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Short communication

Values in socio-environmental modelling: Persuasion for action or excuse for inaction☆

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A B S T R A C T

Science in general and modelling in particular provide in-depth understanding of environmental processes and clearly demonstrate the present unsustainable use of resources on a global scale. The latest report by the Intergovernmental Panel on Climate Change (IPCC), for instance, shows that climate is changing and with a 95% certainty it is the humans have caused the change. The future climatic conditions are shown to be largely adversely affecting human wellbeing on this planet. Yet we see in numerous examples that societies are very slow in reacting to this rapid depletion of natural resources. What still seems lacking is the translation of scientific reports and the results of analysis and modelling into corrective actions. We argue that one of the reasons for this is the traditional workflow of environmental modelling, which starts with the purpose, the goal formulation, and ends with problem solutions or decision support tools. Instead, modelling, and applied science in general, has to enhance its scope beyond the problem solving stage, to do more on the problem definition and solution implementation phases. Modelling can be also used for identification of societal values and for setting purposes by appropriate communication of the modelling process and results. We believe this new approach for modelling can impact and bring the social values to the forefront of socio-environmental debate and hence turn scientific results into actions sooner rather than later. Instead of being separated from the modelling process, the translation of results should be an intrinsic part of it. We discuss several challenges for recent socio-environmental modelling and conclude with ten propositions that modellers and scientists in general can follow to improve their communication with the society and produce results that can be understood and used to improve awareness and education and spur action.

"I have come to the conclusion that politics are too serious a matter to be left to the politicians."

Charles De Gaulle

1. Introduction

Our understanding of environmental processes and knowledge on interactions in social–environmental systems is growing, yet our ability to improve decisions is still limited. We are exceeding several of the planetary boundaries (Rockstrom et al., 2009), and we already are seeing emerging conflicts due to limited resources such as food, water, energy and land (Daily and Ehrlich, 1996; Homer-Dixon, 1999). We realize how climate change, loss of biodiversity and ecosystem function can be detrimental to our life-support systems (Balvanera et al., 2006). However, in all these cases substantial progress towards

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mitigation or adaptation is elusive. Advances in knowledge and understanding do not automatically generate adequate (re)actions in form of policies or management strategies. This disconnect between science and policy-making is well recognized (Bradshaw and Borchers, 2000; Valkering et al., 2005; Cornell et al., 2013; Seidl et al., 2013; etc.) and has stimulated new global change research programs such as FutureEarth (Glaser, 2012). Largely in an attempt to bridge this gap, for 30 years the American Association for the Advancement of Science (AAAS) has been running a Science & Technology Policy Fellowship program putting scientists to work for the government and directly providing scientific expertise to policy makers, while at the same time educating the scientists about the policy making process.[1] In spite of these and other efforts, even some of the most prominent and important attempts to bridge the persistent gap between science and policy such as the Intergovernmental Panel on Climate Change (IPCC) processes have so far achieved only limited success (Rogelj et al., 2010).

There are different views on the relationship of science, policy and decision-making. Some believe science should take side and firmly provide policy solutions beyond a neutral discussion of evidence. John Holdren, scientific advisor to US President Obama, for example, expects science to guide policy makers, especially under conditions of crisis, when stating that "the science of climate change is telling us that we need to get going" (Holdren, 2008). Taking this stance, science should go beyond a neutral discussion of evidence and can tell policy what to do. In contrast, some believe that science should stay value neutral. Robert Lackey former chief of the Corvallis US Environmental Protection Agency (EPA) Lab, states: "science, although an important part of policy debates, remains but one element, and often a minor one, in the decision-making process", and that "scientists can assess the ecological consequences of various policy options, but in the end it is up to society to prioritize those options and make their choices accordingly" (Lackey, 2008; 2013). These two concepts of the role of science in supporting the policy process just scratch the surface of a long-lasting trans-disciplinary debate, which is mostly driven by the definition of values and preferences in science, society and decision-making. The dominant assumption is that science is value neutral and is supposed to provide information for policy and decision-making: only the latter have to account for societal values and preferences (Sarewitz, 2004).

In modelling as well as most often in science in general, societal values and preferences are assumed as a given, permanent and independent. For example, Fuentes (2011) suggests that we "are losing biodiversity because of human preferences and human inefficiencies, not because of economic growth", suggesting that our values and preferences that drive societal and political choices are not influenced by economic growth. In reality, societal values and preferences are not inert but are prone to change over time. Individual behaviour and decision-making are products of complex system interactions, and, in many cases, of well-orchestrated and funded action (see for example Lewis et al., 2013; Baker, 2012, etc.). Scientific evidence presented without taking into account how preferences and values affect decision-making and actions falls short of being effective. Throughout the history of humankind values have been always moulded and modified (say by religious or philosophical teachings), and are still very much in flux (affected, say, by advertisement and mass media). We cannot ignore this if we expect science to lead to actions.

Modelling and simulation of environmental processes once bore the promise of explaining the present and predicting the future and were viewed as powerful instruments for decision-making. In spite of great progress in the development and application of modelling tools, we are yet to see that happening. Why are decisions and actions still missing? Why are the models not used by their intended users (McIntosh et al., 2011)? It appears that at present King Hubbert's statement, "Our ignorance is not so vast as our failure to use what we know" is becoming only more relevant, as the growth in data and evidence on environmental issues does not appear to directly translate into better informed actions. Is this because science in general is miscommunicated to the public, or is there any special role that models play in creating this disconnect? What can be done differently in socio-environmental modelling to change this?

2. Modelling process

When modelling open systems, we have to set system boundaries cutting certain relationships to the 'outside world'. For evolving systems, we look at the past, and assume that the same structures and processes will persist, which often will be inaccurate since systems change while we model them. Moreover, our intrusion into the systems for research purposes can also cause them to change. For example in social systems, we can trigger change of perceptions and preferences when asking a certain question during a survey. People may have never thought about a particular ecosystem service before getting asked about its usage. While giving a negative response in the survey, later on they may start noticing the service and may end up harvesting it. Like in quantum physics, it becomes impossible to separate the observer from the phenomenon observed (Capra, 1975). It may be that the surveyor can also change the social phenomenon simply by asking a question (Voinov, 2008). In too many cases in the current modelling processes, we choose the boundaries of our models in such a way that the societal aspects are left out. Values and norms are assumed as a given, as static. Society in our models does not learn or adapt. In reality, it does (Ehrlich and Levin, 2005; Kohut, 2009).

A standard procedure for good modelling practice (Jakeman et al., 2006) starts with the problem formulation, loops through iterative cycles of model development and analysis and ends with a product that is handed over to the end-user (Fig. 1A), for example as a decision support system (Van Delden et al., 2011; Volk et al., 2010). As McIntosh et al. (2011) state, this practice deliberately leaves out the user and stakeholders interface. On the other hand, participatory modelling (Voinov and Bousquet, 2010; Van Asselt et al., 2003) tries to focus on the modelling process rather than the model itself (Fig. 1B). In this case the definition of project goals becomes one of the stages of the modelling process, which is revisited as many times as needed with active interaction between scientists and stakeholders. Modelling helps defining these goals and clarifying values, intentions, and actions, and, potentially, changing them at the same time. Modelling here engages stakeholders in a process of social learning (Tàbara and Chabay, 2013) and co-design of knowledge (Glaser, 2012) that includes a critical self-control feedback. Similarly, in the analysis of the model results, stakeholders are engaged to ensure that their expectations are met and the results can be used in a trans-disciplinary framework (Seidl et al., 2013). This helps to bridge different disciplines and appropriately account for human values in modelling (Valkering et al., 2009). Yet still in most cases in participatory modelling, the scientists and modellers are assumed to be 'objective' and 'value-neutral' (Voinov and Gaddis, 2008). Moreover, the modelling process still rarely leads to action: scientists usually lose interest in the

[1] http://fellowships.aaas.org/.

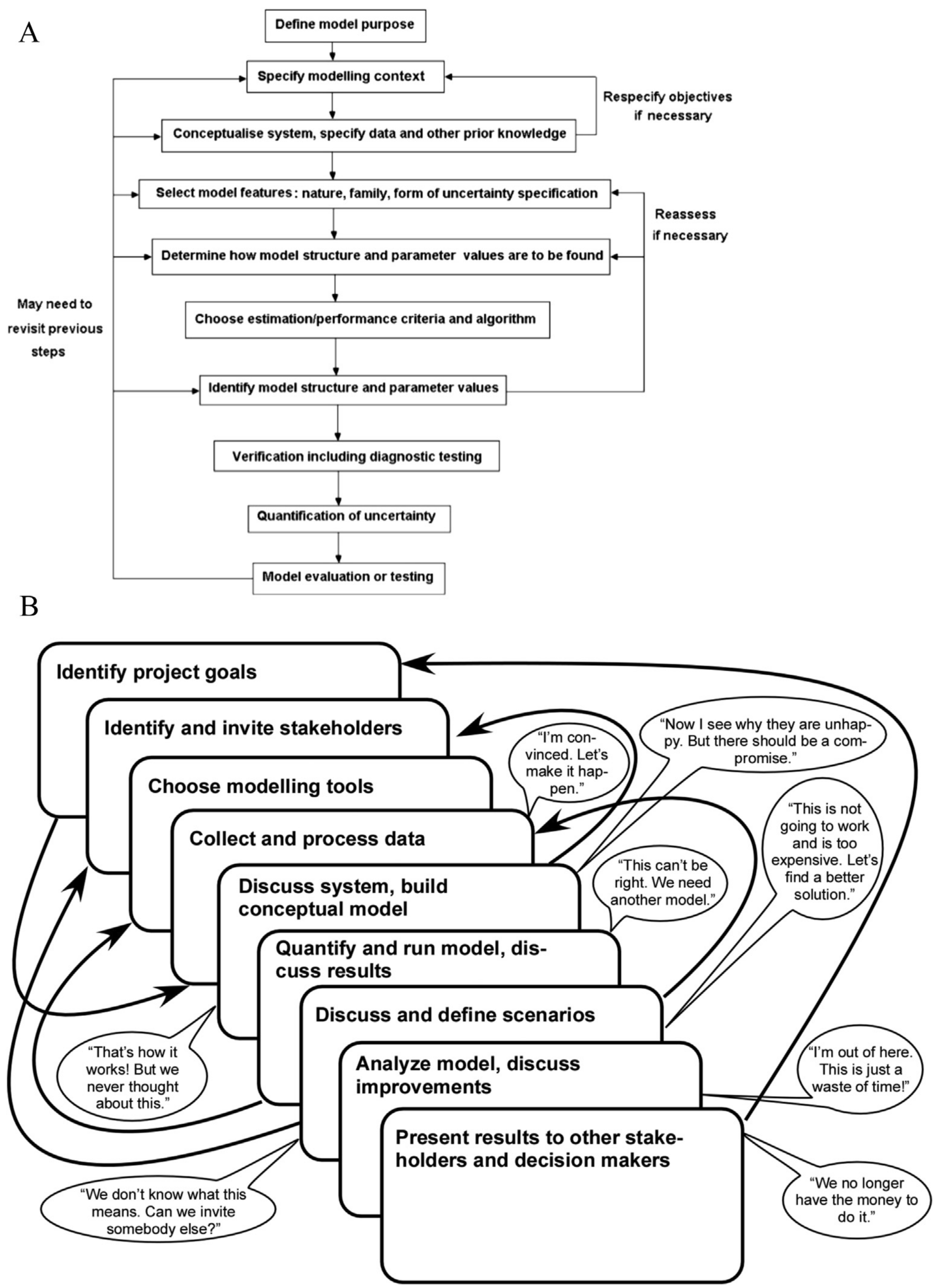

Fig. 1. A more quantitative, 'natural science' approach (A) to modelling vs. a more qualitative, 'social' approach (B). Note the distinction that keeps the model purpose definition and model use mostly outside of the modelling process in natural sciences. In participatory modelling (B) there is more focus on the outcomes of the modelling process, and the modelling sequence is assumed as a stack of cards, which can be shuffled at any time with no predetermined line of events. Stakeholders and decision makers participate throughout the social modelling process. Still scientists are assumed to be neutral and objective, and action is not part of the modelling process. A: Jakeman et al. (2006) B: Voinov and Bousquet (2010).

project once the model is running, the funding is gone and papers are published.

Direct engagement in the value-setting process, is what really matters to instigate action and change. We argue that including this value-setting into an iterative cycle of co-design of knowledge with users and stakeholders is crucial for the success of any exercise in environmental modelling. If we want models to be useful, we do need to acknowledge that the users exist in a socio-political system, and therefore including users' values in the modelling process and providing results based on their requirements becomes essential. In doing so we need to admit that modellers are also stakeholders in the modelling process and also have their own values.

Dunlap et al. (2001) observe that detailed public understanding of highly complex issues such as global warming may be neither feasible nor necessary for effective policy making. Similarly, we argue that adding layers of complexity to our models will not necessarily drive policy making. However, inclusion of social values and the relevance of the model results to public life may translate them into policy decisions. Todd and Gigerenzer (2000) argue that simple heuristics are much more efficient for decision-making than scenario based story telling with complex models. This is especially because complex models have a high degree of uncertainty as Bradshaw and Borchers (2000) demonstrate. Building models with a large number of parameters and complex structures to mimic the reality of the social–environmental systems result in models being too quantitatively uncertain to effectively drive the decision-making process. In other words, high uncertainty becomes a pretext for negating model results and thereafter supports the inaction by the policy makers. Model-based environmental research needs to provide results that navigate through the hierarchies, showing analysis on different appropriate scales and resolution in time, space and structure so that the correct level of information is provided to promote understanding and effective action (Seppelt et al., 2009; Lemos and Morehouse, 2005).

3. Results of modelling

At the end of the day it is the visualisation and explication of model results that determine their use or misuse (Kraak and Ormeling, 2010). There are ingenious and compelling ways to use spatial representation (e.g. Carbon Map[2]), or the dynamics of statistical indicators (e.g. Gapminder[3]). Likewise, there are examples of clever interpretations of data, such as McCandless's (2010) comparison of the CO_2 emissions of the European aviation with the emissions from the Iceland volcano in 2010, that depict the first carbon neutral volcano eruption in history (the grounded aviation has saved more CO_2 than the volcano emitted). Yet, there is still more need to deliver the information to the public and to induce action.

In developing the most persuasive and powerful communication tools, environmental science has a vast area of expertise to learn from: several decades of intensive research in the advertising industry and mass media show how to best present results to make an impact. For now the power of advertising is actively promoting quantitative economic growth, and unlimited conspicuous consumption and works against the environment. While there is much concern about the ethics of advertising, we cannot ignore the fact that it has a huge impact on consumer choices and the public opinions in general. Science may be entirely losing the battle to provide clear and concise information to society, while trying to stay 'clean handed' and neutral. When considering the ethics of scientific advertisement, let us ask ourselves: is it ethical to know something important and not do our best to communicate this knowledge to the public? We would argue that scientists are disservicing the society by assuming their neutrality and divorcing themselves from the political process.

The transparency of scientific knowledge and the fact checking that is an intrinsic part of any peer reviewed science bears promise that the use of science can remain ethical, especially when it is part of a stakeholder process and is actively scrutinized by the society at large.

Presenting scientific evidence from model-based future scenarios and reflecting upon the need of changing societal values, intentions, and actions in similarly persuasive and pervasive ways remains elusive. Hence one of the reasons that scientific understanding and knowledge does not readily translate into actions may be the target audience. Communication of model results should not be limited to the final stage of decision-making and the small group of policy decision makers. In order to be useful, results need to be delivered in a compelling and clear form and modellers need to become more actively involved in the political process, and do their best to engage with the public in the debates about our future. Stakeholder information, involvement and participation become crucial for the success of model applications. Furthermore, stakeholders can teach us how to communicate the results in ways that will be understood and can spur action. Or how to use fear and hope at the same time to warn and encourage a conscious change in people's life style that later get translated to an unconscious behaviour.

4. Conclusions

It appears that science in general and modelling in particular are assigned a certain niche in society and are tolerated as long as they stay within it. In fact, many scientists are quite comfortable with this role, since in a way it safeguards them from direct responsibility for the decisions and actions taken. Cases of officially blaming scientists, like the recent precedent in Italy (Cartlidge, 2012), are rare and, for good reasons produce outrage among scientists.

We argue that by divorcing our modelling process from the problem formulation stage, expecting the problem to be formulated for us to solve, and by ending our modelling exercises with a delivery of a solution then disengaging from the actual implementation of this solution, we are not helping to instigate the urgent actions needed today. Modelling is not an end, it is an evolutionary process of learning to better adapt to the continuing change that societies and ecological systems face (Tàbara and Pahl-wostl, 2007). If we expect actual decisions being made only outside of the modelling process, then we ignore the power that models have: on one end, in framing the problems, asking the questions, comparing alternatives, identifying the contexts and boundaries; and on the other end in determining the actual value sets that lead to action through successful management or governance.

In fact, problem framing and definition are already results of modelling and the problem is most likely to be modified as a result of further modelling. Values and intentions are not static, but instead they are constantly changing, and can and should be influenced by the results of models that we build. It is the responsibility of modellers to communicate the results in such a way that they can be understood by the public and are best framed to influence the values in an appropriate way.

There are good examples of independent bodies, such as the Climate Change Commission in Australia, that translates complex scientific contents, for example the latest IPCC report, into engaging graphics not only to communicate the truth about our environmental processes but also to avoid mass media filling the gap with scepticisms and unrealistic belief of those in political and economic power. The Union of Concerned Scientists (UCS),[4] for example, actively engages in political and advocacy campaigns. The Millennium Alliance for Humanity and Biosphere (MAHB),[5] originally established by Paul Ehrlich as the Millennium Assessment of Human Behaviour, encourages worldwide dialogue about environmental health, social equity and sustainable practices. Environmental modellers could be very instrumental in the efforts of these bodies contributing their tools, methods, worldviews and values, while benefiting from the existing networks and publicity.

Using the very best science and rigorously testing and analysing our models are extremely important (Bennett et al., 2013). However, success in modelling should not only be measured by

[2] http://www.carbonmap.org/.
[3] http://www.gapminder.org/.
[4] http://www.ucsusa.org/.
[5] http://mahb.stanford.edu.

producing a model that best fits the data (model as a result), but also by communicating the information and knowledge gained from models (modelling as a process). This may be missing when choosing the best modelling approach, for instance based only on the decision tree by Kelly (Letcher) et al., 2013. Modellers will be successful in instigating action only, if working with decision-makers and stakeholders on a constant basis, not as temporary value neutral advisors or consultants.[6] Successful examples of such long–term interactions are the science-driven task forces and expert groups within the United Nations Economic Commission for Europe's (UNECE) Convention on Long-range Transboundary Air Pollution (CLRTAP), which provide an established and trusted forum for direct interaction between scientists and policy decision makers, improving mutual understanding and leading to better informed policy development (Reis et al., 2012). If people are most likely to acquire their scientific knowledge by consulting those who share their values and whom they therefore trust and understand (Kahan, 2012), how will we expect them to associate with scientifically laden values when science is expected to be value neutral? Trying to convince people with scientific arguments only is an uphill battle against their values and intentions set by the media and advertisement and is prone to societal inertia. It is lost unless weapons are turned around and the same proven methods are used to spread a different message.

Modellers, and scientists in general, should play an active role in developing the preferences, the 'wants' of the society, not just assume a subservient position only taking them as a given. It is our strong belief that society would benefit from scientifically sound and democratically legitimated 'community coaching' on socio-environmental feedbacks, the connections between individual activities and choices and environmental pressure and resource limitation, and the opportunities for change based on personal choice. It is a long and tedious process, where scientists have to be fully engaged and should play a more active and socially responsible and interactive role. There are an increasing number of calls for scientists to get directly involved in the societal debates (McKibben, 2012) or even in policy making. There are good examples of this actually happening, like when the particle physicist Bill Foster becomes a congressman (Bloudoff-Indelicato, 2012), or as when a Dutch agricultural scientist, Eric Smaling, serves as a Senator and MP, or even when a renown climate researcher Michael Mann plays an active role in a gubernatorial election campaign. Unfortunately, Mann still decides to "leave the policy debate to politicians as long as it is informed by what scientists have to say" (Malakoff, 2013) - a position that we oppose in this paper. Societal intentions often turn out to be more important for decision-making than 'objective' scientific findings. Science cannot ignore this and should play an active role in shaping these intensions.

This does not mean that scientists and modellers should replace journalists or policy makers. We call for science to openly and actively engage both in problem setting and in decision-making, *in addition* to problem solving. In the face of today's dire problems (Ehrlich and Ehrlich, 2013), we can no longer afford to sit back and wait for others to make things happen.

To operationalize some of these ideas we are coming up with a number of propositions for modellers. In Box 1 we present them as 'commandments' though certainly there can be no commandments in how we conduct our research and do science. We are intentionally framing them this way because we are very much driven by the sense of urgency and need for action in the good tradition of precautionary principle. In most of the publications on how to bridge science and policy making we are still talking about 'us' – scientists, and 'them' – politicians and decision makers (e.g. Blockstein, 2002). Our call is for more integration between science and policy, appreciating that there is much science in policy and decision making (Jaeger et al., 2013; Dietz, 2013), where our modelling methods and tools can be instrumental, and that there is much knowledge and skills that scientists can contribute when closely involved in the policy making process.

Box 1
Ten 'commandments' for a socio-environmental modelling agenda:

1. Stop pretending that applied science and models are always objective and value neutral – they are not. Acknowledge implicit decisions and assumptions in modelling, document and communicate them.
2. Be totally transparent about your assumptions and values. Discuss them broad and wide within the modelling process.
3. Do not confuse personal values and interests with scientific facts. Explain how scientific facts can shape values.
4. Science based values are not set in stone – they change when new knowledge becomes available.
5. Engage with stakeholders to define problems together.
6. Engage with policy makers to help them understand the solutions and make sure they act accordingly. Use the modelling process to engage the public in debates about our future.
7. Treat modelling as a process, which evolves and adapts to accommodate new knowledge and data, which does not have a final solution because there are no final solutions for open systems.
8. Always follow the best practices of rigorous model characterization and testing. This is a necessary, but not a sufficient condition of successful modelling.
9. Explain and appreciate all types of uncertainties as an inherent part of all complex systems.
10. Use all available means of communication and interaction. Do not be afraid to turn around the weapons used in mass media and advertisement. Seek for funding and means to deliver your message in the most compelling and powerful way.

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[6] As in the case of model-based games as learning tools for students and stakeholders, see LandYOUs as an example http://www.landyous.org/en.

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