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Modelling human-environment systems in transdisciplinary processes

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Abstract: There is an increased tendency in scientific projects to include different disciplines, policy makers, practitioners, and the general public in unstructured, complex, or potential environmental problems resulting from human activities. Such problems may sometimes be associated with strong value-laden and contested issues. Integrated assessment modelling (IAM) or decision support systems (DSS) are used in transdisciplinarity (TD) settings to organize processes of mutual learning in science and society. In its ideal form, a TD process is characterized by joint leadership, with representatives from the science community and legitimized decision makers having equal roles. We present and briefly illustrate our TD approach to guide a participatory process and indicate important issues to aid IAM and DSS endeavours.

Keywords: Transdisciplinarity, integrated modelling, decision support systems, participatory modelling

1 INTRODUCTION

1.1 Complex problems in human-environment systems

Social-ecological system (SES) or human-environmental system (HES) modelling and integrated assessment (IA) aim to provide knowledge on complex systemic interrelations, such as feedbacks between and within the human and the environmental systems (Le et al., 2012). This system perspective, which takes into account human and environmental interactions, as well as the long-term effects and the possible rebound effects of decisions, helps to shed light on the complexity of these problems. It has become clear that (especially sustainability inspired) science increasingly is and will continue to be involved in the challenge of dealing with normative and value-related issues (Funtowicz & Ravetz, 2001). Involving a range of stakeholders - such as business leaders, and decision makers as well as members of the public at large - in society-oriented scientific research can enhance the knowledge base and ensure the social robustness (Nowotny, 2003) of solutions based on interdisciplinary (or integrated) modelling (Jakeman et al., 2006). However, a drawback of such an approach, which often involves huge interdisciplinary projects with researchers from several natural and social sciences, is the complexity and specificity of the models used and the results obtained. In addition, interdisciplinarity is an issue in itself, yielding complex interaction patterns and communication problems that have to be overcome (Pennington, 2008). The participation of nonscientists – referred to in this paper as transdisciplinarity (see Hirsch Hadorn et al., 2008) – adds another level of complexity to the project (Prell et al., 2007).

1.2 Participatory approaches in integrated assessment modelling and decision support systems

In this paper, we focus on stakeholders and participatory approaches within IAM and DSS for HES or SES (Jakeman et al., 2011). Recently, there has been an increasing tendency to include various kinds of stakeholders and decision/policy makers in integrated projects (Fürst et al., 2010; Matthies et al., 2007; Mostert, 2006; Reed, 2008). The principal goals of this approach are to[1]:

1. formulate research goals and questions, as well as system boundaries so that real-world problems are addressed (Franzén et al., 2011);
2. gain access to specific knowledge, as well as to cognitive framing and perceptions (Smajgl, 2010);
3. develop scenarios and indicators to capture the relevant concepts from a science as well as practice perspective (Lautenbach et al., 2009; Walz et al., 2007);
4. inform decision makers on the scientific state-of-the-art (Sterk et al., 2011),
5. gain access to policy makers/decision makers, i.e., influence decisions (Van Delden et al., 2011);
6. ask decision makers to use the developed models (McCown, 2001);
7. yield socially robust solutions (i.e., those that are accepted by decision makers and the general public) (Nowotny, 2003)

In the following we focus on the challenge noted for instance by Liu et al. (2007b, p. 646): how to fulfil different needs of society and produce usable knowledge in IAM and DSS projects? Given the potential mutual fertilization between the system science knowledge (i.e. systemic-functional structuring of ill-defined problems) and the non-science knowledge of stakeholders, the aim is to meld the system science perspective represented by models in a multi-stakeholder discourse to tackle the social complexity of the problem. This means: how to obtain and represent all of the necessary knowledge and how to ensure that the decisions are socially robust. Stakeholders can help to improve both aspects; however, the inclusion of stakeholders must proceed in a structured way.

Recently, scientists have made several attempts to create DSS tools to help various decision makers, such as farmers, water managers, or politicians (e.g. Salter et al., 2010). However, as noted by Le Bars & Le Grusse (2008), "whatever the quality of the tools used to solve problems, their use is meaningless if we do not benefit from the support of a group of stakeholders concerned by the problem at different levels and by the changes in the way the problem is formulated" (p. 188). Volk et al. (2010) concluded that "there are still many open challenges and problems to be solved" (p. 845). In particular, these authors stressed that "further emphasis must be placed on stakeholders developing a clear vision what they need and want" However, this issue cannot easily be resolved during the project process. Thus, Volk et al. (2010) also stated that they "have learned that it is far easier to design a DSS for a group of stakeholders who actively participate in an iterative process" (p. 846). For a more thorough review of participatory methods in IA, including TD, see for instance Salter et al. (2010). In fact, the decisive factor seems to be the early inclusion of stakeholders and prospective users of these systems into the modelling process (Díez & McIntosh, 2009). In particular, Alcamo (2002) stated that "gaining this legitimacy should therefore be an important explicit goal of integrated modelling" and noted that "the basis for this legitimacy and how to gain it, has not been adequately studied and identified" (p. 10).

[1] Points 1 to 3 refer to the benefit science gets from practice, points 4 to 6 imply consultation of science, while point 7 refers to the benefit for science and practice from a joint process.

1.3 Towards a process template to guide participatory modelling

There have been thorough reviews of the topic (see also Barreteau et al., 2010), for example, Reed (2008) summarized the history of participation and highlighted points for best practice, and Voinov and Bousquet (2010) presented a typology of participatory modelling approaches and tools for formalizing stakeholder knowledge. They also listed collected lessons learned and recognized (among other points) that a crucial step in stakeholder involvement is the development of research questions and goals. Already at this early stage of a planned endeavour a consensus about the goal can be targeted between stakeholders and scientists. Parker et al. (2002) discussed stakeholder participation in relation to issues of scales, models, and disciplines (i.e., interdisciplinarity) focusing on particular areas. In line with other authors, they also stressed that different time-frames and values (of and among scientists and practitioners) have to be dealt with in the participatory processes (Pahl-Wostl & Hare, 2004), that a joint goal has to be found, and that the participatory process has to be managed throughout the whole duration of the project. Experiences from an actual participatory modelling exercise were described in more detail by Landström et al. (2011). Their study showed how the work of two hydrological modellers was inspired when they were confronted at workshops (so-called *competency groups*) with local residents and with their mental models. The authors concluded that the experience was rather satisfying and improved the outcome of the modelling work, especially concerning the definition of what knowledge is important. A template (or framework) of a participatory process has been formulated previously (Matthews et al., 2011; Welp et al., 2006), and a generic framework for effective decision support has been proposed by Liu et al. (2008). Their framework commences with the identification of integrated focus questions using scientific and stakeholder expertise. We go somewhat beyond these notions and propose a *process template focusing on an equal footing principle between science and nonscience*. We particularly identify a need for clarification of the *functions* of science and practice and *dynamics* during a participatory process. Who should be involved when (i.e. phase/step) in what manner (i.e. role) to gain what (i.e. benefit)?

2. A PROCESS TEMPLATE OF TRANSDISCIPLINARITY

We use the term transdisciplinarity (TD) in a way (Hirsch Hadorn, et al., 2008) different to for instance Mittelstrass (2003) or Hinkel (2011), who explicitly focus on a specific kind of scientific interdisciplinarity and intrascientific knowledge integration but eventually exclude stakeholder collaboration.

2.1 Processes in transdisciplinary settings

We subscribe that for complex real-world problems, purely scientific knowledge (in the form of interdisciplinarity) is necessary. We also stress that in specific cases interdisciplinarity is not sufficient; for instance because issues are socially contested, value issues play an important role, or there is a lack of “optimal” solutions to deal with (for example, nuclear waste, future energy systems, sustainable landscape development, urban leisure traffic, closing nutrient cycles) or because the necessary knowledge and power to sufficiently analyse the problem at hand lie not with science but (almost or entirely) in the hands of private companies (e.g., the fertilizer industry) or indigenous peoples (Atran et al., 2005). There is a need to thoroughly examine and describe the structure, dynamics, and properties of resilient, sustainable developments from a coupled HES-view (e.g. Gibbons, 1999; Leshner, 2002; Liu et al., 2007a; Rowe, 2007; Scholz, 2011). In such systems, practical knowledge is often bound to diverse proximate issues and thus research questions based on stakeholder input alone could be too arbitrary and narrow.

Under the umbrella term "transdisciplinarity" (TD), different approaches can be summarized. However, TD as we conceptualize it is fundamentally different from interdisciplinarity and from collaboration (cf. Mobjörk, 2010). Most current TD definitions include some notion of "going beyond science", which means that it "deals with relevant, complex societal problems and organizes processes …" that relate knowledge and values of "agents from the scientific and the non-scientific world" (Scholz et al., 2000, p. 477). TD organizes processes of mutual learning (also: social learning, cf. Pahl-Wostl, 2002) among science and society (Thompson Klein et al., 2001). In this way, TD processes broaden the area of cognition and open the space for alternative solutions because science and society go beyond their respective reference frames. In its ideal form, TD processes are characterized by joint leadership between representatives from the science community and legitimized decision makers, with both entities having equal footing. For some researchers, this might seem an unusual approach, with the problem often identified by scientists who then search for stakeholders or decision makers who could/should be interested in the topic (Sterk, et al., 2011). However, "this is a misdoing, because a conscious and participatory choice ought to begin from the acknowledgment of the problem to be tackled: *it is crucial for the legitimacy of a planning process to start dialogue as early as in the phase of problem definition*" (Castelletti & Soncini-Sessa, 2006, p. 1458). This statement is in line with our notion of TD.

Of course, this challenges scientific autonomy. Therefore, it is important that *joint* problem definition, definition of system boundaries, and goal formation take place to lead to "problem ownership" by all parties involved. Both ourselves (Scholz, et al., 2000) and others (Martínez-Santos et al., 2010) have shown that this is a viable approach, which likely yields, although does not guarantee, a successful outcome. The general public should also be involved, but often at a later stage. Importantly, the TD process should provide an arena that is not directly related to day-to-day politics or business competition. This point is especially relevant for the type of problems tackled in IAM and DSS projects because the concerns and the values of the different parties have to be considered and related to each other.

Figure 1 illustrates the different phases and steps (indicated by the numbers 1 - 4) of the TD process (indicated by the thicker grey lines). During some phases/steps the parties involved collaborate more closely or work on their own. Usually, legitimized decision makers, the science community, and the general public can be distinguished. The details of how the process is managed will depend on the issue at hand (Wiek & Walter, 2009). However, after (1) formulating a plan of action and deciding how to investigate an identified (by scientists or other actors) problem and perform a (first) stakeholder analysis, scientists usually (2) meet with the decision makers and discuss the issue and set possible goals for the project (including system analysis and representation using modelling techniques being comprehensive for lay stakeholders such as system dynamics). This step is taken to ensure that these decision makers in the end have greater legitimacy to make decisions at a later stage and that the models or model results are actually used within the subsequent decision-making process. At a later phase, (3) the results of the first model or the management options identified may be discussed with members of the public who are affected by any possible decisions taken. In this step all stakeholders and scientists come together, for example, in a scenario workshop (using scenario analysis and visualizations of the model's results). The scenarios can be evaluated via multi-criteria-assessment (MCA). This phase can be called an "ideal" or "core TD-process." In the final step, (4) management options or planned actions are implemented. After mutual learning and capacity building have taken place the parties return to their core business. As illustrated by Figure 1 the contact with specific stakeholder groups might be greater or less in different phases of the project (information, consultation, collaboration). Different phases during the project can urge the project leaders to include different stakeholders to different degrees (see also Mostert, 2006).

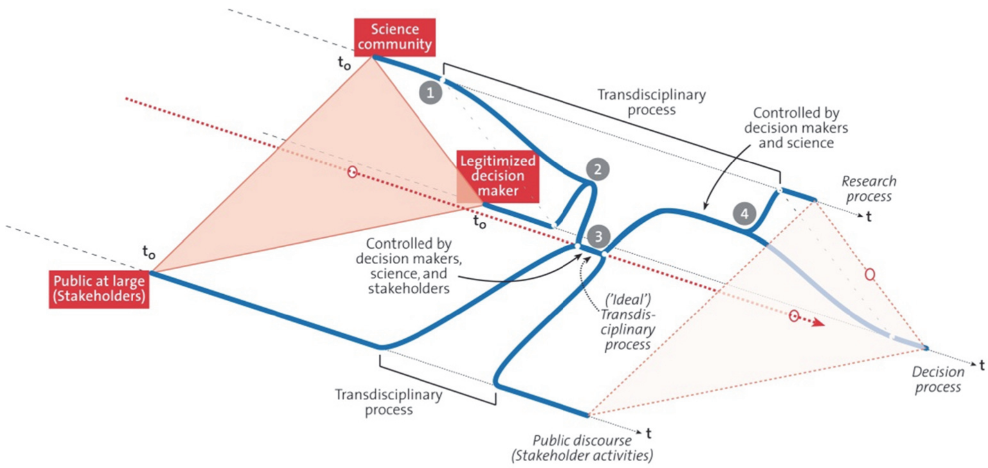

Figure 1: A prototypical transdisciplinary process (numbers refer to the description in the text; figure adapted from Scholz, 2011, p.375)

We refer to this as the functional-dynamic approach (Stauffacher et al., 2008). In each step, various methods and tools are available to involve nonscientists and to obtain their knowledge and to relate (or integrate) their values (Scholz & Tietje, 2002; Voinov & Bousquet, 2010).

2.2. Contributions of TD to the requirements of IAM and DSS

Sound modelling of HES depends on disciplinary research and communication between scientists from different disciplines, i.e., interdisciplinarity has to be organized, for example, using a comprehensive framework of HES/SES (Ostrom, 2009; Scholz, 2011). In addition, contact with nonscientists informs the modelling process and ensures subsequent use of the model. In terms of how *the concept of transdisciplinarity can help,* the following should be considered:

- Full TD settings should be seen as "regulative idea", with different levels of interaction possible. However, it is essential that stakeholders have a considerable degree of problem ownership (not the least by partial funding, which motivates to participate and to ensure valuable outcome). (Barab & Duffy, 2000)
- Disciplinary-based interdisciplinarity in transdisciplinarity settings: integrated modelling not only integrates disciplines and models, but also relates knowledge, values, and concerns from different science and non-science parties. TD can guide this process using the functional-dynamic approach and specific methods.
- Societal capacity building is needed for coping with ill-defined socially relevant problems, i.e., concrete social, regional, and technological processes of adapting to changing environments (cf. for instance the study by Walz, et al., 2007).
- Some degree of consensus is necessary among different stakeholders with conflicting concerns (see e.g., Walter et al., 2007). For instance, experts organize or participate in discourses, such as public consensus conferences in which answers are provided to a citizen panel's questions (cf. the overview in Joss, 1999).
- Legitimize political action programs: this also opens up new perspectives for science and its output, with science becoming more socially accepted and robust. We suggest that developing socially robust knowledge in transdisciplinary processes is a key element of societal capacity building.

3. CONCLUSION: CHALLENGES AND RECOMMENDATIONS

Describing an ideal TD process also illustrates some challenges not only to scientists and stakeholders, but also to the academic system. *On the one hand*, we consider it crucial to keep the scientific essence of a project; including writing scientific papers and developing scientifically relevant models. *On the other hand*, we aim to develop socially robust decisions and management solutions and would like to see our developed models being used. The model's results must also be relevant for actual decisions. In addition, concerns about the *role of the scientist* are seldom discussed. We cannot take for granted that modellers and researchers can act as moderators of a transdisciplinary process. Thus, it is clear that at least in larger projects, this process should be covered by an additional working package (see for example the Glowa-Danube project Barthel et al., 2010; Mauser et al., 2008). This need should be acknowledged by the funding agencies.

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