



The 3rd ATEAM Stakeholder Dialogue Workshop

“Vulnerability of European sectors to global changes”

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ATEAM

Advanced Terrestrial Ecosystem Analysis and Modelling



Environmental Vulnerability Assessment

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EXECUTIVE SUMMARY

ATEAM's primary objective has been to assess the vulnerability¹ of human sectors relying on ecosystem services² with respect to global change. One of the key motivations of the project has been to provide socially relevant scientific information to: 1) promote better awareness and understanding on potential global change impacts, 2) improve management of European ecosystems and 3) help to bring about a sustainability transition. ATEAM has achieved great credibility and international scientific recognition and has produced:

- a comprehensive modelling framework for projecting the dynamics of ecosystem services provided by European terrestrial ecosystems at a regional scale³,
- a set of multiple, internally consistent socio-economic, climate, land use and nitrogen deposition scenarios at high spatial resolution for Europe,
- a vast array of modelled outputs on ecosystem service provision, adaptive capacity and European vulnerability based on these global change scenarios, and
- a CD-ROM with the interactive ATEAM mapping tool displaying the full range of charts and maps of results with exhaustive documentation and summarised conclusions.

ATEAM provides critical information on how the provision of essential ecosystem services may be affected by global change during the 21st century. Vulnerabilities of sectors and/or regions identified within the research may however be reduced by specific adaptation strategies:

- Land use change projections based on socio-economic and climatic changes show an overall decline in arable land in Europe. Climatic changes will shift crop suitability in agricultural regions. While the suitable area for some crops expands, some current agricultural areas become too hot and too dry to support agriculture for any crop type. To make use of the climate protection potential of biomass energy, shifts in suitable areas should be taken into account.
- In the forestry sector climate and land use changes are anticipated to have an overall positive effect on growing stocks in Northern Europe. However, negative effects were projected in other regions, e.g. drought and fire will pose an increasing risk to Mediterranean forests. Management is paramount in the development of growing stock and forest productivity – intensive, sustainable forest management keeps the net annual increment at a high level.
- After an initial increase, the total terrestrial carbon sink strength (plants and soil) is projected to decline over time in Europe. In particular, the decrease in soil organic carbon is significant for all scenarios, calling for increased attention to management practises that sustain soil fertility.
- In the water sector, climate change tends to increase the numbers of basins in southern Europe with water scarcity⁴ and may produce simultaneously more severe droughts and more extreme floods in some areas of north-western Europe. Changes in the timing of river flows, largely due to the reduction in the amount of snowfall, will affect both navigation and run-of-river hydropower potential. Hydropower plants might adapt their water storage strategies to prevent exceeded storage capacity at peak times.

¹ Vulnerability is considered to be a function of potential impacts and adaptive capacity to global change.

² Ecosystem services: conditions and processes through which ecosystems, and the organisms that make them up, sustain and fulfil human life.

³ The framework covers all EU countries, plus Norway and Switzerland at a resolution of 10'x10' (ca. 15x15 km).

⁴ Water availability per capita falls below 1000 m³capita⁻¹ year⁻¹.

- Accelerated biodiversity extinctions rates indicate rapid biological impoverishment for most regions. This adverse trend could be mitigated by developing a more flexible nature reserve management in order to maintain conservation effects under changing environmental conditions.
- The mountain tourism sector will be impacted negatively in both winter and summer. In winter the elevation of reliable snow cover is expected to rise between 200 and 400 m, leaving many ski areas without sufficient snow. In summer the number of extreme heat days is likely to increase, thereby impacting on the attractiveness of mountain activities and increasing the number of mountaineering accidents.
- In comparison between regions, the Mediterranean seems most vulnerable within Europe. Multiple potential impacts on multiple sectors were projected. These include water shortages especially in the summer months when demand peaks due to tourism, increased fire risk in the forestry sector, losses in the carbon storage potential, northward shifts in the distribution of tree species like maritime pine and cork oak, and losses of agricultural potential due to drought. In the Mediterranean these potential impacts combine with low adaptive capacity.

ATEAM's preliminary research outcomes were presented during the third and final general stakeholder workshop, which focussed on exploring and improving the utility of the project's outputs, and constituted an important step in their finalisation. The diversity of the participating group insured that ATEAM's research was discussed from many different angles. Stakeholders in general found ATEAM's conceptual framework and its implementation in the vulnerability assessment methodology and maps useful. Further clarification of the terminology, and transparency in the scenarios and modelling assumptions were found crucial however to enable stakeholders to fully understand what the results meant. For example it was noted that highly aggregated information/indicators (such as ATEAM's adaptive capacity and vulnerability indicators) could only be useful if they were clearly communicated and underlying data and concepts were made transparent. Stakeholders moreover provided invaluable information on the multiple facets and challenges of sectoral management practice and adaptation. The latter was highlighted as a key area for future research.

Stakeholders believed that ATEAM has succeeded in formulating strong messages on potential impacts of global change, which could provide valuable guidance in policy and decision-making as well as raise public awareness. Of great importance to stakeholders is that there exists common trends and conclusions between scenarios (i.e. similar patterns in global change impacts have been observed across a number of scenarios: e.g. tree productivity would increase in most scenarios in North European but be limited by water availability in Mediterranean areas) and, in place between modelling teams (e.g. the particular sensitivity of the Mediterranean area has been observed across the forest, water and agricultural ATEAM modelling). It was added that the way results are framed, interpreted and communicated should be carefully considered as this would play a major role in bringing people to look at them in detail, and using them in an informed manner within their activities. For example although stakeholders praised the production of an innovative atlas on European Vulnerability using the most up-to-date ecological assessment methods, they repeatedly recommended that key outputs and statements should be presented clearly and interpreted using few relevant maps so as to produce meaningful user-targeted syntheses and policy recommendations. 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.

Stakeholders 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. It was recommended that 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. It was further found crucial to clearly and repetitively point out that scenarios represent alternative choices of society, rather than possible futures, which would unfold independently from societal and individual decisions. Comparative assessments of impacts of alternative policies would be of great interest to stakeholders as well as improved knowledge on the interactions between global change and ecosystem provision across different sectors, since these would allow decision-makers to better choose between different future pathways.

It was noted that ATEAM results would not be particularly useful in management practice. The significant and accumulated uncertainty of the modelled outputs makes these difficult to use directly. It is thus important to view integrated assessment results not as potential provider of predictions or detailed quantified outputs, but as food for thought and debate within a wider social discourse on global change. Broad consensus was that ATEAM results, or any state-of-the-art vulnerability assessment, would not as such be sufficient to significantly influence behaviour. Indeed although policy makers and environmental managers could benefit from the information provided by ATEAM delivers, they would not however obtain locality specific information to take practical decisions and significantly change course of action within existing management plans (e.g. change forest composition at a specific location, plan a biodiversity reserve). For example for the nature conservation sector, the exceptionally fine resolution of ATEAM results is still not sufficient and ideally information for scales smaller than 10'x10' (ca. 16 x 16 km) is needed here. Stakeholders moreover attached great importance to information of the economic cost and benefits of a specific policy (e.g. by asking the question "Does it make economic sense to switch to biomass crops?"), or on associating probabilities to specific scenarios rather than others. Thus linking ATEAM's vast information pool to economic valuation was suggested as one way to increase the meaningfulness of ATEAM's results for stakeholders.

Areas of research not investigated by ATEAM but interesting to stakeholders include impacts of accelerated sea-level rise, and human health (e.g. from heat waves). An area that was taken up by ATEAM but needs a lot of future inquiry is the deposition of variant atmospheric pollutants (e.g. Nitrogen depositions). If some of these topics could not be tackled adequately within ATEAM due to lack of resources, data or further model developments, others are currently being addressed by parallel EU 5th Research Framework research projects.

If global change research is to overcome the discrepancies between stakeholders' expectations from science and the scientific agenda, further bridges need to be encouraged to reinforce dialogue and collaboration between science, policy and society. Policy and decision makers deal with a vast number of political, social and economical issues, which compete for resources. Scientists who want to push forward the issues of ecosystem degradation and associated increasing human vulnerability to global change thus need to raise the visibility of vulnerability assessments as critical methods and tools to better understand global change and its potential worrying impacts on society. One way to achieve this would be for future modelling assessments to explicitly address specific policy-and management orientated questions at higher spatial resolution, in close consultation with interested stakeholders. Smaller, dedicated models, expert systems and decision support tools, which consider national and subnational scales, could be useful media to develop for this purpose. The ATEAM analysis would be a relevant broad basis for these. However stakeholders need to understand the roles and limits of scientific enquiry and modelling performances. Scientists cannot provide exact prediction of future global change impacts and vulnerability, and stakeholders should not expect that such a task be feasible. Large uncertainty is indeed unavoidable since society is continuously shaping its future in complex unpredictable manner.

The third ATEAM annual stakeholder workshop has been a great opportunity for stakeholders and scientists to discuss the state of affairs in scenario development, ecological modelling and vulnerability assessment. The overall participants' response has been positive, stimulating and encouraging. Specific stakeholder concerns, which could not be taken into account within the ATEAM project, were discussed. Some of these are being tackled in on-going research launched within ATEAM (e.g. adaptive capacity of the agricultural sector); others will need significant model developments before being addressed adequately (e.g. creating bridges between state-of-the-art modelling scales and local management needs). Participating ATEAMers have emphasised that collaboration and discussion with stakeholder has been beneficial and interesting. The participating group of stakeholders, although smaller than in the previous general stakeholder workshop, represented many key interests and opinions relevant for a discussion on the management of European ecosystems and European policy needs. A number of stakeholders who already participated in an earlier event have been keen to continue collaborating with ATEAM, which illustrates that the project has developed in place a long-term cooperation of benefit to both scientists and stakeholders. Moreover the group of stakeholders wishing to receive information on the outcomes of the workshop is large and diverse. Many of the interested parties are multipliers who will in turn pass on information on the projects results if these are meaningful to them. This will encourage a large dissemination of ATEAM's results across Europe.

The ATEAM dialogue between scientists and stakeholders in itself has been an important part of the ATEAM results. It was our continuous effort to keep this dialogue informed by best science, fair, and focused. The project collaborated with an expanding stakeholder network to develop this dialogue, within which the assessment approach was iteratively reviewed. To promote sustainable environmental management in Europe it would be best if this dialogue were sustained beyond the lifetime of this project. We are confident that many scientists and stakeholders who participated in our dialogue would agree that this activity should go on, improved by professional moderation and a permanent platform for exchange and discussion.

PART 1: SUMMARY OF THE DISCUSSION

1 Introduction

At the heart of ATEAM's research are ecosystems and their functioning and dynamics in relation to human activity. One of the key motivations of this project is to provide scientific information, which can be used by society to promote better awareness on potential global change impacts, improve management of European ecosystems and help to bring about a sustainability transition.

The ATEAM approach is based on two major ideas. First, the health and resilience of ecosystems in the face of global change is critical to society as a whole. To analyse this we use the idea of ecosystem services, which are here described as *the conditions and processes through which ecosystems, and the organisms that make them up, sustain and fulfil human life*. Second, the potential degradation in the provision of these services is one of the key factors contributing to human vulnerability, here described as *the degree to which an ecosystem service is sensitive to global environmental change and the degree to which the sector that relies on the service is unable to adapt to the changes*. This definition contains three elements which determine vulnerability of an area: (1) its exposure⁵ to environmental change, (2) the sensitivity⁶ to that change and (3) the adaptive capacity⁷ of the sector which relies on the ecosystem service. Exposure and sensitivity of a region result in *potential impacts*⁸, which sometimes can be avoided or modified by adaptation. Potential impacts (the resultant of exposure and sensitivity) are combined with adaptive capacity to constitute a region's vulnerability.

The concept of vulnerability, which has been debated in the last decade primarily within a socio-economic perspective, is still relatively new in the ecological community. ATEAM has brought and implemented this concept into ecological research and modelling and in so doing has opened up this natural science discipline to a broader interdisciplinary research and stakeholder community.

ATEAM is an integrated Vulnerability Assessment across multiple sectors and regions, which has already achieved significant credibility and international recognition in a scientific community that is only just beginning to open up to the interests and needs of integrated assessment research. Global initiatives, like for example the Millennium Ecosystem Assessment⁹ Project have demonstrated great interest in ATEAM.

ATEAM has produced:

- a comprehensive modelling framework for projecting the dynamics of ecosystem services provided by European terrestrial ecosystems at a regional scale¹⁰,
- a set of multiple, internally consistent socio-economic, climate, land use and nitrogen deposition scenarios at high spatial resolution for Europe,
- a vast array of modelled outputs on ecosystem service provision, adaptive capacity and European vulnerability based on these global change scenarios, and
- a CD-ROM with the interactive ATEAM mapping tool displaying the full range of charts and maps of results with exhaustive documentation and summarised conclusions¹¹.

⁵ Exposure: The nature and degree to which the human-environment system is exposed to environmental change.

⁶ Sensitivity: The degree to which a human-environment system is affected, either adversely or beneficially, by environmental change.

⁷ Adaptive Capacity: The potential to implement planned adaptation measures.

⁸ Potential impacts: All impacts that may occur given projected environmental change, without considering planned adaptation.

⁹ Millennium Ecosystem Assessment (MEA) – See - <http://www.millenniumassessment.org>

¹⁰ The framework covers all EU countries, plus Norway and Switzerland at a spatial resolution of 10'x10' (ca. 15x15 km)

ATEAMs preliminary results were presented during the third and final general stakeholder workshop, which focussed on exploring and improving the utility of the project's outputs, and constituted an important step in their finalisation. The diversity of participants insured that ATEAM's research was discussed from many different angles. Beyond the end of the project, most of the participating scientists continue to research global change and ecosystem provision issues insuring that stakeholders' critique and praise will feed future research agenda.

2 ATEAM scenarios of global change drivers

The ATEAM scenarios of main global change drivers are fundamental to the whole approach and provide a first level of integration across ATEAM's separate modelling exercises since the scenarios have been consistently used across most modelling teams. Scenarios are multiple alternative, internally consistent pathways, none of them being a best guess. As such, different scenarios represent alternative futures, which can be explored to discuss the consequences of potential societal choices and sectoral adaptation.

The variation between scenarios seeks to encompass the range of possible futures as well as the scientific uncertainty about the functioning of the Earth System. To adequately reflect this scientific uncertainty, ATEAM used a range of state-of-the-art models, each of which representing an alternative set of hypotheses of how the Earth System works. The ATEAM scenarios are spatially explicit (10' x 10' - ca. 16 x 16 km grid) and were created for four time slices (i.e.: 1990, 2020, 2050, 2080). They are Europe-wide scenarios downscaled from the four IPCC Socio-Economic Scenarios: A1FI, A2, B1, B2,¹² and their respective greenhouse gases emission trajectories. The set is composed of seventeen Climate Scenarios (four climate models, one control), seven Land Use Scenarios and four Nitrogen Deposition Scenarios. The ATEAM scenarios are readily available to the research community, which has already expressed great interest in using this unique set of modelled outputs (See ATEAM final report - Section 6.2.1).

During the workshop the methodology and assumptions used to produce the scenarios were first clarified and discussed with stakeholders. Scenario assumptions were produced using extensive literature reviews (e.g. on forest policy and management), expert consultation (e.g. agricultural economists, local authorities, governmental bodies), existing storylines and scenarios (e.g. IPCC SRES) and models (e.g. IMAGE 2.2¹³), as well as stakeholders' feedback during previous ATEAM activities. It was clarified that assumptions used in the land use scenarios addressed broad generic factors and trends. For example assumptions were made on how technological change might influence generic agricultural yields as opposed to how specific technologies, such as genetically engineered crops, might affect the yields of a special breeding variety. It was accepted that some of the assumptions were too simplistic (e.g. continuation of current trends), although without appropriate data, or further resources more refined and realistic assumptions could not be produced. Stakeholders' comments on scenario and model assumptions are an important "reality check", which contributes to significantly improve further scenarios and modelling developments.

¹¹ The mapping tool, as well as the final report of ATEAM results, is available for free download at www.pik-potsdam.de/ateam.

¹² IPCC SRES = Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios. There are four scenario families (A1, A2, B1, B2) representing different future worlds with different greenhouse gas emission trajectories. The A1FI is a special scenario within the A1 family, representing a world with intensive fossil fuel use.

¹³ IMAGE-team, 2001. The IMAGE 2.2 implementation of the SRES scenarios. A comprehensive analysis of emissions, climate change and impacts in the 21st century. CD-ROM publication 481508018, RIVM, Bilthoven, The Netherlands.

The common trends and differences between ATEAM scenarios were then considered. In most scenarios climatic changes (e.g. changes in precipitation and temperature) have less influence on patterns of land use than socio-economic factors (e.g. population trends, technology uptake). The general trends shown by the land use scenarios are of small increases in urban areas with different spatial patterns, large reductions in agricultural areas for food production partly compensated for by increases in bioenergy production, forests and areas protected for conservation and/or recreation. The large declines (of over 50%) in the surface areas of agricultural land use (especially grassland) for the A (economic) scenarios are caused primarily by the assumptions about the role of technological development. These area reductions are only partly compensated for by increasing biofuel production and forest land use, so that surplus land occurs within the A1f and A2, and to a lesser extent in the B1 scenarios. It is unclear what could happen to these areas of surplus land, although it seems that continued urban expansion, recreational areas and forest land use would all be likely to take up at least some of the surplus. Declines in agricultural areas were less for the B (environmental) scenarios. This assumes, however, that the pressures toward declining agricultural areas are counterbalanced by policy mechanisms that seek to limit crop productivity. These could include measures to promote (a) extensification¹⁴ or organic production (particularly consistent in the environmental scenarios), (b) the substitution of food production by energy production and the planting of trees, or an acceptance of overproduction (as with the current EU's Common Agricultural Policy).

In relation to the modelled surplus land, stakeholders emphasised that provided private owners have the incentives to do so, surplus land will continue to be used for one purpose or another. For example the wood industry of the European Union (before enlargement) requires large imports of wood. Future land surpluses could be used to address this high wood demand. Other possible uses for surplus land could be the emergent demand in biomass energy crops, carbon storage and recreation purposes. A critical issue here is how to guide policy makers towards specific land uses in future. The climate mitigation potential of afforestation at European scale was then discussed. It was noted that state-of-the-art carbon cycle modelling suggests that large-scale conversion to biomass energy and associated carbon emission offsets may have a significant role to play in European energy and climate mitigation strategies.

The discussion then turned to the effects of different driving forces of change and their complex interactions. With the help of the scenario approach it becomes possible to elucidate which drivers may be more important at which scale. For example future climate effects would result in a small increase in aggregated agricultural production (i.e. due to a positive effect of carbon fertilisation on plant growth), although there would be losses of marginal agricultural areas (due for example to water scarcity). Similarly, if technological change appears to be a critical driving force at European scale, climatic change would have a significant effect regionally and locally.

Scenarios are mostly fixed interpretations of the future, and dynamically feedback loops between different sets of drivers such as climate and land use changes are highly desirable, but in practice a time and resource consuming exercise. An example for such a dynamic feedback loop within ATEAM, is the information on biodiversity species distribution modelled using climate change scenarios which was fed back to define designated nature conservation areas in the land use scenarios.

In summary it was emphasised that scenarios are not predictions and do not aim to be. A multiple scenario approach allows the exploration of plausible future land uses, inter-sectoral relationships and adaptation strategies. Multiple scenarios further help to identify gaps in knowledge (e.g.: role of technology), and to investigate the possible range of plausible future paths.

¹⁴ The transition of a land cover or land use type associated with high intensity of use to a lower intensity of use (e.g. improved grassland to semi-natural cover).

ATEAM's take home messages from the stakeholder dialogue

- A multiple scenario approach is useful and interesting. However, transparency in scenario and model development, underlying assumptions and relationships, as well as assessment methodologies is crucial so that stakeholders can fully understand what the results mean.
- Further discussion with stakeholders would be welcome to enable scientists to improve present assumptions on the complex interplay between driving forces of change from international to regional level and on the possible uses for surplus land.

3 Potential impacts of global change

The overall ATEAM methodology was presented as well as the ecosystem services considered during the project and the indicators calculated (Table 1). The potential impacts of global change on ecosystem service provision as computed within the project were first introduced in plenary, then discussed in break out groups. Summaries and discussions have been grouped per sector or group of sectors rather than following the workshop's agenda (See Appendix 3 for the workshop agenda and Appendix 4 for brief summaries of results presented per sector).

Table 1. Sectors, ecosystem services and ATEAM modelling indicators

Sector	Service	Indicator
Agriculture	Food & fibre production Soil fertility maintenance Bioenergy production	Agricultural land area (Farmer livelihood) Soil organic carbon content Nitrate leaching Suitability of crops Biomass energy yield
Forestry	Wood production Recreation Sense of place	Forest area Tree productivity: growing stock, increment, age class distribution Tree species suitability
Carbon storage	Climate protection	Net biome exchange ¹⁵ Carbon off-set by fossil fuel substitution ¹⁶
Water	Water supply (irrigation, hydropower, domestic and industrial use) Drought & flood prevention	Runoff quantity Runoff seasonality Water resources per capita "Drought runoff" ¹⁷ "Flood runoff" ¹⁸
Biodiversity and nature conservation	Beauty Life support processes (e.g. pollination)	Species richness and turnover (plants, mammals, birds, reptiles, amphibian) Shifts in suitable habitats
Mountains	Tourism (e.g. winter sports) Recreation	Elevation of reliable snow cover Number of heat days

¹⁵ Net biome exchange (NBE) = the net flux of carbon from the terrestrial system to the atmosphere, which is determined by net primary production (net carbon uptake by the plants), and carbon losses due to soil heterotrophic respiration, fire, harvesting, and land use change.

¹⁶ Carbon offset by fossil fuel substitution = The difference between the carbon dioxide that would have been released had fossil fuels been used and the carbon dioxide released when biomass energy is used.

¹⁷ "Drought runoff" = The annual runoff that is exceeded in nine years out of ten.

¹⁸ "Flood runoff" = The mean maximum monthly runoff.

European agricultural sector

Land use change projections based on ATEAM socio-economic and climatic changes result in an overall decline in arable land (cropland, grassland) in Europe, a trend that creates “surplus land”. It is unclear what could happen to these areas of surplus land, although it seems that continued urban expansion, recreational areas and forest land use would all be likely to take up at least some of the surplus. This assumes, however, that the pressures toward declining agricultural areas are counterbalanced by policy mechanisms that seek to limit crop productivity. This could include measures to promote (a) extensification¹⁹ or organic production (particularly consistent in the environmental scenarios), (b) the substitution of food production by energy production and the planting of trees, or an acceptance of overproduction (as with the current EU’s Common Agricultural Policy).

European land demand for biomass energy crops may go up. When biomass energy products are used for energy production instead of fossil fuels, less carbon dioxide per unit energy produced is released. To make use of this climate protection potential, shifts in areas suitable for biomass energy crops related to climate change should be taken into account. Although the suitable area for specific crops expands, some current agricultural areas become too hot and too dry to support agriculture for any crop type. Furthermore a climate driven decline in soil fertility is expected (indicated by soil organic carbon losses) in some areas and would be primarily due to temperature changes. Carbon losses modelled differ whether they occur in cropland, forest or grassland, and there are significant regional differences. This trend is only partly counteracted by land use changes and stimulated plant growth and calls for increased attention to management practises that sustain soil fertility.

Farmer livelihoods may thus be substantially affected as over the long term large areas of near marginal land may become unsuitable for agriculture. A pessimistic assessment of impacts can be suggested for the Mediterranean region where crop suitability could decrease significantly. It is important to consider irrigation potentials for the modelled water scarce agricultural land and conflicting demands for water across ecosystem services and sectors. Overall it appears that global change may not bring fundamentally new impacts, rather the exacerbation of current trends (e.g. current marginal areas would be even more unsuitable for agriculture). Soil carbon, an indicator of the ecosystem service soil fertility maintenance, may also significantly decrease in agricultural land.

In the discussion it was further clarified that as an indicator for farmer livelihood, ATEAM simulated changes in the area of arable land across Europe based on climate and socio-economic change (such as changing demand based on population dynamics and trade flows simulated by the global integrated assessment model IMAGE 2.2). Whether the potential arable land will be used for agriculture or not largely depends on technological, social and legal factors (e.g. willingness to change agriculture practice, risk in new ventures, capital, EU policy). Stakeholders emphasised that although broad assumptions on policy and demand for specific ecosystem services are to a certain extent captured within the scenarios, further work is needed to better address these major driving forces, as these can dramatically affect European land use in the next decades.

The potential for biomass energy at the time of the workshop had been simulated only from agricultural biomass; that of woody biomass crops had not yet been estimated. It was however noted that forest residues as well as residues from the wood industry sometimes represent important providers of biomass energy at national level. For example, as one stakeholder emphasised, 21 % of the total energy used in Sweden comes from biomass energy. Of this energy, 50% is produced from forest residues (40% of which being generated within the forest industry sector), 49% from domestic waste,

¹⁹ Extensification – The transition of a land cover or land use type associated with high intensity of use to a lower intensity of use (e.g. improved grassland to semi- natural cover).

and only 1% from agriculture. These figures are likely to be different in other European countries. Country specific potential for non-woody and woody biomass crops needs to be assessed in the light of the specific current national practice.

European forestry sector

Land use change scenarios indicate an increase in forest area under all but one socio-economic scenario. Climate change is anticipated to have an overall positive effect on growing stocks in Northern Europe. However, negative effects were projected in other regions, e.g. drought and fire will pose an increasing risk to Mediterranean forests. The distribution of some tree species is projected to change, e.g. cork oak, holm oak, aleppo pine and maritime pine. Management seems to have a greater influence on the development of the growing stock and forest productivity than climate or land use change. When forest resources are not fully utilised, the age-class distribution shifts towards old and unproductive forests, while intensive, sustainable forest management keeps the net annual increment at a high level. (The discussion points relating to the European forestry sector are presented within the section on adaptive capacity below).

European terrestrial carbon balance

Europe's terrestrial biosphere currently acts as a small carbon sink. Despite considerable regional differences all scenarios show a weakening of this carbon sink after 2050. This trend is the net result of positive effects of land use change (i.e. reforestation) and negative effects of climate change on the Europe wide terrestrial carbon balance (considering all types of land uses, e.g. crop and grassland as well as forests). While European forest trees accumulate carbon, the soils of boreal forests may lose more carbon than the trees take up. Furthermore drought stress and increased fire risk in Mediterranean leads to increased carbon fluxes to the atmosphere. The relative importance of positive forest management effects on carbon stored in Northern forests for the Europe wide carbon balance is currently under debate.

It was clarified that the simulated decrease in European carbon storage was due to a changing balance between the amount of carbon stored in vegetation and in soils. The decrease in soil carbon estimated independently by forestry, agriculture and carbon storage models would suggest that UNFCCC²⁰ targets might be more difficult to reach than previously thought. One conclusion from ATEAM is that to achieve climate mitigation long-term carbon stocks need to be secured (e.g. in a forest as opposed to wood products). Even if this were implemented across the EU (using for e.g. afforestation strategies) the long-term trend towards a weakening of the European carbon sink after 2050 might not be offset. A more promising strategy is thus to explore biomass energy in combination with other means of substituting fossil fuel or, or fossil fuel intensive products. It was noted that this critical information needed to be communicated appropriately so that policy-makers and resource managers do not feel that there is no point in trying to implement the UNFCCC targets.

A lively discussion took place on temporary, long term and permanent carbon sinks. It was noted that scientists and stakeholders who have different timeframes in mind, might not use these terms similarly. For example, carbon storage in wood products (i.e. from paper to houses) may last decades, which is rather "short term" in terms of carbon pools. Currently, harvested wood products are counted in the modelling as carbon released to the atmosphere. The time lag brought about by the lifespan of the wood products is neglected, since it is limited. Nevertheless, if there was a big change in the amount of carbon stored in wood products this would need to be accounted for in modelled estimates of the terrestrial carbon balance.

²⁰ UNFCCC: United Nations Framework Convention on Climate Change

Carbon substitution strategies (e.g. promoting the use of wood rather than other building material) are mechanisms, which could increase the terrestrial carbon sink. It was suggested that the mitigation potential of such strategies should be explored. In this context, the potential magnitude of carbon stored in wood constructions and their lifespan until that carbon is returned to the atmosphere needs to be estimated. It was understood that simulating carbon stocks and fluxes as well as substitution strategies touch many sectors and a wide area over a long temporal scale. One stakeholder believed that a clearer ownership of carbon stocks through their lifespan could give incentives for substitution strategies although this raises many debatable issues (such as: what sort of ownership? Should carbon stocks become a tradable commodity?). It was noted that coupled measures aimed at raising carbon stocks and promoting carbon substitution strategies would also be interesting to explore. For example, incentives could be developed towards afforestation with the objective of increasing forest and thus carbon stocks, while at the same time other measures could encourage the use of wood products reaching the end of their lives as biomass energy fuel.

Adaptive capacity in the sectors forestry and agriculture

The adaptive capacity of the forestry and agriculture sectors was then discussed. It was noted that the management timeframes of these sectors vary significantly (i.e. typically in decades in forestry, but (inter)annually for agriculture). Stakeholders believed that land managers are generally resourceful and resilient, although at the same time their capacity to adapt is largely constrained by traditional management practice, risk avoidance, and lack of investment power. It was emphasised that policy and incentives play a critical role in promoting or hindering changes in management practices. Thus getting the legal framework to adequately consider plausible global change and develop an explicit overarching vision on desirable adaptation is a critical step towards sustainable environmental resource management. Moreover the demand for specific products also plays a major role in which activities managers decide to focus on. So changes in policy and market preferences directly guide adaptive management decisions.

In agriculture management timescales are much shorter than in the forestry sector and allow some flexibility to change to more suitable crops. In marginal areas where agricultural activity would become unviable there will be a need for diversification and/or irrigation. Typically only after different paths in adaptation have failed will an agricultural system collapse and be abandoned. However cumulative impacts in certain areas (e.g. the Mediterranean) will make adaptation particularly difficult. For example areas, which are unsuitable for agriculture, may also not be suitable for forestry or recreation. Finally European agriculture has long functioned in a closed system protected from external pressure by subsidies. This system is currently undergoing structural transformations and different policy paths are plausible. These transformations will probably have a profound impact on agriculture.

In forestry, management changes such as changing species composition of plantations operate slowly. Long-term climate change impacts could be important factors in managers' decisions, although more determinant would be policy and market trends. One stakeholder stated that global markets dynamics have contributed to a high economic "adaptive capacity" of large firms in the forest sectors, which can shift the nature or geographical distribution of their activities to respond to changes in wood supply. Moreover there are many smaller local players in the forestry sectors. Their reliance on forest income varies greatly (e.g. as one stakeholder pointed out, in Finland forestry revenue typically represents only 15% of the total family income). In this case, ability and willingness to adapt will depend on the importance of forestry activities compared to other activities and income sources of the forest owner.

Specific adaptation options to face for example a climate driven increase in fire frequency and magnitude were discussed in more detail. It was noted that often it is not economically viable to replant a forest after it has burnt down. In many areas managers simply let the forest regenerate naturally,

which has economic and environmental advantages. To accelerate the built up of carbon storing forest cover, policy can, in place provide incentives towards reforestation using more suitable species (via subsidies). Nevertheless, forest management managers often still prefer natural regrowth, as pointed out by one stakeholder concerned with the Mediterranean. Decision to replant will vary with many factors. For example in small-scale forestry activities by families, such options will often be chosen that bring some benefit at least to the next generation. Information on plausible changes in species suitability, wood production etc. can in place help long-term decision making.

In conclusion it was agreed that sectoral adaptive capacity depends on many political, legal, economical, social and cultural factors, which play different roles at different spatial and temporal scales. Some of these are considered by means of assumptions in scenarios or models within ATEAM, although it is noted that this framework is too broad to encompass the full complexity of sectoral adaptive capacity. This points towards one of the limitations of top-down modelling approaches, which here need to be complemented by bottom-up case study approaches. For example within ATEAM one such case study on adaptive capacity in the agriculture sector is currently being performed in Wageningen University). It is hoped that general insights will be developed on alternative adaptation paths and methods as well as factors hindering and/or promoting adaptation so that these can feed state-of-the-art vulnerability assessment.

European water sector

Despite considerable regional differences, there is some broad consistency in the pattern of projected change – reductions in runoff in southern Europe and increases in northern Europe. Reductions in 30-year mean runoff in parts of southern Europe can be as great as 30%. Climate change tends to increase the numbers of basins in southern Europe with water scarcity (i.e. water availability per capita falls below 1000 m³ capita⁻¹ year⁻¹). Climate changes have a much greater impact on runoff than land use changes in the catchments. At least under one climate model, climate change may produce simultaneously more severe droughts and more extreme floods in some areas of north-western Europe. Large reduction in maximum flows in eastern Europe is mainly due to the shift in timing of flows from spring to winter, as a greater proportion of precipitation falls as rain rather than snow. Case studies for Rhine, Rhone and Danube indicate that changes in the timing of river flows, largely due to the reduction in the amount of snowfall and hence spring snowmelt, will affect both navigation and run-of-river hydropower potential. The reduction of water storing snow cover is expected to have a profound impact on the Alpine stream flow pattern. Currently, most of the major floods in the Alpine area occur in summer. Model results indicate that this summertime characteristic will shift towards or even into the winter half year as all scenarios produce a decrease in summer stream flow, an increase in winter stream flow and a shift of monthly peak flow to earlier dates. As a consequence, winter floods will become more frequent, and in lower lying Alpine catchments they might even become more common than summer floods under a warming climate.

The discussion first focused on clarifying the model assumptions and indicators. Within ATEAM three scales were used: 1) river basin scale for Europe 2) 0.5 x 0.5 degree grid scale for Europe, and 3) the catchment scale for a small number of Alpine valleys. It was emphasised that the scale chosen for the assessment plays a fundamental role, as different scales will lead to different modelled outputs for different drivers. For example at the lowest resolution used land use change effects are small. However, at higher resolution land cover and use could significantly affect the results (e.g. forest instead of grassland). This may become particularly relevant in modelling assessments, for example when specific land uses are allocated to the surplus land calculated according to the land use scenarios.

It was clarified that the simulated water shortages in the Mediterranean were obtained using indicators for runoff (i.e.: volume of water in the river) at different times of the year. To calculate water exploitation indices, national water usage projections were used, which were not based on SRES scenarios. The

indicator on water resources per capita was deemed more reliable since it does not depend on calculations of water usage, depending on lifestyle changes, water infrastructure efficiency etc. It was suggested that available water resources and groundwater levels are more interesting than runoff *per se* to some stakeholders. Moreover it was specified that, if groundwater discharge is considered within the model, lake storage capacity is not. Although it would be possible to map groundwater recharge, to calculate groundwater levels explicitly would need too much local data, which are not available for the whole of the ATEAM grid.

It was emphasised that the ATEAM results are useful as a background context for stakeholders interested in water management and smaller scale analysis (e.g. GLOWA-Elbe²¹). They could, for example, suit some of the information needs of policy makers or their advisers (e.g. the EU and the European Environmental Agency). Many other stakeholders in the water sector rely on information on a finer spatial scale. Information on water rich regions/countries is of limited use to water scarce ones, since water is not easily transportable. Precipitation projections could however be useful for regional water managers, who could use these to calculate water tables in their catchments. The maps produced by ATEAM challenge the way in which water management is currently thought and done. Indeed, although there is mounting evidence to suggest that the European water resource base is changing, climate change is not yet acknowledged within the EU Water Directive.

The discussion then considered the possible adaptive capacity of the water sector. It was noted that there are vast on-going changes in the way water is supplied (e.g. changes in seasonality, in total water available, privatisation of water companies) or consumed (multiple uses and increasing needs). Thus the sector needs flexibility to adequately face future changes. Incentives to change behaviour could be encouraged by pricing systems and water saving regulations. It was added that the awareness of policy makers and managers often relates to whether the countries/regions they deal with are already sensitive to variations in water availability. The biggest problems in water management may be found in areas which have never had to face water scarcity or floods before. An interesting way to develop the adaptive capacity index would be to consider past experiences of natural hazards and extreme events.

Biodiversity and nature conservation in Europe

Projections of occurrence of more than 2000 species across Europe (1350 plants, 157 mammals, 108 herptiles - reptiles and amphibians - and 383 breeding birds) for 2080 show great sensitivity of biodiversity under all climate change scenarios. The A1f (economic, global, fossil fuel intensive) represents the most threatening scenario for species diversity with some regions expected to lose more than 80% of current species richness. This scenario also produces the greatest variability across Europe, while B1 (environmental, global) appears to produce the lowest species loss and species turnover by pixel. Hot spots of expected biodiversity change were the Iberian Peninsula, Central Europe, and Scandinavia. The ranking of regional sensitivities was consistent across scenarios. The detailed examination of the projections for plants in 2050 under the full dispersal hypothesis revealed that 93% of species were projected to have overlapping populations with current distributions, while 2% had totally non-overlapping future distributions and 5% lost all available habitat. These changes meant that, over a range of reserve selection methods, 6% to 11% of species modelled would be potentially lost from selected reserves in a 50-year period. The modelling framework used here was developed to allow reserve area selection to optimise the protection goal of nature conservation areas under restricted resources and changing climate. This framework could support the flexible management of nature reserve areas, which is necessary to maintain the conservation effect under changing environmental conditions.

²¹ <http://www.glowa-elbe.de/index1.html>

It was clarified in the discussion that the decrease in biodiversity obtained was simulated at a broader scale than the ATEAM grid (i.e. a 50 km grid rather than 16 km) due to data restrictions. At this resolution, land use change is primarily determined by climate change, thus in the modelling assessment the effects of land use intensity and change are not taken into account explicitly. This shortcoming could in future be resolved by embedding landscape models to explore the potential effects of landscape fragmentation. Assumptions on species migration potential were discussed. Currently, the model is run twice for every scenario, once with full migration potential and once with no migration potential of the species. A stakeholder argued that at higher resolution (i.e. 10 km grid) land cover rather than land use becomes important, although it is still climate change, which is the dominant driver of species shifts. However, it was added that ATEAM's ecosystem service approach should be able to demonstrate that changes are not necessarily negative as different services are connected with different species.

Motivations, goals and approaches in conservations were discussed. Within the ATEAM work some dynamic reserve selection strategies were thus developed. The results presented by the biodiversity group were found by participants to question the legal framework of biodiversity (Natura 2000). The decisions to establish Natura 2000 reserves are generally less based on scientific knowledge than on political reasons. If the reserves are fixed and cannot be changed the connections between these should be considered to take into account possible impact of global change not only on species numbers, but also and even more importantly, on species composition. Moreover conservation goals should be extended beyond the boundaries of nature reserve network to tackle biodiversity issues in urban, agricultural and forestry land uses. Dynamic reserve selection and management are desirable and are being developed in place (e.g. English Nature). Much can be learnt from experiences in dynamic environments such as South Africa. However in many cases, especially in Europe we are dealing with cultural landscapes, where numerous users and interests compete, as well as different ideas on what landscapes and species to preserve. It was noted that ongoing changes in biodiversity are slowly being recognised in society and that a debate is emerging on whether and how change should be managed. A cultural shift from conservation to dynamically managing diversity is thus progressively taking place. The importance of education and communication of scientific information on potential impacts of global change on biodiversity was emphasised since the debate on biodiversity conservation/management is embedded in complex institutional, cultural and legal factors.

European mountain tourism

The hydrological cycle is expected to intensify in mountain environments. Modelled outputs suggest that snow and ice volumes would decrease to 2100, and that runoff seasonality and distribution would change. Snow cover, an indispensable prerequisite for winter tourism, is highly sensitive to changes in temperature. Simulations indicate that the elevation of a reliable snow cover will rise between 200 m and 400 m, i.e. from about 1300 m a.s.l.²² today to 1500-1700 m a.s.l. at the end of the 21st century. The predicted increase in winter precipitation can partly compensate for the temperature-related rise of the snow line, but it cannot prevent the upward shift. At present, about 85% of all Swiss ski areas still have sufficient snow. A 300 m rise of the snow line, however, would reduce this to about 63%. Sensitivity studies for the five catchments have shown that the elevation of reliable snow cover moves upward by approximately 150 m per degree Celsius of warming. An analysis of the number of summer heat days revealed that particularly in the southern Alps heat days become more frequent, which likely reduces the attractiveness of this area for a range of outdoor activities such as hiking or biking and also increases the number of mountaineering accidents. Hence, mountain tourism may be impacted negatively in both winter and summer.

²² a.s.l. above sea level

Since modelled results were obtained for 5 separate case studies in specific Alpine valleys the question of transferability of the results to other mountain areas was discussed. It was noted that the key issue, which should concern all mountain areas is the loss in snow cover. Most other mountain ecosystem services and impacts on those depend on this variable. Concerning impacts on the water balance the ATEAM results are relatively transferable to other mountain areas. Moreover it was agreed that although critical, modelling of extreme weather events is at present unsatisfactory (i.e. primarily due to the current inability of general climate models to adequately reproduce extreme events) and should be developed in future research. Finally, impacts of slope instability on existing infrastructure were found difficult to evaluate. The key issue here would be to assess the changing risk from related natural hazards as well as to increase awareness of users.

The discussion then focussed on adaptive capacity in mountain environments. Two issues were particularly considered. It was noted that mountain areas are already adapted to shifting conditions. Stakeholders believed that tourism had a high adaptive capacity. Specific adaptation is already taking place and can be performed with adequate finances. For example the increasing variability in snow reliability has already led to decisions to stop heavy investments in winter tourist facilities located below 1100m in both Switzerland and France. Summer tourism and alternative activities are already being developed in the last decades in many Alpine areas.

Concerning hydropower generation and irrigation for agricultural purposes adaptation may be more difficult. The main issue would be to increase the storage capacity of extra winter run off in existing or new artificial lakes. Again with sufficient wealth, adaptation is possible although here the major issue is to adequately balance the needs of up and downstream areas as any new dam infrastructure upstream may disrupt sensitive mountain areas downstream and significantly affects runoff and water availability. Conflicting interests and priorities between different mountain sectors, and between different regions and countries may be difficult to resolve, especially in the face of increasing public opposition to new dam projects. International agreements and regulations thus play a major role (especially with Switzerland not being within the EU).

ATEAM's take home messages from the stakeholder dialogue

- Clear guidelines on what the results exactly mean and encompass is paramount.
- Assumptions on alternative policies, market trends and sectoral management are incorporated within the SRES storylines and within the ATEAM land use scenarios. In stakeholders' opinion these assumptions often are too unspecific or questionable.
- Comparative assessments of impacts of explicitly modelled alternative environmental policies and management strategies would be of great interest to stakeholders, since these would allow decision-makers to better decide between different paths. For example an assessment of how effective different climate mitigation measures are, alone or in combination would be very useful. Moreover estimates of maximum carbon emission offset potential for biomass energy for different strategies would be a very interesting research outcome, which could be directly used in promoting and discussing biomass energy at policy level²³. Another example would be to evaluate different nature conservation strategies for a specific area.
- Impact assessments, which consider the complex interactions of global change impacts across different sectors more specifically than ATEAM would be very useful to stakeholders.

²³ Such offset estimates are currently studied by a group of researchers from ATEAM. However, results will not be finalised within project lifetime.

- Modelling at a high resolution spatial scale is of great relevance to many stakeholders and in many sectors. For example, a more detailed modelling assessment on potential of biomass energy would be of great interest to many stakeholders. To be more realistic this should adequately represent the share of different biomass energy generation methods (i.e. biomass waste, forest and wood residues, as well as dedicated agricultural and woody biomass crops). It could be expanded to address the use of biomass energy for heat generation (so far electricity generation and transport are considered).
- Explicitly covering the enlarged European Union would be interesting²⁴.
- Stakeholders provide invaluable information on the multiple facets and challenges of sectoral adaptive capacity, which would gain to be explored in-depth. For example it was stated that ownership of land, and the degree of reliance on the managed ecosystems on this land play a major role in the way managers perceive and implement adaptation needs.
- Policy, global trade and market dynamics strongly influence the agricultural/forestry activities managers choose to develop. Global trade and market trends provide new opportunities for large firms, which become less dependent on specific locations and the associated ecosystems. Shifting the focus of activities away from impacted areas may be an economic adaptation measure, although whether this coincides with measures to promote sustainable management of ecosystem resources remains open.

4 ATEAM vulnerability maps

The ATEAM's operational definition of vulnerability, as well as of its components (i.e.: Exposure, Sensitivity and Adaptive Capacity – See Section 1 for definitions) was introduced and the vulnerability assessment methodology (i.e.: the analytical interface which integrates ATEAM results) presented. ATEAM has primarily focused on modelling potential impacts. However, pioneer work has been performed concerning ways to consider adaptation and adaptive capacity in state-of-the-art ecological modelling. Adaptive capacity varies greatly across scales, sectors, and specific actors within these sectors and modelling so far has not captured this multidimensionality.

Adaptation is any adjustment in natural or human systems in response to actual or expected environmental change, which moderates harm or exploits beneficial opportunities (IPCC, 2001²⁵). Adaptation can be autonomous and planned. Autonomous adaptation is “triggered by ecological changes in natural systems and by market or welfare changes in human systems, but does not constitute a conscious response to environmental change” (IPCC, 2001). Autonomous adaptation changes sensitivity by changing a system's state. In other words, it is part of the internal feedbacks in the human-environment system and its subsystems like ecosystems and markets, such as when forest tree species extend their bioclimatic range due to evolutionary adaptation, or the demand is slowed in a market after price increase resulting from supply shortages. However, ecosystem models are currently hardly able to represent such system state changes, i.e. they do not dynamically model adaptive feedbacks in a coupled way (e.g. Smith et al. 1998²⁶).

²⁴ Although officially ATEAM covers EU-15 + Norway and Switzerland, many results are already available for the enlarged European Union. This can form a basis for further inquiry.

²⁵ Intergovernmental Panel on Climate Change (IPCC) 2001. Climate Change 2001: Impacts Adaptation, and Vulnerability. J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White (eds.). Contribution of the Working Group II to the Third Assessment Report. Cambridge University Press, Cambridge.

²⁶ Smith, P, Andr n O., Brussaard, L., Dangerfield, M., Ekschmitt, K., Lavelle, P. and Tate, K. (1998). Soil biota and global change at the ecosystem level: describing soil biota in mathematical models. *Global Change Biology*, 4, 773-7784.

Adaptation also comprises planned adaptation²⁷. Planned adaptation can take place locally, as adaptive management decisions by individuals or small planning groups, such as planting a drought resistant crop type. Furthermore, planned adaptation can be implemented on a larger or macro-scale by communities and regional representatives, such as establishing flood plains to buffer seasonal river-runoff peaks. In this study, we distinguish such local scale and macro-scale adaptation, with the awareness that this separation is not always clear. Local scale adaptation is captured in our ecosystem models by taking into account local management for example in agriculture, forestry and carbon storage. Macro-scale adaptation enters our assessment in two ways. Broad overarching management choices based on the SRES storylines are incorporated in to the land use scenarios (Rounsevell et al., 2004²⁸) via the IMAGE model, which considers the impacts of climate change and CO2 concentration on, for example, crop yields and markets.

Secondly, the capacity of regions for macro-scale adaptation is considered by a generic adaptive capacity index. This index of adaptive capacity enters the vulnerability assessment directly. Our approach to developing an index of adaptive capacity for use in ATEAM has been shaped by an extensive literature review on adaptive capacity and on vulnerability and sustainability indicators, as well as by discussions with project partners. Determinants of adaptive capacity were chosen and indicators and associated data for these were selected.

To obtain scenarios of adaptive capacity future projections of the data were necessary. However, such data were only available for population and gross domestic product (GDP) such (downscaled SRES projections). Therefore time series data (1960-2000) were collected for all indicators on a regional scale (NUTS2 level²⁹). The functional relationships between the indicators and population and GDP data were developed. Indicator scenarios were then extrapolated using the historical functional relationships between the respective indicator and population and GDP. Finally, we developed a conceptual framework to aggregate indicators to a generic index of adaptive capacity. For future scenarios of the index of adaptive capacity, the projected indicator data were aggregated per scenario and time slice (See Final Report – Section 6.2.3.1 for a detailed description on the work on Adaptive Capacity). Using this methodology, maps of the generic adaptive capacity index for the four SRES scenarios and four time slices for each of the scenarios were produced.

Vulnerable region: In comparison between regions, the Mediterranean seems most vulnerable within Europe. Multiple potential impacts on multiple sectors were projected. These include water shortages especially in the summer months when demand peaks due to tourism, increased fire risk in the forestry sector, losses in the carbon storage potential, northward shifts in the distribution of tree species like maritime pine and cork oak, and losses of agricultural potential due to drought. These potential impacts combine with low adaptive capacity (based on a socio-economic regional scale generic index).

ATEAM's take home messages from the stakeholder dialogue

- Considerable effort is needed to fully communicate what the specific terms within the vulnerability concept mean. The interactions between the different components of vulnerability, and the assumptions used to qualify the resulting vulnerability need to be better understood and communicated.

²⁷ Planned adaptation: the result of a deliberate policy decision based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain or achieve a desired state.

²⁸ Rounsevell, M.D.A., Ewert, F., Reginster, I., Leemas, R. and Carter, T.R. 2004. Future scenarios of European agricultural land use. II: Estimating changes in land use and regional allocation. Submitted to *Agriculture, Ecosystems and Environment*, July 2004.

²⁹ NUTS2 - Nomenclature des Unités Territoriales Statistiques 2: regions or provinces within a country. There are around 500 NUTS2 units, as apposed to only 17 EU countries.

- Adaptive capacity is a useful concept and ATEAM's generic indicator is interesting. Sectoral adaptive capacity, the interactions between macro and (inter)sectoral adaptive capacities and how adaptive capacity could counter global change impacts are key areas for future research.
- It is important to emphasise that adaptation to change has always taken place in all social and economic sectors and will continue to do so. Access to wealth or to technology is a critical factor determining adaptive capacity, although policy, regulations, cultural traditions and market dynamics play a fundamental role from local to international scales.
- Not least from our interactions with stakeholders we conclude that aggregated measures of vulnerability are of limited value. In our integrated assessment they came to serve as a way to alert us to regions or sectors that were then analysed further by consulting the underlying data. Often information on potential impacts will be sufficient to stakeholders who conclude about vulnerability using knowledge about their own adaptive capacity and their individual values.

5 ATEAM mapping tool

The ATEAM mapping tool is an analytical and communication tool designed to facilitate the use and understanding of the final vulnerability maps. It is an interactive digital atlas of over 2,500 maps, and a computer interface, which allows users to select between scenarios, modelled outputs to be mapped, scales, regions, countries or environmental zones. The maps are inserted within a fact sheet view, which gives further information on the scenarios and models used to create the map as well as on the model outputs. To help appropriate understanding and use of the maps it is not possible to download the map without the accompanying information sheet. Further information will be made available by means of pdf files in the final CD-ROM.

Participants generally praised the ATEAM mapping tool. They welcomed the considerable effort, which went into designing such a tool. They requested however sufficient time to be able to evaluate the tool before being able to state whether they would be able to practically use it in their activities. Stakeholders confirmed that easy access to clarifications on scenarios, models and model outputs is indeed critical so that users can make informed choices when creating or using a map. One stakeholder suggested that beside explanatory information, visual and analytical elements, which help users to better comprehend and compare the maps, would be very useful (e.g. a diagram per emission path allowing the user to quickly link each time slice with simulated CO₂ concentration level and associated temperature change would be of great use). The mapping tool does indeed allow illustration of results not only as maps but also as charts categorised per scenario, country or environmental zone.

ATEAM take home message from the stakeholder dialogue

- Analytical and communication tools such as the ATEAM digital atlas of European vulnerability are interesting for stakeholders, provided users can easily understand the purpose of the tools, what they cover, and how the results were obtained.
- There are many ways to make such tools more useful for stakeholders. In particular functions, which enable users to compare results within a wider context, would be desirable.
- Tools such as the ATEAM atlas need to be embedded in a rich debate in specific dialogue platforms to be of greatest meaningfulness to users. As tools to use alone at work they require much more attention and time, but they can be valuable depository of information one consults at specific times.

6 Stakeholders' influence on ATEAM's research

The invaluable help stakeholders provided ATEAM in the different activities organised during the project was summarised. Overall stakeholders have had a diverse and significant impact in both the ATEAM research process and content. The need to produce results, which would be useful to a large and diverse group of stakeholders, has continuously and strongly steered the consortium's work, thereby giving the project leadership a powerful coordination tool. Stakeholders have moreover provided thought-provoking perspectives and opinions on ATEAM research. They have contributed to creating bridges between scientific knowledge generation and evaluation and use of this knowledge. Practically, they provided useful comments on ATEAM research plan, reviewed and evaluated ATEAM scenarios, indicators and near final results, and acted as a valuable reality check. Stakeholders further provided ATEAM with inspiration and support for specific case studies (e.g. biomass energy). More generally, the stakeholder dialogue was a stimulus to improve result communication/dissemination and the opportunity to develop a future agenda for both scientifically and socially relevant research.

More specifically, stakeholders contributed to the work of each modelling team in many ways (See also Table 2). In particular, the indicators of ecosystem services that were estimated by the ATEAM modelling framework were chosen together with stakeholders from the list of indicators that the ecosystem model 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 we experienced surprises during the stakeholder interaction. For example, many stakeholders from the agricultural sector were less interested in crop yield estimates than they were in estimates of future agricultural area ("farmer livelihood"). Furthermore, additional indicators were found to satisfy stakeholders' interest in biomass energy production.

We also discussed the temporal and spatial scales of our analyses and received a diverse range of answers. For some stakeholders both the temporal (time slices 1990, 2020, 2050, 2080) and spatial scales (10'x10') were useful. Some wished to focus on long term developments (i.e. the forestry sector stakeholders could consider 2050 and 2080 time slices), but the majority of stakeholders was more interested in short term estimates for the next five to ten years. For some the spatial scale of the assessment was still too coarse, even though the resolution is already exceptionally fine for global change assessment. Especially stakeholders from regional nature conservation parks need more local information than ATEAM was able to provide. Specific case studies would have been very welcome and ATEAMers were highly interested in conducting such research, but this plan could not be realised due to budget and time constraints.

ATEAM researchers learned especially how ecosystem services are recognised and managed by stakeholders. Within ATEAM considerable effort has been made to include human management in the vulnerability assessment. For example human 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. To give one example, the diversity of forest ownership and forest use in terms of area owned, financial relevance relative to other income sources of the stakeholder 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 use, over recreational to spiritual meaning. Here our choice of indicators (i.e. wood production, carbon stored in vegetation and soil, species turnover, tree species distribution) falls 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.

Table 2: Stakeholders' impact on ATEAM research³⁰

Research teams	Stakeholder impact
Land use scenarios	Evaluation of sectoral drivers of change and of the decision rules on land use prioritisation
Agriculture	Reality check (e.g. importance of food quality vs. quantity in the European context) Supported the farmer livelihood assessment
Biodiversity	Participated in the choice of indicator species Rich discussions on modelling approaches and the meaningfulness of available indicators (e.g. species diversity and richness) and desirable one (e.g. habitat richness)
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.
Forestry	Reality check on forest management and adaptation measures
Mountain environments	Reality check on priorities in the tourism sector (e.g. infrastructure/accessibility are more important aspects than aesthetics) Rich and diverse perspectives on the meaningfulness of indicators/impacts for different mountain stakeholders (e.g. changes in water storage peak will affect differently the hydroelectric and agricultural sectors)
Water	Information at national and supranational scales are useful, in particular for European water regulations and transnational issues which need to encompass both up- and downstream water supply, but need to be supplemented by information at river catchment scale to be meaningful for local and regional water managers.

7 Evaluation of the ATEAM results

Results usefulness

Stakeholders emphasised that ATEAM results are useful to identify which ecosystem services could be significantly impacted in future and to explore adaptation issues at European, national and regional levels. To them ATEAM has succeeded in formulating strong messages, which could provide some guidance in policy and decision-making in a range of sectors, including landowners and farmers organisation, forestry and biodiversity managers and environmental Non Governmental Organisations, as well as contribute to raising the awareness of the general public on climate change issues. Stakeholders appreciated and valued that there exists some agreement between scenarios (e.g. tree productivity increases in most scenarios in North European but is limited by water availability in Mediterranean areas), and that in place all scenarios and results from all sectors agree on particular regional sensitivities (e.g. the Mediterranean area).

Stakeholders believed that ATEAM results would not be particularly useful in management practice. State-of-the-art global change modelling outputs are characteristically associated with long temporal scales (< 20 years), large geographical areas (e.g. ATEAM grid), mixed impacts and significant and accumulated uncertainty. Thus they are difficult to use in practice. Stakeholders who await predictions or detailed quantified outputs to guide their decision-making will be disappointed by the lack of "answers", such as those proposed by decision support and expert systems. As such there was a broad consensus was that any state-of-the-art vulnerability assessment would not in themselves be sufficient to significantly influence behaviour.

³⁰ The table was compiled from observations from the authors as well as feedback from modelling teams throughout the project and in particular during interviews run in the months preceding the final general stakeholder workshop

Moreover stakeholders attached great importance to information of the economic cost and benefits of a specific policy (e.g. does it make economic sense to switch to biomass crops?), or on associating probabilities to specific scenarios rather than others. Thus linking ATEAM's vast information pool to economic valuation was suggested as one way to increase the meaningfulness of ATEAM's results for stakeholders.

Areas of research not investigated by ATEAM but interesting to stakeholders include impacts of accelerated sea-level rise, and human health (e.g. from heat waves). An area that was taken up by ATEAM but needs a lot of future inquiry is the deposition of variant atmospheric pollutants (e.g. Nitrogen depositions). If some of these topics cannot be tackled adequately due to lack of resources, data or further model developments, others are being addressed by parallel research projects (e.g. DINAS-COAST³¹ assesses potential impacts of accelerates sea-level rise at global, national and regional scales, and cCASHh³² which focuses on potential impacts of climate change on water born diseases).

Results communication

It was emphasised that the way results are framed and communicated should be carefully considered as this will play a major role in encouraging people to consult and question them and in the process, learn from them. For example if perspectives are presented with a too negative outlook, people may feel powerless and reluctant to commit themselves to adaptation. Thus scenarios needed to be clearly presented as alternative societal choices that can be steered in one directions or another.

It was judged critical to develop creative and innovative ways to communicate the complexity associated with global change. For example analogies between current areas and adaptive measure for specific sectors and future trends could be useful. However if stakeholders are to benefit from scientific insight, scientific results should not be over-simplified.

To practically ease the use of the ATEAM mapping tool, stakeholders suggested to limit the number of indicators per sector displayed on the ATEAM atlas. The accompanying information on the results and their interpretation, was found important. However, stakeholders believed that the results would gain to be further processed, documented and synthesised to be used to their full potential. Finally additional levels of interactivity would be desirable (e.g. the possibility for stakeholder to create their own scenarios).

Stakeholders welcomed initiatives to develop of closer greater links between scientists and decision makers. Important tasks are to develop a common language and to design especially targeted scientific documents, which: 1) highlight the main results, recommendations and follow-up questions raised by the research, 2) provide visual information which can be acquired straight away by means of graphs or diagrams, and 3) link to further reference in case readers need detailed information on the topic.

Stakeholders recommended specific organisations, which could be interested in the ATEAM results, such as networks and umbrella organisations (e.g. CIPRA³³ and CAN³⁴), which are useful partners. At European level: the European Directive and Topic Centres as well as the Environment Agency were suggested. For the Water sector River basin districts the Water Framework Directive and river basin managers of key locations were recommended. The Alpine Convention and the insurance sector would also be relevant.

³¹ DINAS-COAST (See www.dinas-coast.net)

³² cCASHh <http://www.euro.who.int/ccashh>

³³ CIPRA - Confédération Internationale pour la Protection des Alpes (www.cipra.org)

³⁴ CAN – Climate Action Network (www.climnet.org)

ATEAM take home messages from the stakeholder dialogue

- ATEAM has produced a vast array of results, which needs to be carefully framed and communicated to be of higher value to stakeholders.
- Stakeholders found important that the scientific community should phrase relevant societal questions regarding the causes and impacts of global change, and possible mitigation and adaptation options.
- Stakeholders further recommended that assumptions on critical driving forces such as policy, market trends and sectoral management be elaborated to better represent their key role at European, national and sectoral level.
- Comparative assessments of impacts of alternative policies were of great interest to stakeholders, since these would allow decision-makers to better choose between different future pathways. Furthermore, cumulative assessments of impacts within and across sectors would be interesting to raise awareness on the complexity of global change issues.
- ATEAM has managed to create rich collaboration links with the stakeholders involved, many of them are keen to continue this dialogue, particularly when the final results will be available. Although this will not formally take place, as the project comes to an official end in June 2004, it is expected that ATEAM partners and specific stakeholders will continue this common reflection.

8 Conclusions

If global change research is to overcome the discrepancies between stakeholders' expectations from science and scientific capability to fulfil these, further bridges to reinforce dialogue and collaboration between science, policy and society need to be encouraged. Policy and decision makers deal with a vast number of political, social and economical issues, which compete for resources. Scientists who want to push forward the issues of ecosystem degradation and associated increasing human vulnerability to global change thus need to raise the visibility of vulnerability assessments as critical methods and tools to better understand global change and its potential worrying impacts on society. One way to achieve this would be for future modelling assessments to explicitly address specific policy- and management orientated questions at higher spatial resolution, in close consultation with interested stakeholders. Smaller, dedicated models, expert systems and decision support tools, which consider national and subnational scales, could be useful media to develop for this purpose. The ATEAM analysis would be a relevant broad basis for these. However stakeholders need to understand the roles and limits of scientific enquiry and modelling performances. Scientists cannot provide exact prediction of future global change impacts and vulnerability, and 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.

The ATEAM dialogue between scientists and stakeholders in itself has been an important part of the ATEAM results. It was our continuous effort to keep this dialogue informed by best science, fair, and focused. The project collaborated with an expanding stakeholder network. The assessment approach was continuously being reviewed in this dialogue. To promote sustainable environmental management in Europe it would be best if this dialogue were sustained beyond the lifetime of this project. We are confident that many scientists and stakeholders who participated in our dialogue would agree that this activity should go on, improved by professional moderation and a permanent platform for exchange and discussion.

PART 2: EVALUATION

1 Introduction

Aims of ATEAM stakeholder dialogue

ATEAM's overarching goal was to develop a more appropriate assessment of ecosystem vulnerability, i.e. to produce results that would adequately inform the decision making of stakeholders. In so doing we wished to open up the global change and ecological modelling world to a wider audience, foster greater knowledge integration through inter- and transdisciplinarity and mutual learning through collaboration

In particular the dialogue aims were to:

- identify and evaluate indicators of changes in ecosystem services;
- settle useful scales and units at which these indicators should be measured or modelled;
- discuss thresholds for these indicators that represent limits outside which the adaptive capacity of the sectors is exceeded; and
- present and discuss results as well as the format they are presented in (clarity of maps, graphs, etc).

Steps leading to the 3rd ATEAM stakeholder workshop

A first stakeholder workshop took place 10 months after the initiation of the project to introduce ATEAM to a small number of stakeholders and obtain initial feedback on the modelling framework and the planned products. This first meeting had many important outcomes. Feedback from stakeholders reassured ATEAM that the overall aims and methodology of the project were adequate and useful. Suggestions from stakeholders led to some major changes in the research plan of specific teams and further adjustments within the modelling framework, as well as the development of new focuses within the project (e.g. biomass energy) and of a more appropriate dialogue strategy. The participating stakeholders moreover suggested a number of important contacts of individuals and organisations to approach.

ATEAM modelling partners engaged in a number of stakeholder activities on a sectoral basis (e.g. agriculture/biomass and mountain environments/biodiversity workshops). In September 2002 the second general stakeholders workshop took place. 22 stakeholders and 19 scientists evaluated and discussed the ATEAM land-use scenarios and the vulnerability mapping methodology being developed within the project, as well as the usefulness of preliminary model indicators, and future key areas for model improvement. 2003 was mostly dedicated at implementing the model developments, finalising the scenarios, developing the integrating interface and the mapping tool, and obtaining near final results in time for the final general stakeholder workshop. In early 2004 preparations were made for this final event. In particular the stakeholder database was broadened, up to 100 stakeholders were invited in writing and by phone, material for presentation to stakeholders was developed and updated.

2 Workshop preparation

Aims of the 3rd ATEAM stakeholder workshop

The aims of event were:

- to evaluate the near final results both on European vulnerability and per specific modelling group on potential global change impacts on the provision of ecosystem services.
- to discuss sectoral adaptive capacity to potential impacts of global change in relation to the generic macro-scale adaptive capacity index developed within ATEAM
- to present the ATEAM mapping tool and discuss ways to improve it.

The agenda of the meeting is located in Appendix 3, and the synthesis of the debates that took place during the 1.5-day workshop is located in Part 1 of the present report.

Stakeholders approached

The full list of the participants and their interests in ATEAM can be found in Appendices 1 and 2. Stakeholders who were invited to the workshop are very diverse, and their decision-making and activities take place at different temporal and spatial scales. They include:

- private land and forest owners or representatives,
- environmental resources managers both for the private and public sector,
- representatives of specific sectors and specific activities within these sectors,
- environment and policy advisers at national and European level,
- technical and management consultants for the public and private sector,
- journalists dedicated to cover environmental, scientific and climate issues, and
- academics who are interested in using ATEAM's outputs.

The stakeholder group was smaller (13) than in the last general workshop (22), although the targeted group was broader than before, and the list of invited parties much larger (100). This may be due to a number of reasons, including: the busy schedule of invitees, the fact that the workshop took place during a UK bank holiday, the lack of funding for travel arrangements and consultancy fees³⁵, and the limited relevance of ATEAM for specific organisations. We noted that stakeholders who followed us since the first workshop were keen to continue collaborating with ATEAM, which illustrates that ATEAM has managed to develop a long-term cooperation between scientists and stakeholders in some cases.

The participating group of stakeholders represented many key interests and opinions relevant for a rich discussion on the management and protection of European ecosystems and more widely European climate policy needs. Stakeholders were aware of, and knowledgeable on, current scientific research on global change impacts, as well as having a relevant expertise on how global change affects their sectors. They could thus provide key professional insights and as well as comment on the achievements and limits of ATEAM's developments. Their goals in attending

³⁵ At all previous ATEAM stakeholder events travel arrangements were covered by the project budget. At this last event, the budget was not sufficient to do so, therefore stakeholders had to pay their own travels.

ATEAM's workshop were clearly to obtain information, which can help them in their activities, as well as to network with people relevant to their activities. Finally the group of stakeholders waiting to receive information on the outcomes of the workshop is large and diverse. Many of the interested parties are multipliers who will in turn pass on information on ATEAM if the project results are meaningful to them (e.g. European Environmental Agency, the Climate Action Network). This will promote wider dissemination of ATEAM's results across Europe.

Information presented to stakeholders

ATEAM produced information material³⁶ to help stakeholders familiarise themselves with the research being performed and the progress to date. This included: 1) an introductory flyer on the ATEAM project, 2) a flyer on land use scenarios and downscaling developments for Europe, 3) a flyer on vulnerability mapping, 4) sectoral summaries of model developments, indicators for ecosystem services, and preliminary results on potential impacts on ecosystem service provision, and 5) guiding questions (See Appendix 4: Additional material distributed to stakeholders).

In an evaluation questionnaire (the issues addressed and results obtained are detailed in Section 3 below and Appendices 5 and 6) stakeholders declared that they were in general satisfied with the amount of information provided and had sufficient time to consult it. However, some respondents emphasised that documentation was sometimes too rough, too broad, or on the contrary too specific, as well as sent too late for them to fully understand the research focus and methods used. This points out at the need to better target the information material to different stakeholders, and to allow plenty of time for them to reflect on it. When contacting stakeholder over the phone, it is possible to direct their attention to the information most useful to them, although this is very time consuming.

3 Stakeholders' evaluation of the workshop content and process

An evaluation questionnaire was distributed to stakeholders, half of them returned it at the end of the workshop. The questionnaire is broadly the same as that filled in by stakeholders during the 2nd general stakeholder workshop and the Mountain environments/biodiversity sectoral workshop to allow for compilations of all results (Appendix 5). The results are presented in detail in Appendix 6.

Most respondents believed that the ATEAM workshops had been overall relevant to their work and worth the time taken from their work. This is supported by informal feedback during the workshop, as well as the readiness of a number of stakeholders/organisations to participate to more than one activity. Indeed 7 of the 13 participating stakeholders took part in at least 2 of the ATEAM dialogue activities. It should be nevertheless noted that half of all participants did not fill the questionnaire and might have given less positive responses.

Overall stakeholder appreciated the workshop contents and the topics covered. Participation in itself confirmed that stakeholders had an interest on European vulnerability to global change and sectoral adaptation. The presentations were in general interesting for stakeholders who believed that they had gained some useful insights on the topics covered, and would to a certain extent be able to integrate these in their work. However some stakeholders emphasised that too many topics were covered during the events, which sometimes prevented to have in depth discussions.

³⁶ Some of these documents are available online at:
http://www.pik-potsdam.de/ateam/stakeholderweb/ateam_stakeholder_material.html

Moreover some stakeholders mentioned that some topics had been treated in a too dispersed way so that the outcomes of specific discussion were too vague (e.g. on sectoral adaptive capacity and dissemination of the results). Furthermore due to the broad nature of the research, which encompassed 6 different areas of modelling over the European scale sector specific or local interests could not be catered for as adequately as some stakeholder would have liked (e.g. local scale impacts to biodiversity, downstream activities in agriculture or forestry sectors).

The time for discussion was judged sufficient and the mix between plenary and break out session adequate by most respondents. Stakeholders were left free to decide which breakout session they wanted to join, and the respondents believed that breakout sessions they had attended were in general appropriate.

Specific questions were asked to evaluate the quality of the interactions. Overall stakeholders believed that they had been comfortable enough to express their opinions and that their views had been adequately valued by all participants. Although again it is possible that non-respondents may have felt otherwise, it appears that ATEAM has managed to develop an atmosphere of trust and friendliness in which positive comments and constructive criticism were encouraged and valued. Both stakeholders and ATEAMers moderated the sessions, which allowed most speakers to participate actively.

One of the incentives to participate was for many stakeholders the possibility to network with scientists as well as other stakeholders relevant to their activity, although ATEAM was not explicitly a forum, and thus not primarily about networking. Networking was valued as a way to encourage synergies and exchange views on topics of common interest. In general stakeholders believed that fellow participants were relevant to their own activity, and many considered keeping in touch with some of them even independently from follow-up ATEAM events. This is a positive outcome of the dialogue in itself, which needs to be emphasised.

Most respondents had been sufficiently interested in the project to consider participating in follow-up activities. Interest in future participation was motivated by the possibility to obtain more information on potential European vulnerability, on sectoral adaptive capacity and adaptation measures, as well as by the opportunity for closer collaboration and networking. Many would prefer to take part in a sector specific event, although many had no preference on this. All of them wished to be kept informed of future activities and to receive further information in the project and its final results. Many had already talked about ATEAM to colleagues or planned to do so. These answers confirm that ATEAM has managed to successfully engage participants, to raise interest in its research and to provide a dynamic and stimulating discussion and dissemination platform.

4 What can be improved?

In the evaluation questionnaire, stakeholders were asked to identify what elements could be improved in future dialogue activities. The following summarises their suggestions.

- Since scientists-stakeholders interactions are restricted, more frequent targeted information on ATEAM's research framework, terminology and methodology and how stakeholders' comments were being addressed would have been desirable to foster greater commitment and understanding of ATEAM's research.
- A clearer focus on key ATEAM issues would be helpful in the discussion, as well as further clarification of the areas where stakeholders' expertise and contribution is needed.

- Prioritisation of the topics and results presented would be needed so that discussion can be more focused as well as in depth.
- Tailoring the approach and activities to specific groups of stakeholders is important. For example innovative formats could be designed to consider in detail both sectoral and intersectoral issues in small groups rather than plenary. It is felt that in this way stakeholders could contribute more fully to the research.
- The moderator's role as neutral guides of the discussion is appreciated, so that all stakeholders feel free to provide feedback.
- Contact should be made well in advance (4 to 5 months). Personalised invitations and follow up documentations/telephone conversations should show each person/organisation the relevance of ATEAM, so that invitees can best decide whether their participation would be useful.

Collectively, the above comments suggest that stakeholders call for more background material, a clearer leadership from ATEAM in setting the agenda and guiding the discussion and more opportunities to actively contribute to ATEAM in its diverse aspects. This feedback confirms that ATEAM has stimulated stakeholders sufficiently for them to ask for a closer, more in depth collaboration.

ATEAMers did not fill the evaluation questionnaire, but provided feedback throughout the project and in particular during interviews run in the months preceding the final general stakeholder workshop. This was summarised in Part 1 of the present report (See Table 2).

5 Final steps in the ATEAM stakeholder dialogue and dissemination

- The executive summary of the present report will be sent to all stakeholders who participated to ATEAM activities as well as all stakeholders contacted in building the ATEAM network (<140 individuals and organisations)
- The full report of the 3rd general stakeholder workshop, the final report on the stakeholder dialogue will be loaded on ATEAM's webpage and announced in the ATEAM stakeholder network.
- A CD-ROM of the ATEAM mapping tool, an interactive, digital compilation of European vulnerability and constituting results will be finalised and placed on the projects' website for free download.
- An ATEAM archive of input data, results and maps is being offered to the European Environmental Agency and may be kept there for maintenance and continued dissemination.
- The on-going evaluation of the stakeholder dialogue will be published in the ATEAM Special Issue of *Regional Environmental Change*.
- Although ATEAMers will individually continue to be in touched with certain stakeholders with whom closer collaboration links have been developed (e.g. PIK and Umweltbundesamt), there will be no formal further ATEAM stakeholder dialogue activities in the future.

CONCLUSIONS

The third ATEAM annual stakeholder workshop has been a great opportunity for stakeholders and scientists to discuss the state of affairs in global change and ecological modelling and vulnerability assessment. The participating group of stakeholders represented many key interests and opinions relevant for a rich discussion on the management and protection of European ecosystems and more widely European climate policy needs.

The preliminary conclusions of each modelling group and of the whole project were presented and discussed intensively. In view of the potential impacts of global change on ecosystem services as calculated by ATEAM, sectoral adaptation was repeatedly touched upon, although this vast topic could not be discussed exhaustively in the opinion of certain participants. Stakeholders were also introduced to the ATEAM mapping tool and provided valuable suggestions on ways to improve it.

Stakeholders in general praised the ATEAM goal, approach and preliminary results. The information on potential impacts per ecosystem service *per se* was judged more useful however than an aggregated indicator of vulnerability (including a macro-scale indicator on adaptive capacity). This suggests that vulnerability as a concept and its quantification may be of more scientific than societal relevance. It could also indicate that stakeholders are well aware of the adaptive capacity of their sector and need primarily to understand the risk their activities face in the context of global change.

Most stakeholders agreed that they had gained useful insights on European vulnerability to global change, some of which they would be able to integrate in their work. Fellow scientists and scientific/environmental advisers to the policy and management process were generally positive in the usability of the ATEAM results in their own research and work. However, for more professionally orientated stakeholders the actual model outputs, though interesting, were not suitable to specifically guide their strategic and daily decision-making and management practices. As awareness raising background information however, the ATEAM results were found useful, although here the need to synthesise the research into clear messages and to target these to specific audiences was highlighted.

The need to include explicitly policy alternatives and their potential effect on ecosystem services, and to explore ways to attach probabilities to specific scenarios was emphasised. More transparent documentation was asked for as stakeholders wanted to understand fully how ATEAM results were calculated, which assumptions were made (in particular concerning policy and management), and what the results really encompassed. This is especially important since the ATEAM mapping tool will potentially store 2500 maps and users need to be able to assess rapidly the relevance of these. The mapping tool in itself was judged interesting and innovative, although stakeholders thought they would need adequate time to evaluate its relevance and usability in their work. Efforts to synthesise the information gained by the maps would be valuable and would increase the dissemination and use of the ATEAM results. As a consequence, summarising charts of the results have been incorporated into the mapping tool.

Overall response of stakeholders has been a positive, stimulating and encouraging one. Specific stakeholder concerns, which could not be taken into account within the ATEAM project have been discussed. Some of these are being tackled in on-going research launched within ATEAM (e.g. adaptive capacity of the agricultural sector); others would need significant model developments before being addressed adequately (e.g. creating bridges between state-of-the-art modelling scales and local management needs). Participating ATEAMers have further emphasised that collaboration and discussion with stakeholder has been beneficial and interesting.

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Appendix 2: Participants' expertise and interests in ATEAM

Dr Rob Alkemade (Netherlands Environmental Assessment Agency, The Netherlands). Expertise in biodiversity modelling at European and global scale. Interested in communicating biodiversity issues to the government using scenarios.

Dr Franz Badeck (PIK, Germany). Expertise in forest ecology and modelling.

Ms Maria Teresa Baiges (Centre de la Propietat Forestal, Spain). Expertise in private forestry management issues. Interested in information on climate change threats to forest and in discussing how can vulnerability maps help her public organisation to address these threats into forest management.

Dr Pam Berry (Environmental Change Institute, UK). Expertise in climate change impacts on species and habitats and implication for nature conservation/policy. In participating in ATEAM activities Dr Berry represents the sponsors of the MONARCH projects, which are a range of UK stakeholder organisations interested in nature conservation issues.

Ms Dagmar Dehmer (Der Tagesspiegel, Germany). Expertise in ecological, agricultural issues within which climate change one of her topics. Mrs Dehmer is interested in elaborating new ideas/angles to write about climate change.

Mr Matthias Duwe (Climate Action Network, Belgium). Expertise in climate change and environmental policy. The Climate Action Network is an international network of Non-Governmental Organisations on climate change (including Greenpeace and Friends of the World), particularly focussed on west Europe. Mr Duwe interest in meaningful information and tools to better communicate possible impacts to policy makers in order to promote climate mitigation and adaptation.

Dipl. Cornelia Fürstenau (PIK, Germany). Expertise on modelling of climate change and management in local forest management within the SILVISTRAT project. Interest in discussing the potential impacts of forest management on forest functions.

Dr Petra Mahrenholz (Umweltbundesamt, Germany). Expertise in information required for environmental policy and climate negotiations. Currently developing a national adaptation strategy to complement German climate protection strategy. Interested mostly vulnerability maps and how these are produced

Dipl. Christoph Müller (PIK, Germany). Expertise in land use modelling within the ARIES project.

Mr Kent Nyström (Swedish Bioenergy Association, Sweden / European Biomass Association). Expertise in bioenergy business, and handling and transportation of biofuels. The Swedish Bioenergy and the European Biomass Associations are non-profit organisations created to tackle the greenhouse effect via the promotion of bioenergy as an alternative to fossil fuels.

Prof. Dr Tony Patt (Boston University, USA / PIK, Germany). Expertise in participative research on weather forecasting in small subsistence farming communities in Zimbabwe. Interested in issues of communication of scientific knowledge (observer)

Dipl. Joachim Post (PIK, Germany). Expertise in ecological, carbon cycle and forestry modelling. Interested in human impacts on the environment and changes in carbon fluxes.

Mr Michel Revaz (Confédération Internationale pour la Protection des Alpes, Liechtenstein). Expertise in Alpine conservation issues within CIPRA, a network of 100 alpine organisations (from Slovenia to France). Interested in meaningful scientific information to improve CIPRA's awareness raising work.

Mr Oliver Scholz (Confederation of European Forest Owners, Arbeitsgemeinschaft Deutscher Waldbesitzerverbände e.V., Germany). Expertise in forestry management at German and European level. Interested in how ATEAM incorporated feedback from previous stakeholders events.

Dr Emma Tompkins and **MSc. Katherine Vincent** (University of Southampton, UK). Expertise research on adaptation to climate change at different scales and in different sectors. Interested in the stakeholder dialogue methodologies and outcomes (observers).

Mr Hannu Valtanen (Finnish Forest Industries Federation, Finland / Confederation of European Paper Industries). Expertise in forest and wood based industries from a Scandinavian and European point of view, and in certification issues within the forestry sector. Interested in information on future wood productivity and availability.

Dr Michael Vogel (Nationalparkverwaltung Berchtesgaden, Germany / Réseau Alpin des Espaces Protégés). Expertise in natural park management and in Alpine conservation and biodiversity issues. Interested in how to transfer scientific information into policy and management practice.

Dr Sipke de Vries (Comité des Organisations Professionnelles Agricoles de l'Union Européenne – Comité de la Coopération Agricole de l'Union Européenne - COPA-COGECA - The Netherlands). Expertise in bioenergy and biotechnology issues. Interested in modelling of agricultural and biomass energy, as well as in agricultural adaptive capacity.

Dr -Ing. Bodo Weigert (Berlin Centre of Competence for Water, Germany / part of Veolia Water). Expertise in bringing together knowledge on water issues. Interested in water modelling issues.

ATEAM group

ATEAM leadership: Prof. Dr Wolfgang Cramer and Dr Dagmar Schröter (Potsdam Institute for Climate Impact Research, Germany)

Vulnerability methodology and mapping: Marc Metzger (Wageningen University, The Netherlands)

Agriculture and biomass energy: Dr Pete Smith (University of Aberdeen, United Kingdom)

Biodiversity: Dr Sandra Lavorel (Laboratoire d'Ecologie Alpine, France)

Carbon storage: Prof. Dr I Colin Prentice (University of Bristol, United Kingdom) and MSc Sönke Zaehle (PIK, Germany)

Forestry: Dr Santi Sabaté (Centre de Recerca Ecologica i Aplicacions Forestals, Spain)

Land use scenarios: Prof. Dr Mark D A Rounsevell (Université Catholique de Louvain, Belgium)

Mountain environments: Dr Bärbel Zierl (ETH-Zentrum, Switzerland)

Water: Prof. Dr Nigel W. Arnell (University of Southampton, United Kingdom)

ATEAM stakeholder dialogue: Dr Anne de la Vega-Leinert and Mrs Brigitta Krukenberg (Potsdam Institute for Climate Impact Research, Germany).

Appendix 3: Agenda of the workshop and break-out groups

Monday 03.05.04

10.00-14.00	Participants registration and lunch (from 12.00)
	Plenary
14.00-14.30	Wolfgang Cramer: Welcome -Introduction – The goals of ATEAM and of this meeting / Workshop agenda
14.30-14.45	Round of introduction
14.45-15.30	Mark Rounsevell: ATEAM scenarios: Main assumptions and trends + Discussion
15.30-16.00	Break
16.00-17.00	Dagmar Schröter: ATEAM's main conclusions on sectoral impacts under plausible multi-scenarios of global change Discussion
17.00-18.00	Marc Metzger: Brief introduction of the ATEAM vulnerability methodology and demonstration of the ATEAM maps (and mapping tool) Discussion: Map transparency and readability
18.00-18.30	Anne de la Vega-Leinert: ATEAM feeds back: What did we learn from stakeholders and how did it affect our work? Discussion
19.30	Dinner

Tuesday 04.05.04

09.00-12.30	Sectoral breakout sessions: Presentation of specific results and vulnerability maps per sector: Agriculture, Biodiversity, Carbon/Biomass energy, Forestry, Mountain environments, and Water Discussion: Results meaningfulness, relevance, credibility and uncertainty (Including break 10.30-11.00)
12.30-14.00	Lunch
14.00-15.00	Sectoral breakout sessions: Sectoral adaptive capacity to global change: confronting theory with practice
15.00-15.45	Report back in Plenary + Discussion: Main issues and challenges in integrating ATEAM's results
15.45-16.15	Break
16.15-17.00	Brainstorming: Evaluating ATEAM: Will you be able to use the maps? what for? if not what should be improved?
17.00-17.30	Final round of discussion, thanks and goodbye

The ATEAM Vulnerability Atlas will be made available for testing throughout the workshop

Day 2 Break-out groups

Agriculture, biomass energy, Forestry and carbon storage

Presentations:

Pete Smith (University of Aberdeen, UK),

Franz Badeck (PIK, Germany)

Santi Sabaté (Centre de Recerca Ecologica i Aplicacions Forestals, Spain) and Sönke Zaehle (PIK, Germany)

Matthias Duwe (Climate Action Network, Belgium)

Petra Mahrenholz (Umweltbundesamt, Germany)

Moderator: Teresa Baiges Zapater (Centre de la Propietat Forestal Spain)

Kent Nyström (Swedish Bioenergy Association, Sweden)

Colin Prentice (University of Bristol)

Reporter: Anne de la Vega-Leinert (PIK, Germany)

Mark Rounsevell (Université catholique de Louvain, Belgium)

Notes: Cornelia Fürstenau and Joachim Post (PIK, Germany)

Oliver Scholz (Confederation of Forest Owners, Germany)

Hannu Valtanen (Finnish Forest Industries federation, Finland)

Sipke de Vries (OBL, The Netherlands)

Biodiversity, Mountain environments and Water

Presentations:

Nigel Arnell (University of Southampton, UK),

Wolfgang Cramer (PIK, Germany)

Sandra Lavorel (Laboratoire d'Ecologie Alpine, France) and

Mark Metzger (Wageningen University, Netherlands)

Bärbel Zierl (Swiss Federal Institute of Technology, Switzerland)

Michel Revaz (Confédération Internationale pour la Protection des Alpes, Liechtenstein)

Moderator: Rob Alkemade (Netherlands Environmental Assessment Agency, Netherlands)

Dagmar Schröter (PIK, Germany)

Reporters:

Rob Alkemade (Netherlands Environmental Assessment Agency, Netherlands) and Pam Berry (Environmental Change Institute, UK)

Michael Vogel (Nationalpark Berchtesgaden, Germany)

Notes: Christoph Müller (PIK, Germany)

Bodo Weigert (Berlin Centre of Competence for Water, Germany)

Observers:

Tony Patt (Boston University, USA - PIK, Germany),

Emma Tompkins and Katherine Vincent (University of Southampton, UK)

Logistic coordination: Brigitta Krukenberg (PIK, Germany)

Appendix 4: Additional documents distributed to stakeholders

The following flyers and posters were presented at the workshop:

- **ATEAM flyer**

(available online: http://www.pik-potsdam.de/ateam/stakeholderweb/ateam_stakeholder_material.html)

- **Land use scenario flyer**

(available online: http://www.pik-potsdam.de/ateam/stakeholderweb/ateam_stakeholder_material.html)

- **Summaries of potential impacts** (See below)

- **Some food for thought** (See below)

Agriculture – Loss of Soil Organic Matter under Future Climate

Pete Smith et al., School of Biological Science, University of Aberdeen

During the 21st Century, agriculture will be radically altered. Climate change will mean that many areas become too hot or too dry to support agriculture. Changing world economies, and likely changes in the Common Agricultural Policy and the subsidies currently paid to farmers and land managers, will also mean that less land will be used for agriculture in the future. The impact of climate differs between different future climate scenarios and the impact of land-use change also differs between future land management scenarios. It was our aim to examine how these changes would impact upon soil organic matter, important for maintaining soil fertility and important for locking up carbon that would otherwise be lost to the atmosphere as carbon dioxide.

To examine the impact on soil organic matter (expressed in terms of soil carbon) we looked at changes in cropland and grassland soil carbon during the 20th and 21st Centuries using the Rothamsted Soil Carbon (RothC) model for the ATEAM grid³⁷ using 20th Century climate and 21st Century climate (for A1FI, A2, B1, B2 scenarios³⁸ with HadCM3³⁹, and three additional GCMs⁴⁰ for the A2 scenario). We also used the best available soils data (European Soils Database), outputs on potential evapotranspiration (PET, water loss from the soil and the plant), and net primary production (NPP, plant growth) from the LPJ model⁴¹. We used a land use change reconstruction for the 20th Century and the future land use scenarios that are consistent with the climate scenarios (see above) from the ATEAM land use group. The model was used to examine the effects of climate only, climate including the effects on plant growth, and the combined effects of climate and land use change.

Looking at climate impacts alone, the decrease in soil carbon is significant for all scenarios but is most pronounced in the A1FI scenario and least pronounced in the B1 scenario. Differences between the different climate models were of a similar magnitude to the scenario differences showing that uncertainty in the future climate is important. Including plant growth is shown to slow the decrease in soil carbon relative to climate only. However, land use change has the most pronounced effect. In some cases, land use change (from abandoning croplands) halts the decline in soil carbon such that it completely counteracts the loss induced by climate change.

In terms of soil fertility in the future, then, climate change will tend to decrease soil carbon, but greater plant growth will slightly decrease this adverse effect. Land use changes during this century (particularly abandonment of agriculture) might completely counteract the adverse effect of climate change on soil carbon in some cases, but not in others.

³⁷ ATEAM produces spatially explicit results for Europe with a resolution of 10'x10', that is approximately 16x16 km per grid cell.

³⁸ IPCC SRES = Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios. There are four scenario families (A1, A2, B1, B2) representing different future worlds with different greenhouse gas emission trajectories. The A1FI is a special scenario within the A1 family, representing a world with intensive fossil fuel use.

³⁹ HadCM3 = a general circulation model used to estimate climate change resulting from greenhouse gas emissions.

⁴⁰ GCM = general circulation models, coupled atmosphere/ocean-models to estimate climate change resulting from greenhouse gas emissions

⁴¹ The LPJ (Lund-Potsdam-Jena) Dynamic Global Vegetation Model. A model that uses input on climate, land use, soil and atmosphere to calculate vegetation growth.

Biodiversity – Turnover and losses due to climate change

Sandra Lavorel et al., Laboratoire d'Ecologie Alpine

The biodiversity results have several major differences with those from other sectors.

- The resolution of input and output data of the models is 50 x 50 km (instead of ca. 16x16 km) as a constraint from the biodiversity atlas data for Europe.
- Input data were the European atlases including the orders plants, birds, mammals and herptiles⁴². The European atlases present the full list of species for terrestrial vertebrates, but only about 20% of the total flora (of which the majority of trees).
- Potential impacts were only calculated in response to climate change scenarios, because at the scale of 50 x 50 km, land use impacts on current species distributions cannot be discerned.
- We explored several measures of sensitivity and potential impact in order to explain results and to highlight the main sources of uncertainty (i.e. risk).

Main results

- 1) Species richness per grid cell changes only moderately by 2050. Hot spots of change are observed in the Iberian Peninsula, Central Europe, and Scandinavia.
- 2) On the other hand changes in species composition in the order of 40% on average are expected in many parts of Europe by 2050, with little difference across scenarios (i.e. species turnover⁴³ could be very high, regardless of actions taken to limit climate change).
- 3) On average, changes are similar across orders (plants, mammals, reptiles and amphibians), except for birds, where turnover would exceed 50%.
- 4) For plants, the strongest turnovers are expected to occur in the regions that form ecotones between currently warmer (e.g. Mediterranean) and temperate regions, mimicking the zones of strong migration after the last glaciation. In addition to these, northern Scandinavia is projected to have a high turnover as well.
- 5) By 2050, 93% species will have habitats that overlap with their current ones, while 2% will need to migrate to habitats that are disconnected, and 5% will lose all habitats in Europe.
- 6) Nevertheless whether migration will occur accounts for an uncertainty of 70% in our predictions, being strongest for reptiles and amphibians.
- 7) Applying reserve selection methods to current distributions and comparing the networks obtained to 2050 distributions shows that 6-11% species would be lost from reserves in 50 years just because of change in climatic conditions.
- 8) Published results on rates of changes in species richness in response to climate change need to be taken with care as the choice of modelling method can introduce a 6-fold variation in the prediction of number of species extinct. In our approach we estimate the best of four different modelling methods for each projection to reduce some of this uncertainty.

⁴² Herptiles = generic term for reptiles and amphibians.

⁴³ Following a change in the environment, species turnover is the number of new species in a grid cell plus number of species lost from a grid cell divided by the initial number of species.

Bioenergy – The potential of bioenergy crops in Europe

Joanna House et al., Max Planck Institute for Biogeochemistry

We have calculated the potential energy production and carbon offsets from growing dedicated energy crops in Europe. The areas of land under dedicated energy crops are based on the IPCC SRES⁴⁴ scenarios. These scenarios have been interpreted by the IMAGE model⁴⁵, which makes certain assumptions about energy consumption (transport/gaseous/liquid fuels), efficiency and fuel mix (oil/coal/gas/biomass/wind/solar). The IMAGE model then estimates the area of land used for dedicated bioenergy crops under each SRES scenario. These land area allocations take in to account competition for food. The land areas are spatially allocated on the European landscape based on a series of allocation rules and maps of crop suitability (areas where it is possible or not to grow each crop due to climatic and topographical reasons). The allocation rules first account for land demand for food, urban areas, forestry and protected areas, then allocate bioenergy crops to remaining areas based on using the highest potential surplus land first.

This analysis considers three types of bioenergy crop for Europe:

1. Agricultural-type crops to produce liquid fuels⁴⁶ (ethanol, biodiesel). Yields are currently derived from the LPJ model⁴⁷ output.
2. Grass crops to produce electricity, parameters based on *Miscanthus*⁴⁸. Yields are based on published data.
3. Short Rotation Coppice (SRC) woody crops to produce electricity. Yields are based on published data.

Energy production is calculated from crop yield. Assumptions are made about changing crop yields, and increasing efficiency of energy conversion over time. For calculating carbon offset, it is assumed that the saving in carbon-equivalent emissions per EJ (exajoule⁴⁹) of fuel replaced is 80% for electricity (grass and SRC), 60% for biodiesel, and 50% for bioethanol. This takes account of lifecycle greenhouse gas costs e.g. in fertiliser use and transport. These results are still preliminary, and only give an indication of what we expect for the final results.

⁴⁴ IPCC SRES = Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios. There are four scenario families (A1, A2, B1, B2) representing different future worlds with different greenhouse gas emission trajectories. The A1FI is a special scenario within the A1 family, representing a world with intensive fossil fuel use.

⁴⁵ IMAGE team (2001) The IMAGE 2.2 implementation of the SRES scenarios: A comprehensive analysis of emissions, climate change and impacts in the 21st century. National Institute of Public Health and the Environment (RIVM), Bilthoven, The Netherlands.

⁴⁶ IMAGE classes this category as Maize, but it is a proxy for a range of crops such as wheat, soybeans, sugar beet, etc. In our analysis we also assumed some of the straw residues would be used for further production of liquid fuels and electricity.

⁴⁷ LPJ model = The Lund-Potsdam-Jena Dynamic Global Vegetation Model. A model that uses input on climate, land use, soil and atmosphere to calculate vegetation growth.

⁴⁸ *Miscanthus* = A bioenergy crop common in the UK that is directly used in specifically built power plants nearby. *Miscanthus* is a reed grass (C4-plant) that is simple in cultivation and carbon neutral in burning.

⁴⁹ Exajoule = 10¹⁸ Joule.

We intend to carry out further analyses:

1. Use of “surplus” agricultural land: Within the ATEAM analyses, there was land still available once demand for all uses (agriculture, forestry, protected lands, urban areas, etc.) had been accounted for. We will look at the extreme “**what if all surplus land was used for bioenergy production?**”. To give a range of results we will compare using all the land for electricity from grass crops (this is also a proxy for SRC, since grasses give a similar energy output per hectare), compared to using all the land of agricultural-type energy crops based on whatever crop type is dominant in each grid cell⁵⁰, for production of biodiesel, bioethanol and electricity from residues.
2. Use of agricultural residues from food crops as source of bioenergy.
3. Use of forest residues as source of bioenergy.

⁵⁰ ATEAM produces spatially explicit results for Europe with a resolution of 10'x10', that is approximately 16x16 km per grid cell.

Carbon – Europe’s terrestrial carbon sink may last until 2050 and then decline

Sönke Zaehle, Colin Prentice et al. PIK and University of Bristol

The Kyoto Protocol specified legally binding commitments by most industrialized countries to reduce their collective greenhouse gas (GHG) emissions. To reach these targets at the lowest possible cost, the protocol created two flexibility mechanisms, GHG emissions trading and the Clean Development Mechanism (CDM). Important CDM strategies are carbon dioxide emission reduction by using hydropower and biomass energy, as well as by maintaining important carbon sinks like soil organic matter and European forests. Within this political framework, net terrestrial carbon storage becomes an ecosystem service. Information on European carbon storage is useful in negotiations regarding the Kyoto process. Additionally, a range of stakeholders are interested in estimates of net carbon storage potential of their land. Depending on European Union (EU) mitigation policies, owners or managers of land may receive credits for carbon storage. Besides the direct commercial interest in carbon storage, there are the potential positive side effects of increasing the carbon storage in terrestrial biomass, such as enhanced recreational value of a landscape and possible positive impacts on water purification.

Recent studies indicate that Europe’s terrestrial biosphere presently acts as a small net carbon sink. The future of this sink will, among other things, depend on the combined effects of climate and land use changes. We use an advanced version of the process-based LPJ model⁵¹ to evaluate the effect of future climate and land use changes on Europe’s terrestrial carbon balance. The model is driven with a consistent set of climate and land use scenarios (climate and land use for the A1FI, A2, B1, B2 scenarios⁵² with HadCM3⁵³, and three additional GCMs⁵⁴ for the A2 scenario). The approach allows to separate the effects of climate change and land use change on the carbon budget, as well as to assess the uncertainty associated with the results of different climate models and socio-economic assumptions.

Model performance has been evaluated for present day conditions on several scales applying a set of benchmarking exercises, including point scale observations of plant processes, satellite observations of vegetation cover, and comparison to recently published continental scale carbon budget studies.

Our results agree with the view that Europe’s terrestrial biosphere currently acts as a small net carbon sink. Our results indicate that the current net carbon sink will be maintained until about the mid of the 21st century. Thereafter, all scenarios consistently show a weakening of the net carbon uptake rate, depending primarily on the rate of warming, and also on the magnitude of re- or afforestation activities. Hence, even though land management offers some potential to sequester carbon, climate change may dominate future carbon balance due to increased soil respiration that is likely to outstrip net primary production (NPP, plant growth) increase in the boreal zone. Further carbon is likely to be lost due to increased drought stress and fire risk in the Mediterranean. Despite considerable regional differences within Europe all scenarios show a weakening of the European carbon sink after 2050.

⁵¹ The LPJ (Lund-Potsdam-Jena) Dynamic Global Vegetation Model. A model that uses input on climate, land use, soil and atmosphere to calculate vegetation growth.

⁵² IPCC SRES = Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios. There are four scenario families (A1, A2, B1, B2) representing different future worlds with different greenhouse gas emission trajectories. The A1FI is a special scenario within the A1 family, representing a world with intensive fossil fuel use.

⁵³ HadCM3 = a general circulation model used to estimate climate change resulting from greenhouse gas emissions.

⁵⁴ GCM = general circulation models, coupled atmosphere/ocean-models to estimate climate change resulting from greenhouse gas emissions

Forestry – Strong regional differences South vs. North

Santi Sabaté et al., Centre de Recerca Ecologica i Aplicacions Forestals

ATEAM Forestry sector analysis has two complementary approaches to assess the effects of climate change on tree growth, wood supply and carbon sequestration in European forests.

The first approach has been developed by the European Forest Institute (EFI). It uses a forest resource projection model based on current stocks provided by forest inventory data (growth and yield tables). Climate change effect on forest services is introduced by scaling the net annual increment with relative changes in net primary production (NPP), which is supplied by a process-based model⁵⁵. This approach assumes that relative changes in productivity reflect relative changes in the growth of stem wood. Results are averaged at country level or when available at regional level within the country. The second approach has been implemented by the Centre de Recerca Ecologica i Aplicacions Forestals (CREAF). It works directly with a process-based model at 10'x 10' resolution all over Europe⁵⁶. This approach includes physiological processes such as photosynthesis, respiration, and water use, to calculate vegetation growth and the forest carbon balance.

Both approaches are able to produce comparable variables to analyse forest ecosystem services: wood production (total aboveground wood biomass production), yield (harvested timber over the analysed period), and greenhouse gas regulation (carbon stored in tree biomass and forest soils).

Why two approaches? These two approaches are complementary in terms of strengths and weaknesses. The first one has a good approximation for the statistics on the current situation of forests but loses the heterogeneities within the country or region. It also depends on another model to provide the signal of the effect of climate change. The second one works directly with the processes at the grid cell level but it does not take into account the forest situation statistics. It takes average conditions at this spatial resolution.

Main results and tendencies observed with the first approach are:

- In general the effects of climate change on growing stocks in European forests were positive, particularly in the Northern part of Europe.
- Differences between climate change scenarios were relatively small compared to the effect of management, which seems the main driving factor for growing stocks in forests.

However, it should be taken into account that averaging across regions/countries and species is simplifying and ignores local differences (e.g. local effects of drought). Negative effects of climate change that occurred for example regionally in Mediterranean countries were masked by positive growth changes in other regions.

Main results and tendencies observed with the second approach are:

- There was a differential impact according to the severity of the climate change scenario, which intensified mortality in the simulation runs.
- Projections with climate change scenarios show higher activity concerning processes related to carbon dynamics (photosynthesis, autotrophic and heterotrophic respiration).
- The net carbon balance of the forests was positive until the middle of the century (carbon sink), especially in the Atlantic region. Afterwards the balance became negative (carbon source) due to different environment conditions; for example due to a general reduction of soil water content that was projected as a consequence of increased evapotranspiration of the forest.

⁵⁵ The LPJ (Lund-Potsdam-Jena) Dynamic Global Vegetation Model. A model that uses input on climate, land use, soil and atmosphere to calculate vegetation growth.

⁵⁶ ATEAM produces spatially explicit results for Europe with a resolution of 10'x10', that is approximately 16x16 km per grid cell.

Mountains – Water towers, unique ecosystems and tourism resorts

Bärbel Zierl & Harald Bugmann, ETH Zürich

Mountain ecosystems provide human society with a wide range of goods and services. They provide freshwater to about 50% of the world's population both in the mountains themselves and, more importantly, also in many downstream lowlands. Mountain water is used for irrigation, production of electricity, transportation, fishing, and water sports. In addition, mountain regions and their ecosystems are expected to act as carbon sinks, because highland agriculture and grazing land are being abandoned and become reforested by natural regeneration or tree planting. Furthermore, mountainous areas are important vacation destinations due to their aesthetic and recreational benefits. Finally, mountain ecosystems, particularly mountain forests, protect society from natural hazards such as landslides, rock falls, floods or avalanches.

Global change imposes significant environmental pressure on mountain and particularly high alpine ecosystems. In fact, the continued capacity of mountain regions to provide goods and services to society is threatened by global change. Therefore, we assessed the potential impacts of changes in climate and land use on water resources, carbon storage and tourism at five alpine catchments.

Water resources

Model simulations show that summer discharge is particularly sensitive to global change. Summer discharge in mountain catchments strongly depends on snow accumulation and snowmelt. During the winter months, water is stored as snow or ice. In spring this water is released and largely contributes to summer stream flow. Under a warming climate this storage function of the snow cover gets lost. The simulations show a decrease of summer discharge between 10% and 50% over the next century. In contrast, changes in annual discharge are small.

Furthermore, mountain catchments show maximum monthly stream flow during the melting season in late spring or early summer. With a warming climate this maximum flow shifts to earlier dates by up to one month within the 21st century. At the same time, maximum monthly stream flow decreases as a result of the diminished snow cover in winter. However, it is difficult to achieve reliable estimates of daily peak flows under changed climate conditions, as climate scenarios only give a very rough estimation of future daily precipitation.

Carbon storage in the vegetation

Simulating the impact of climate and land use change on carbon storage in the vegetation it became clear, that land use change is the dominating process. The alpine catchments under investigation show strong signals in carbon emission or uptake depending on the land use scenarios, which predict changes in forest area by up to $\pm 25\%$.

Climatic shifts only marginally affect this ecosystem service. In principal, forests at high elevations profit from the warmer conditions, whereas forest at low elevations often show a reduction in carbon storage. Though, these changes are small compared to the land use effect.

Tourism and recreation

The snow cover, an indispensable prerequisite for winter tourism, is highly sensitive to changes in temperature. Simulations indicate that the elevation of a reliable snow cover will rise between 200 and 400 m from about 1300 m today to 1500 m to 1700 m at the end of the 21st century. The increase in winter precipitation partly can compensate for this temperature impact, but cannot prevent the upward shift.

At present, about 85% of all Swiss ski areas still have sufficient snow. A 300 m rise of the snow line, however, would reduce this to about 63%.

Water – The effects of climate and land cover change on indicators of water resources in Europe

Nigel W. Arnell and David Wilson, Tyndall Centre for Climate Change Research

This component of the ATEAM project examined the effects of changes in climate and land cover on river flows and runoff across Europe, and the implications for a range of water resources indicators. River flows were simulated using a macro-scale hydrological model.

Patterns of changes in the volume of river runoff vary between the climate models used to create the climate change scenarios. Broadly, runoff increases in northern Europe (by up to 10% annually by the 2030s) and decreases in southern Europe (by up to 25% annual by the 2030s), although there are some significant regional differences. Runoff decreases across England under some models, for example, but increases under others. Reductions in summer runoff across Europe are more widespread and proportionally greater than changes in annual runoff.

Across much of Europe climate change leads to an increase in the range in flows from high to low, but only in relatively small areas are there changes in the timing of flow through the year. These are restricted to the parts of northern and upland Europe where rising temperatures mean that an increasing proportion of precipitation falls as rain rather than snow, and the peak flow season shifts from spring to winter.

At the European scale, the effects of land cover change on hydrological regimes are small, largely because land cover changes in relatively few grid cells⁵⁷. Even in the individual cells that do change, the effects of land cover change on runoff are smaller than those of climate change.

A number of indicators have been determined from these changes in runoff, including change in runoff by major European river basin district (very similar to the districts used for the European Framework Water Directive), resources per capita by river basin district, change in low flow and high flow (indexed by change in peak flow season runoff), and changes in monthly flow regimes at key points along major rivers used for power generation and navigation.

⁵⁷ ATEAM produces spatially explicit results for Europe with a resolution of 10'x10', that is approximately 16x16 km per grid cell.

Some questions as food for thoughts

During the workshop we will present short talks on:

- General goals of the meeting
- General description of ATEAM's objectives and methodology
- Main conclusions on European scenarios, impacts and vulnerability
- What has ATEAM gained from its stakeholder dialogue?
- What are the main issues to consider in future agenda?

Some topics that we would like to discuss with you:

- How can modelling best serve stakeholders?
- How can stakeholders further contribute to our research?
- How can we bridge the scale gaps?
- How can we guide stakeholders in using ATEAM results?
- How can we reconcile our scientific objectives with stakeholders needs?
- How can we best disseminate our results?

More specific questions we would like to consider with you:

Regarding result format and display:

- Do you find that results displayed in maps are useful? Do you prefer histograms or other type of diagrams/tables? Which format is most understandable/useful for you?
- When reading maps/diagrams, do you find the accompanying text sufficient for you to understand/analyse/interpret the results?
- If not, what other information would you need?
- Are the titles of the maps/diagrams and the units used meaningful?
- If not, how could we better communicate the information the maps/diagrams show?
- Is the mapping tool easy to use? Is it of interest to you? Can you suggest any changes to make it more useable?
- In which other ways could ATEAM results be enhanced?

Regarding the ATEAM approach to vulnerability:

- Can you relate to scenarios, impact models and "what if.. then" approaches in your activity? Are they useful in exploring possible futures and adaptation measures?
- Can you use ATEAM results directly or indirectly in your activity? In which way?

Regarding the ATEAM results themselves

- Do you believe that the overall conclusions from ATEAM make sense? Are these close to what you expect?
- Do you believe that the sector specific conclusions from ATEAM make sense? Are these close to what you expect?
- If not, can you point out where you believe that main discrepancy between ATEAM's results and your ideas lie?
- Do you in general agree with the assumptions made within the ATEAM approach? Which ones are unrealistic?
- Are the indicators modelled by ATEAM interesting to your activity?
- Which further indicators would you consider useful?

Appendix 5: Evaluation questionnaire

Thank you once more for participating in the 3rd ATEAM stakeholder workshop. Please take a little time to complete the present evaluation questionnaire. This should take about 15 minutes. Your answers will be used to improve future ATEAM stakeholder dialogue activities and to report to the European Commission.

Please return during the workshop

1. Workshop preparation

	Yes	Mostly	Not really	No	No opinion
Did you receive sufficient information on ATEAM and the workshop (e.g. logistics, background information etc)?	<input type="checkbox"/>				

	Sufficient time	Not enough time	No opinion
Did you receive the information with sufficient time to read it appropriately?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

On what topic would you have liked to receive more information?

.....

Feel free to add other comments on the workshop preparation:

.....

2. Workshop content

	Yes	Mostly	Not really	No	No opinion
Do you think the workshop was worth the time you took away from your work?	<input type="checkbox"/>				
	Yes	Mostly	Slightly	No	No opinion
In general, was the workshop relevant to your work?	<input type="checkbox"/>				
	Yes	Mostly	Slightly	No	No opinion
In general, were the presentations interesting?	<input type="checkbox"/>				
	Yes	Some	Not really	No	No opinion
Do you think you have gained useful insights on the topics covered?	<input type="checkbox"/>				
	Yes	Some	Not really	No	No opinion
Do you think you will be able to integrate these insights into your work?	<input type="checkbox"/>				
	Too many topics	Enough	Too few Topics		No opinion
Was the number of topics covered adequate?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>
Which topic/s was/were most relevant to you?					
.....					
Which other topic/s would you have liked to cover?					
.....					
	Too much time	Enough	Too little Time		No opinion
Was time allocated per topic adequate?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>
Feel free to add other comments:					
.....					

3. Discussion

Was time allocated for discussion adequate?	Too much time	Enough	Too little Time		No opinion
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>
Was the mix between plenary and breakouts adequate?	Too much plenary	Adequate	To many break-outs		No opinion
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>
Did you feel you were in the appropriate sector breakout groups (Day 2)?	Yes	Mostly	Sometimes	No	No opinion
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Did you feel comfortable enough to express your views?	Yes	Mostly	Sometimes	No	No opinion
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Did you feel that your views were adequately valued?	Yes	Mostly	Sometimes	No	No opinion
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Was the role of the moderators clear to you?	Yes	Mostly	Sometimes	Did not notice the moderators	No opinion
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
In general, are moderators important for you?	Yes	Sometimes	No		No opinion
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>

Feel free to add other comments:

.....

4. Networking

Were the other participants relevant to your work?	Yes	Most	Some	No	No opinion
	<input type="checkbox"/>				
Do you consider keeping in touch with some of them outside ATEAM activities?	Yes	Perhaps	No		No opinion
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>
If yes/perhaps , what would motivate you to do so?					
				
Do you think that ATEAM should act as a networking platform?	Yes	No			No opinion
	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>

5. Future collaboration with ATEAM

Would you consider attending another ATEAM stakeholder dialogue activity? Yes Perhaps No No opinion

If **yes**, would you prefer to participate in:

a sector-specific activity

a project-wide activity

no preference

If **perhaps**, what could we improve/change in our future stakeholder workshop (e.g. shorter activity, more focus on a specific topic, closer to your work...):

.....

If **no**, please tell us why (e.g. not relevant enough, no time...):

.....

Have you talked about ATEAM with colleagues of yours?

Who else should we approach?

.....

Can we contact you later to obtain their details? Yes No

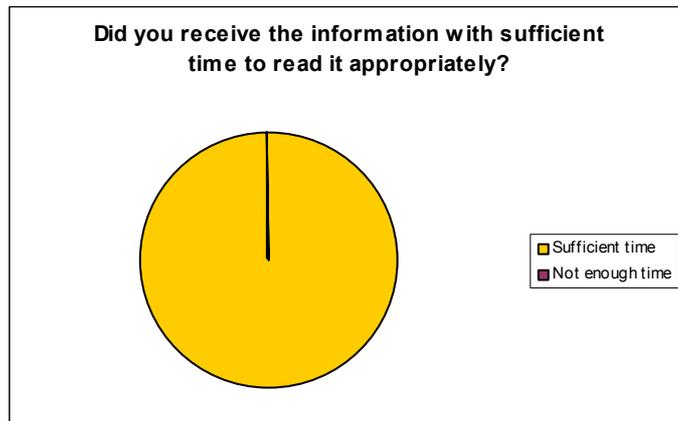
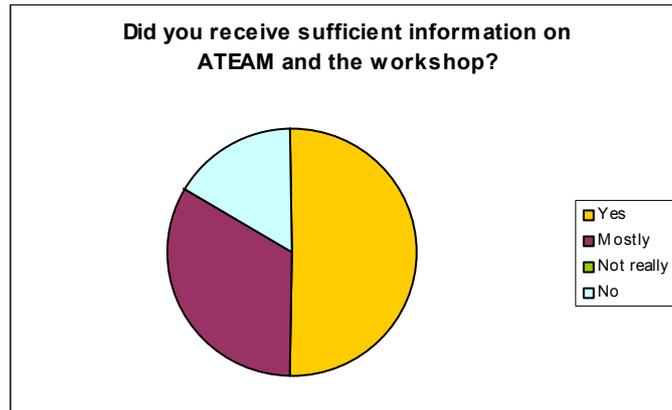
Would you like to remain informed of ATEAM's activities? Yes No

Would you like to receive information on ATEAM's results? Yes No

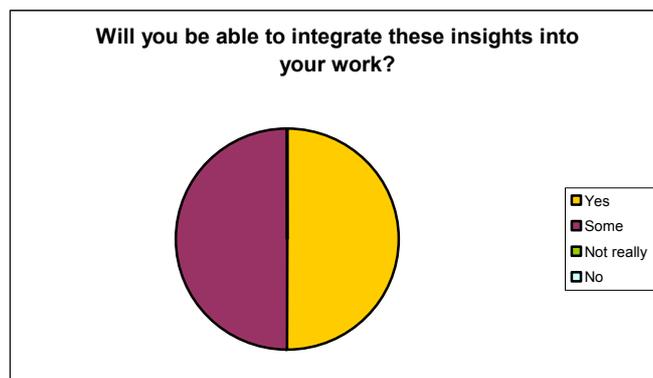
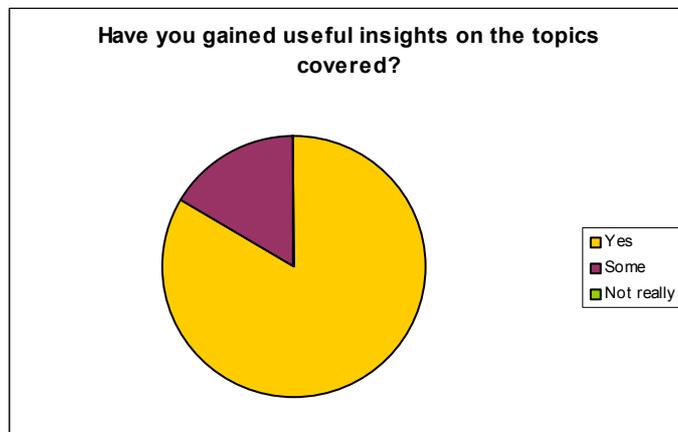
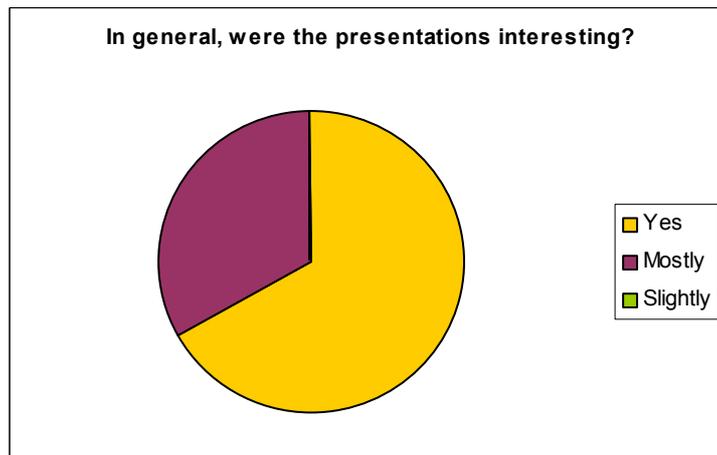
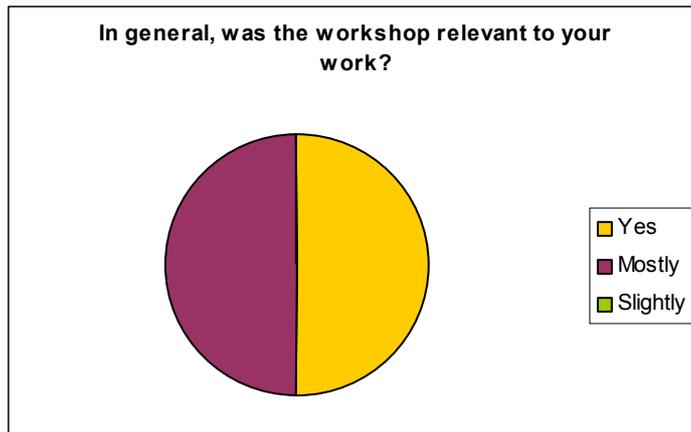
Thank you very much for answering this questionnaire!

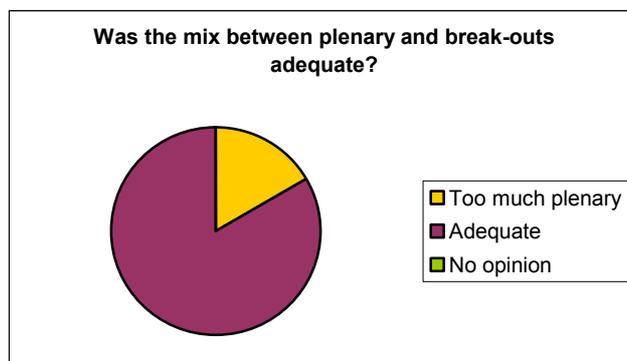
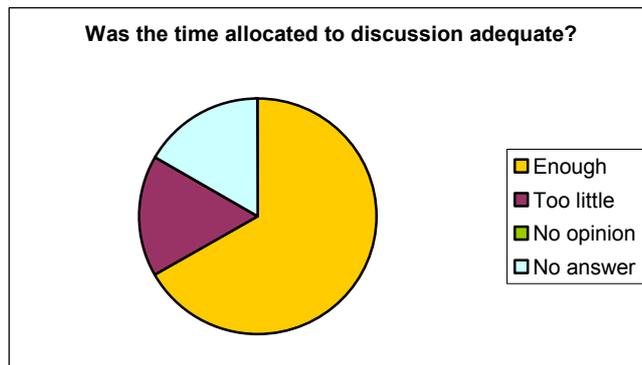
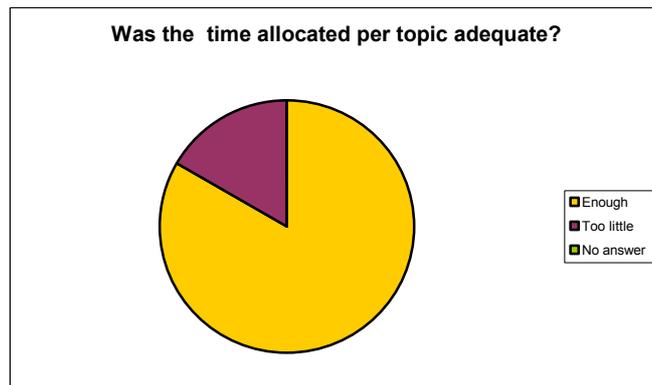
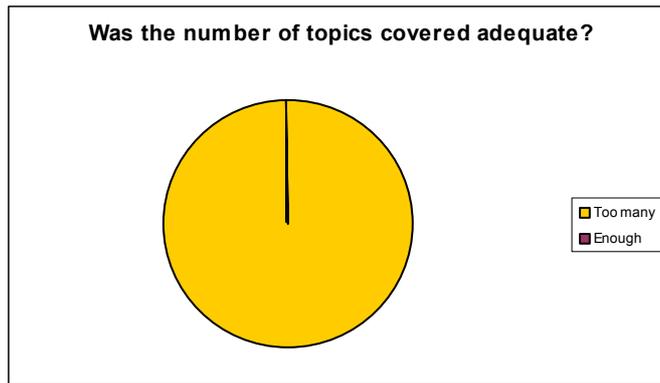
Appendix 6: Results of the evaluation questionnaire

Note: the evaluation questionnaire was only filled by stakeholders. Six out of thirteen questionnaires were handed in. All charts displayed in the following pages are based on absolute numbers, rather than percentages.

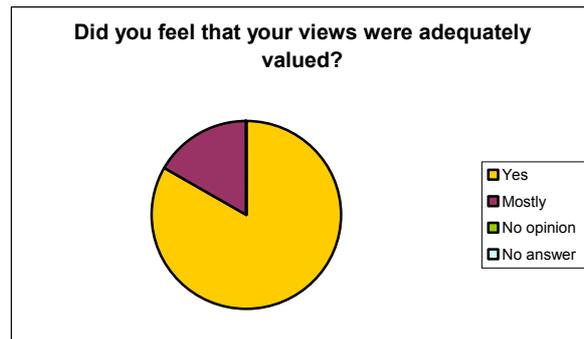
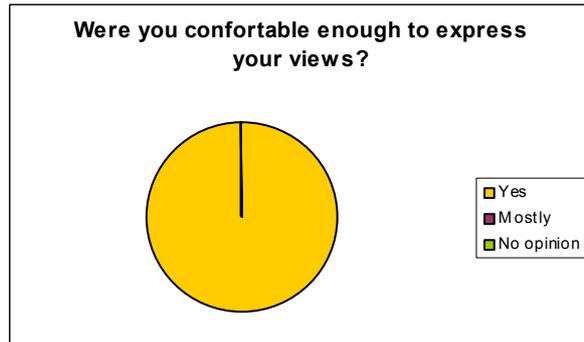
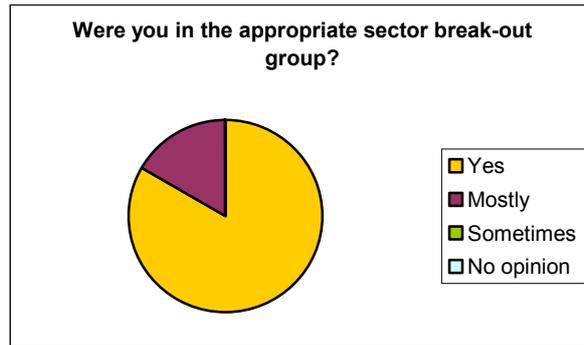


Report on the 3rd ATEAM stakeholder dialogue workshop
Appendix 6: Results of the evaluation questionnaire

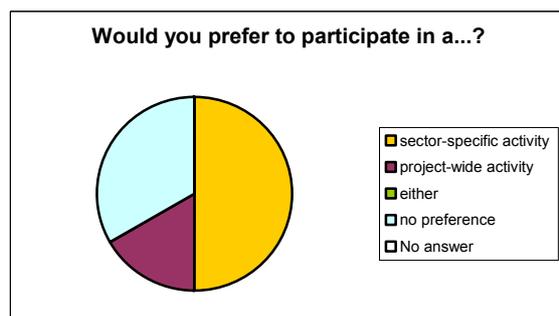
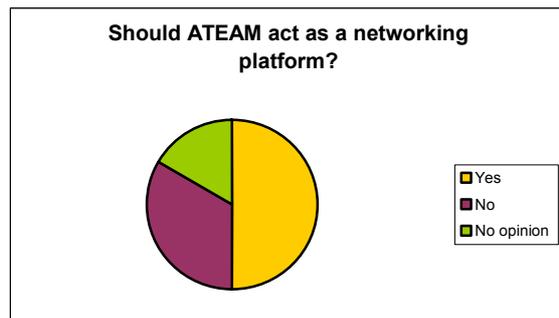
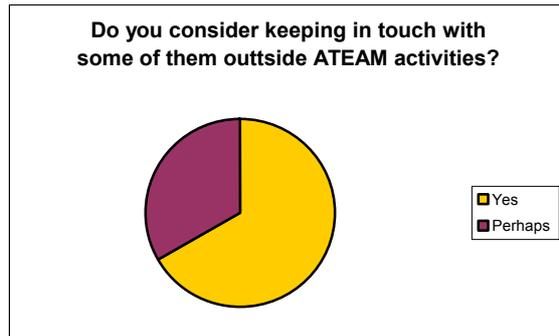




Report on the 3rd ATEAM stakeholder dialogue workshop
Appendix 6: Results of the evaluation questionnaire



Report on the 3rd ATEAM stakeholder dialogue workshop
 Appendix 6: Results of the evaluation questionnaire



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Appendix 6: Results of the evaluation questionnaire

