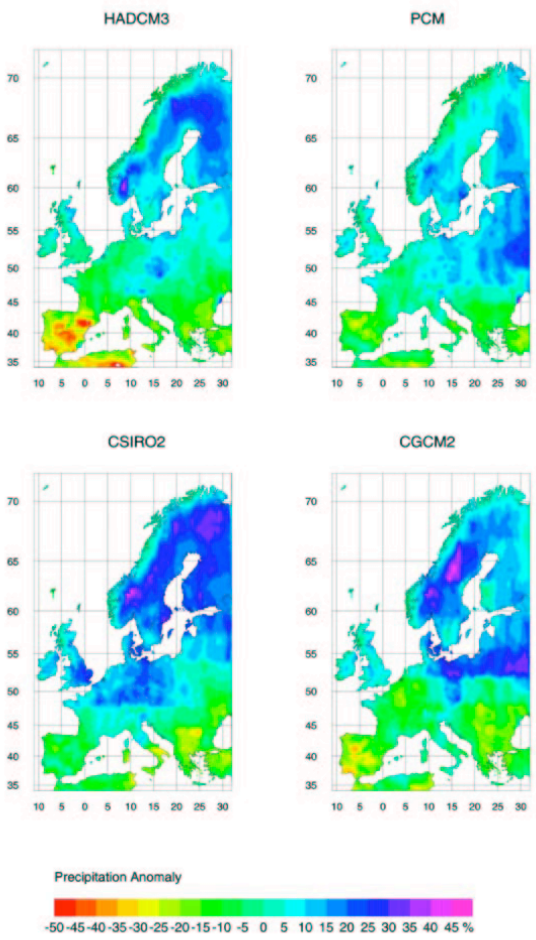

Figure 3. Annual precipitation anomaly for the A2-scenario (2091-2100) compared to 1961. The relative spatial pattern projected by each climate model remains the same over different emission scenarios, and only the size of the anomaly varied between the emission scenarios for one and the same Global Climate Model. Therefore these maps demonstrate the complete relative spatial variability of the climate projection on the annual timescale, even though only one emission scenario (A2) is shown (taken from Schröter et al., 2005)

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 way, 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 scientific knowledge production, integration and communication process. However, few

scientists are keen to perform all these tasks, while those who do are often considered as 'interpreters' or 'communicators' of science rather than scientists *per se*. In ATEAM a middle way was explored: to take the initiative and the risk 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, including the attached uncertainty. This is a first step in developing participating interfaces in ecological modelling, which promote collaborative inquiry as proposed by van den Hove (2006).

4.2. 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 ideally be 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 scientists or stakeholders, have an implicit and explicit agenda when engaging in a dialogue process. Explicitly, scientists may for example want to evaluate their research with stakeholders, 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 to steer scientific research in specific directions suited to their particular needs. There is nothing wrong about these objectives as such, if these are made transparent, so that participants are aware of the diverse motivations at hand, and so that conflicting interests may be addressed openly. To reconcile these widely different expectations and views within a participative research process, science-stakeholder dialogue can be a valuable method and an innovative negotiation, or even mediation platform. For the latter, however a sympathetic, fair, open and rigorous third party is required, that both parties may accept and trust in this demanding but profoundly rewarding process of collective learning.

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 thus an explicit aim of the project. At the same time, scientists wanted 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: e.g., on how to adapt the planned research programme to best tackle stakeholders' needs. Moreover, scientists face substantial restrictions in terms of data availability and quality. Even if resources were 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 scientific and socially relevant research questions.

4.3. Reconciling scientists' and stakeholders' expectations

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 'post-normal science' paradigm (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). 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 mutual 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).

5. Conclusions

The potential of numerical modelling as a guide for policy-making primarily relies on its scientific credibility at disciplinary and interdisciplinary levels, but also on the degree of societal relevance and acceptance that models achieve among policy and decision-makers. We argue that both are to a certain extent a negotiated social process rather than purely a scientific exercise. This is the fundamental challenge 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 simulated systems.

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: 818) 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 middle ground 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, or vice versa. This compromise will have to be negotiated on a case-by-case basis from the design to the implementation 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. Here scientific inquiry is conceived as a process of co-creation of knowledge where scientists and stakeholders collaborate as partners, each bringing to the partnership valuable questions, conceptualisations, contents and methods (Welp et al., 2006a). Furthermore, 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 stakeholder dialogue has been an important result. The project collaborated with an expanding stakeholder network and its assessment approach was improved through stakeholders' critique. The original research plan and the ecosystem modelling *per se* were not fundamentally changed by stakeholders. However, stakeholders provided healthy and constructive 'outsider' views. Through this experience scientists considerably adjusted their thinking and work. They gained valuable insights on stakeholders' perceptions on ecosystem services and global change and on ecosystem management and sectoral adaptive capacity. Together scientists and stakeholders contributed to developing bridges between the generators of scientific knowledge and their users.

We believe that stakeholders need to understand the roles and limits of scientific enquiry and modelling performances. It is vital to understand that scientists cannot provide *predictions* of future global change impacts and vulnerability, instead they make *projections* and explore *multiple scenarios*. Stakeholders should not expect that such a task is 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 producing stakeholder-targeted products and more broadly results that are socially relevant over the short term. To achieve these, scientists 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 formats preferred by stakeholders, or to dedicate more time still to 'educate' stakeholders to understand and use scientific results, while stakeholders 'educate' scientists to produce more relevant and helpful information.

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