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Participatory decision making for sustainable development—the use of mediated modelling techniques

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Abstract

In this paper, the integration of mediated modelling (MM) techniques with multi-criteria assessment (MCA) in a participatory decision-making context is discussed. We briefly present the major features of MCA, of system dynamics methodology, and of group model building techniques. The application of MM in a participatory exercise is illustrated by a case study developed in a protected coastal wetland (Ria Formosa, Portugal). Possible avenues to integrate MM into multi-criteria decision making in the framework of sustainable development issues are discussed.

Keywords: System dynamics; Mediated modelling; Participatory tools; Complex environmental decisions

Introduction

Environmental decision making requires the integration of complex interactions between ecological, economic and social aspects. This is equally true for evaluating the environmental impacts of a specific project, the environmental assessment of a programme, or the development of sustainability pathways. In this process, one has to take into account not only "the facts", but also values, asking what ought to be honoured, protected, sustained, or developed (Forester, 1999). This constellation requires the active participation of all relevant stakeholders and their early involvement in the process.

It is particularly relevant when dealing with problems falling into the so-called "post-normal science" paradigm, when "facts are uncertain, values in dispute, stakes high and decisions urgent" (Funtowicz and Ravetz, 1994, 1991). In these cases, which cannot be tackled by "normal" scientific approaches, the policy dialogue has to be extended to all those who have a stake in the issue, that is, to the extended peer community (Funtowicz and Ravetz, 1997).

In fact, the results of decision processes which rely solely on formal assessment techniques and in which the analysts are in full control of decision support have been questioned—raising issues such as equity, trust and representativeness. Sustainable development decisions require the active engagement of stakeholders. Hereby the usefulness of developing deliberative processes such as citizen juries, focus groups or consensus conferences has been acknowledged. However, to be effectively useful for decision making, these processes have to be complemented with some kind of formal appraisal of alternatives.

We suggest that the integration of system dynamics modelling approaches, in particular, the mediated modelling techniques (MM), with multi-criteria assessment (MCA) can provide an important contribution in these situations.

In the following sections, we briefly present the major features of MCA and group model building techniques and illustrate the application of the latter to a MM

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exercise in a protected coastal wetland (Ria Formosa, Portugal). Finally, we discuss possible avenues for the integration of MM with MCA in a participatory approach to decision making for sustainable development.

Multi-criteria assessment

MCA is a decision-making tool applied to evaluation problems where one is faced with a number of different alternatives and desires to find optimal solutions with regard to several conflicting criteria. The usefulness of MCA to support decision making for questions concerning sustainable development, where conflicting ecological, economic, societal and technical objectives and multiple interest groups are involved has been increasingly acknowledged (Paruccini, 1994; Beinat and Nijkamp, 1998).

A typical multi-criteria problem (with a discrete number of alternatives) may be described this way: considering that A is a finite set of n feasible actions (or alternatives) and G is a set of m evaluation criteria (or points of view), it is possible to built an $n \times m$ matrix (P) called impact (or evaluation) matrix, whose elements $p_{i,j} = g_j(a_i)$ $(i = 1, 2, \ldots n;\ j = 1, 2, \ldots m)$ represent the evaluation of alternative i by means of criterion j. An action a_1 is evaluated to be better than action a_2 (both belonging to the set A) according to the jth criterion if $g_j(a_1) > g_j(a_2)$. The impact matrix can include quantitative, qualitative or both types of information (Munda, 1995).

Supposing that it is possible to evaluate each alternative in relation to each criterion, we can obtain a weak ordering of the alternatives for each criterion, ranging from best to worst. The multi-criteria decision problem consists of ranking the alternatives according to an ordering that is a legitimate synthesis of the criteria (Arrow and Raynaud, 1986).

Generally, there is no solution optimizing all criteria at the same time and compromises have to be found. A wide set of multi-criteria methods has been developed for this purpose. These methods have particular features regarding information requirements, criteria assessment, modelling of preferences and decision rules (see for instance Bana e Costa, 1990; Janssen and Munda, 1999; de Montis et al., 2000).

Beyond the discussion regarding the adequacy of a given method for a particular purpose, and of the usefulness of the MCA results, the process itself and the enhanced understanding about points of view, criteria, preferences and trade-offs are very important contributions for decision making regarding sustainability issues. In this context, the need and advantages of public participation in a multi-criteria decision-aid framework have been more and more recognized (Munda, 2004; Stagl, 2003).

There are several MCA methods capable of being implemented in participatory contexts, and some applications have already been described. For instance, the NAIADE method (Munda, 1995) has been applied in combination with social enquiry methods, namely institutional analysis and social research methods, to address the water scarcity problem in Troina, Sicily, and for decision support in groundwater management (Guimarães Pereira and Corral Quintana, 2002). There are other examples of the application of MCA methods in participatory contexts, such as IANUS (Messner, 2002), the Analytical Hierarchy Process (Saaty, 1980; Schmoldt and Peterson, 2000) and ELECTRE (Norese, 2002).

Multi-criteria methods supply a powerful framework for policy analysis in the context of sustainable development, since they can accomplish the goals of being inter- or multi-disciplinary (accounting for the multiple dimensions of sustainability problems), participatory (open to all stakeholders), and transparent (Munda, 2003). However, MCA itself is not sufficient to address policy decisions regarding sustainability issues, namely due to the difficulties of accommodating the dynamic nature of most social and ecological systems. In this aspect, we suggest that system dynamics modelling can bring a valuable contribution.

System dynamics modelling

System dynamics is a method for learning and managing complex feedback systems, such as environmental and social systems, that originated in the work by J. Forrester, in 1961 in the book "Industrial Dynamics". It is grounded in control theory and in the theory of nonlinear dynamics (Sterman, 2000).

The underlying assumption of system dynamics is that the behaviour of a system derives from its structure. The emphasis of system dynamics lies in the study and modelling of the feedback relationships which determine the behaviour exhibited by a system as a whole. It has been applied to a broad range of fields and problems, ranging from business decision making to biological and medical modelling, environmental systems and public policy.

The system dynamics methodology involves the following basic stages:

- problem identification;
- development of a dynamic hypothesis explaining the cause of the problem;
- building of a computer simulation model of the system;
- model test and validation;
- study and analysis of alternative policies to change model behaviour.

The modelling process separates consideration of underlying assumptions (structure, policies and parameters) from implied behaviour. By debating assumptions independently from the resulting behaviour, there is less tendency for people to differ on assumptions with which they can actually agree, merely because they initially disagree with the dynamic conclusions that might follow (Forrester, 1987). Therefore, system dynamics can have a potentially powerful role in structuring participation in environmental management.

System dynamics offers a consistent and rigorous problem-solving framework for identifying the scope of the problems, eliciting participants' views about problem causes and system connections and identifying policy levers. When simulation models are built, they can provide an internally consistent tool for comparing the effects of alternative policy options (Stave, 2002). Ford (1999) provides examples of the use of system dynamics in the study of environmental systems.

Mediated modelling

The foundations of MM are grounded in the group model building literature, which is a concept that emerged in system dynamics, referring to those interventions in which a client group is deeply involved in the process of model construction (Vennix, 1999). Group model building signals the intent to involve a relatively large client group in the business of model formulation, not just conceptualization (Richardson and Andersen, 1995).

This field has been growing rapidly since the first studies into the effects of client involvement in system dynamics modelling, dating back to 1961, as pointed out in the survey of group model building studies performed by Rouwette et al. (2002).

A wide variety of techniques can be used to involve the clients in the modelling process (Rouwette et al., 2002). The elicitation of information from the participants can be performed individually—using techniques such as interviews, cognitive mapping or work books—or in small subgroups. This usually starts after there is an agreement on the problem to be addressed.

There are also cases in which a preliminary model is discussed and adapted by the participants. Participants are then asked to choose between alternative problem formulations, model structures and policy options to be included in the model. These tasks require the input and confrontation of opinions of the group of participants as a whole, taking usually the form of face-to-face discussions.

The evaluation of model results also requires the group as a whole to discuss and agree on issues, although individuals and subgroups can be used to prioritize them.

Most group model building processes take the form of two to four workshops (usually an intensive full-day meeting each) with intermediate feedback and reports. The number of participants in these exercises ranges from small groups of 5–12 participants, to large groups of 50–100 participants. In the larger groups, participants work in subgroups that meet at regular intervals to present findings to the others.

Group model building is particularly suited to address ill-defined strategic issues, often labelled messy problems, i.e. situations in which there are large differences in opinion on the problem, or even on the question of whether there is a problem or not (Vennix, 1999). Many sustainable development issues share the characteristics of messy problems.

Participants in group model building exercises acknowledge that these processes have several advantages for them, namely (Vennix et al., 1996; Akkermans and Vennix, 1997):

- fostering team learning, by providing increased insight into the problem, namely in terms of identifying relationships between elements of the problems and in knowledge on feedback processes;
- establishment of a positive attitude towards cooperation;
- providing an equal opportunity for all group members to engage in the discussion and sharing of mental models. The quality of communication among group members is significantly improved;
- promoting consensus, allowing for the development of a mutual understanding of the problem. The model is perceived as the result of the integration of ideas from all participants;
- increasing commitment to the conclusions and recommendations of the exercise, deriving from the sense of ownership developed throughout the process.

MM is the process whereby stakeholders, and not only clients as in the original group model building exercises, collaborate together in the development of a simulation model about a specific problem, usually in a series of modelling workshops supported by a facilitator (van den Belt et al., 2000, 1998; van den Belt, 2004). It combines the advantages of modelling and systems thinking, namely the improved understanding of the dynamics of a complex problem, with the gains of collaborative practices to create a shared vision of a problem. The decision-making process can therefore be improved due to the emphasis on consensus building in the group.

MM is a promising tool to support the early involvement of stakeholder groups in environmental decision-making processes. It is particularly useful as a method for scoping and consensus building among a broad range of stakeholders in industry, government, academia and the public. Dynamic modelling can also be used to collect and organize data, synthesize knowledge and communicate the key issues for decision making about an environmental problem (Costanza and Ruth, 1998).

Experiences in the use of group model building/MM techniques for environmental management are still restricted to a few exercises, namely the use of modelling as a consensus building tool as part of the development of the Patagonia Coastal Management Plan, reported in van den Belt et al. (1996), and the case presented in Stave (2002) about public involvement in transportation and air quality management. Recent developments in the application of MM for environmental consensus building are described in van den Belt (2004). To provide further material the following section discusses the application of MM in a protected coastal wetland in Portugal (Ria Formosa).

The Ria Formosa experience

The use of MM to address sustainability issues was tested in a scoping exercise developed in the Ria Formosa coastal area, in Portugal (described in detail in van den Belt et al., 2000; Videira et al., 2004).

The Ria Formosa is a coastal wetland of 18 400 ha, with sandy barrier islands, located in the Algarve Region of Southern Portugal. This area is a haven for many bird species and an important humid area, classified as a Natural Park since 1987, considered in the Ramsar Convention and included in the Natura 2000 Network of European Protected Sites.

Spread along 55 km of low-lying coastline, the Ria Formosa Natural Park includes areas of five municipalities. The area is subject to strong pressures, which generate several environmental, social and economic conflicts, namely:

- extremely high pressure for urban and tourism development, including construction in the barrier islands;
- pressure on the ecosystems generated by recreational activities such as boating, golf courses, water sports, and walking on the dunes;
- overexploitation of fish and shellfish stocks by local fishermen;
- abandonment of traditional activities such as salt extraction;
- inadequate treatment of domestic and industrial wastewaters, which causes water quality problems, especially during the summer high season when pollutant loads increase significantly;
- overexploitation of groundwater, particularly during the summer, for human consumption, irrigation and tourism.

As in all Portuguese coastal areas, many different authorities—at the local, regional and national level—have jurisdiction in the Ria Formosa. This complex institutional setting generates an overlap of responsibilities and of regulations, with too many actors, many different roles, and sometimes conflicting objectives involved in the management process.

The procedure for stakeholder involvement in this process was initiated in a Coastal Zone Management Conference in Algarve (van den Belt et al., 1997), where the idea was presented and initial contacts were made. Following that, a referral procedure was initiated in which people were asked to suggest names of additional potential participants. This procedure was repeated until no further new names were suggested.

A total of 30 stakeholders were invited to join the process, from which 20 showed up in the first workshop (see Box 1). The whole process was followed by a group of 12 stakeholders, who participated in all workshops, where the main actors in the region, particularly at the technical level, were included.

The group of stakeholders gathered for three modelling workshops, each with a duration of 2 days, and a final workshop of 1 day (Fig. 1). During the workshops, the model being developed was projected on a screen. This allowed for a structured group discussion about the issues involved. Through this facilitated process of stakeholder discussions and group model building, a system dynamics model was built, using the STELLA Software (High Performance Systems Inc.) (van den Belt, et al., 2000; Videira et al., 2004).

During the first workshop, the participants discussed the problem to be studied, coming to agree upon the following formulation: "Development of a scoping model which aims at the balancing of the economic activities development with the conservation of the natural heritage of Ria Formosa".

In this case there was an initial agreement on the problem to be addressed and this statement was not contested in the remaining workshops. However, there can be situations, where the problem definition initially adopted is itself contested immediately or throughout the process. Also for this reason, the involvement of stakeholders in all stages of the model development process is an advantage, allowing one to adapt the problem definition to the knowledge generated during the process.

The resulting "scoping model" for the Ria Formosa includes four main sectors as defined by the stakeholder group: land use, natural system, socio-economic activities and management (Fig. 2).

Land use

The land-use sector describes the main types of land use occurring in Ria Formosa, including "terrestrial"

Box 1
Participants in the Ria Formosa scoping exercise.

- Nature Conservation
  - Ria Formosa Natural Park Authority
  - Institute for Nature Conservation
- Regional Authorities
  - Regional Directorate for the Environment
  - Algarve Regional Coordination Commission
  - Regional Directorate for Fisheries
- Local Authorities
  - Municipalities of Faro, Loulé, Olhão, Tavira and Vila Real de
  - Santo António
- NGOs
  - Environmental NGOs (Almargem, LPN)
  - Aquaculture and fisheries associations
  - Tourism promoters
- Industry
- Universities and Research Institutes
  - University of Algarve and New University of Lisbon
  - Fisheries Research Institute

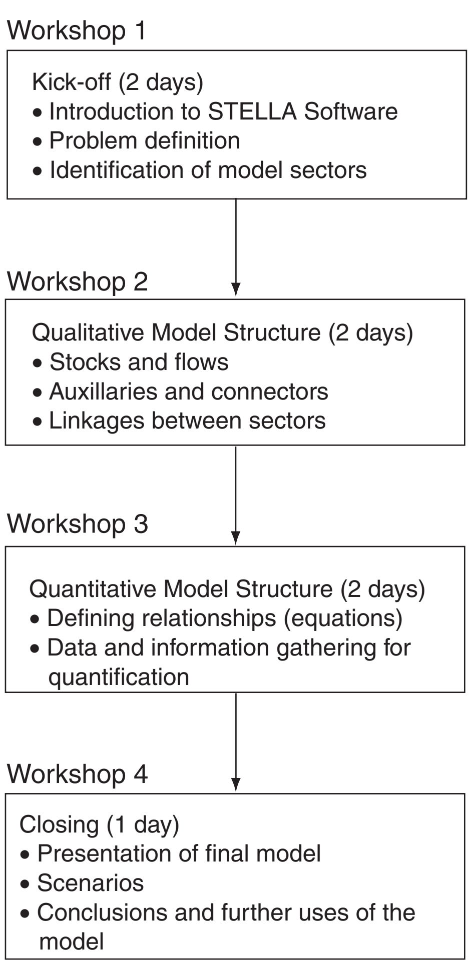

Fig. 1. MM process in the Ria Formosa case.

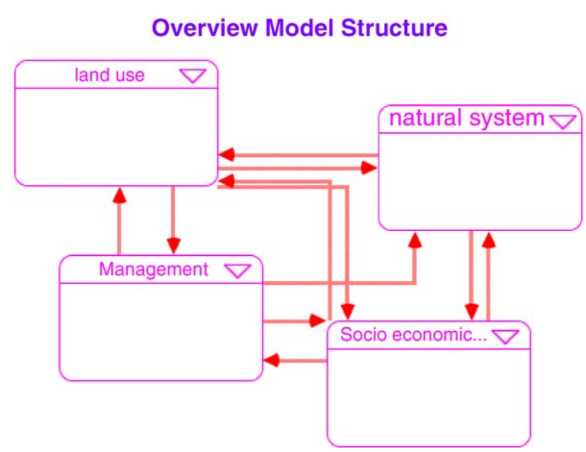

Fig. 2. Ria Formosa generic model structure.

(natural areas, urbanized areas, areas occupied by tourist resorts and barrier islands area) and "humid" areas (area cultivated with bivalves, area cultivated with fish, area with commercial salt marshes and the natural area). All areas in human use are subtracted from the natural area available.

This sector of the model also includes the major relations describing accessibility to the Ria Formosa area. Improved accessibility will increase the ease with which tourists and visitors can reach the area, increasing the economic revenue of the region. However, when too much investment is done in accessibility, the area may become congested and overshoots its optimum.

The land-use sector also includes a quality of life index and an attractiveness index. Population is a composite of residents and tourists in the area. This drives the amount of pollution, which affects the natural system.

Natural system

The natural system sector describes the water quality of the Ria Formosa (using wild bivalves as indicators), as well as the water flow and the sedimentation/erosion processes which occur. Natural processes and human activities on the barrier islands affect accretion/erosion processes, creating a need for dredging if the goal is to keep this dynamic system stable (from the human point of view).

Socio-economic activities

Several economic activities are modelled in this section of the model, including fishing, shellfish catching, fish and shellfish cultures, salt making and tourism. A "benchmark value" for ecosystem services (disturbance regulation, waste treatment, raw material source, habitat, food production and recreation) was also derived as an indicator, based on the "starting point" values for marshes proposed by Costanza et al. (1997), which was multiplied by the natural area remaining in the Ria Formosa.

Management

The management sector depicts the allocation of budget from public funds, European Union (EU) funds, government funds and local taxes. The funds can be spent on policy enforcement, policy making, technical projects and information. The funds that are made available in the management sector for different purposes are driving the other model sectors.

The model is described in more detail in van den Belt et al. (2000). It can also be downloaded from http://ecoman.dcea.fct.unl.pt/projects/riaformosa/.

During the final workshop, a set of scenarios was discussed in a plenary session with the stakeholder group. The scenarios included alternatives for funding sources and budget allocation, as well as policy decisions such as accessibility development, licensing of new activities, wastewater treatment, dredging and restoration of the barrier islands. The purpose was to conclude on the lessons learned from the process of building the model and from the model itself.

It should be stressed here that the resulting model was a "scoping model", meaning that a group of stakeholders interactively "scoped out" the linkages between ecology and the economy. Many of the values and relationships incorporated in the model are "estimates", "guesstimates" or assumptions to further the discussion in terms of "what if"- scenarios (van den Belt et al., 2000).

A group of about 12 participants remained involved during the whole process.

The MM process in Ria Formosa was accompanied by two sets of questionnaires, done before and after the series of workshops (for a more detailed description of the results of these questionnaires, see van den Belt et al., 2000).

The "before" questionnaire was intended to elicit a baseline perception of the group in order to compare with perceptions afterwards, and also served as a way to elicit the problems perceived by the stakeholders in order to construct a draft model for the first workshop.

The learning experience of the stakeholder group that was involved in the construction of the model, including the development of a shared understanding of the problems concerning the Ria Formosa region, was pointed out by the participants as the most important outcome of this process in the "after" questionnaires. Most of these participants stated that they had learned something and that the MM process had been well worth their time.

Overall, the participants indicated that they felt relatively confident with the qualitative structure of the model. The quantification of the relations was perceived as weaker, and the participants felt that more effort was needed in order to make firm conclusions based on the model.

In summary, despite the success of this process as a stakeholder involvement and consensus building exercise, there was a perception that the finally obtained model should be further developed in order to be useful for environmental decision making.

So far, MM has been applied mainly as a scoping and consensus building tool among a broad range of stakeholders. However, we argue that it can also be useful to collect and organize data, synthesize knowledge and communicate the key issues for decision making. MM is a promising tool to support the involvement of stakeholders in environmental decision-making processes.

Using MM improves the decision-making process in two ways: it places emphasis on collaboration in the group and provides a common neutral platform for communication: the simulation language (which does not correspond to language usually employed by any of the participants).

A framework for participatory decision making

A structured decision approach to public involvement should address the following fundamental tasks (adapted from Gregory, 2000; Hammond et al., 1999):

- framing the decision: defining the problem to make sure the "right" problem is addressed;
- defining key objectives and criteria: what values matter most to stakeholders;
- establishing alternatives and considering the relevant constraints: these alternatives should be seen more as portfolios of actions rather than individual options, since for most sustainability issues there is no such thing as a single "best action", but rather a "more desirable policy mix";
- identifying consequences: i.e. the most important impacts that can affect the stated objectives and associated uncertainties;
- evaluating the desirability of the consequences according to the proposed criteria;
- clarifying trade-offs: identifying important conflicts across the desired objectives to use this knowledge for decision making and to create new and better alternatives.

The adoption of a mixed approach—combining MM with MCA—contributes effectively to the development of these tasks. In this approach, the two methodologies can be linked, the MM exercise serving as an initial phase of the multi-criteria assessment process as depicted in Fig. 3.

The group model building process can be seen as a structuring exercise during which stakeholders develop new insights to help them frame the decision problem. The mapping of the key variables and relationships that forms the basis of the model building exercise, and the learning about the system's structure and behaviour gained throughout the whole process, can be very helpful for the identification of points of view (or criteria) and also for the formulation of alternatives.

The resulting system dynamics model, developed by the group of stakeholders, can then be useful to help them identify alternative scenarios and discuss their possible consequences on the whole system using a dynamic perspective in a participatory framework. This contribution of the system dynamics approach used in the MM exercise is a very important feature for decision making in sustainability issues.

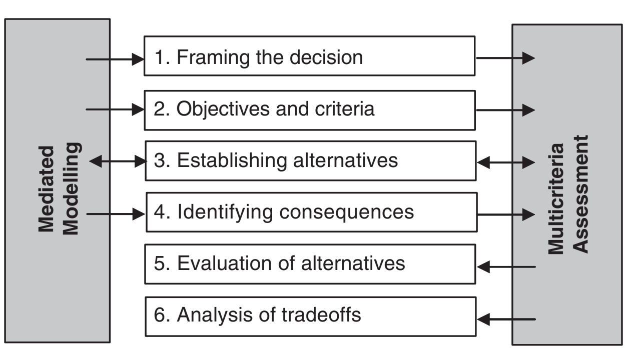

Fig. 3. The use of MM and MCA in a decision-making process.

A participatory MCA methodology can then be used to evaluate the different alternatives in relation to the adopted criteria and also to evaluate trade-offs among conflicting objectives and points of view. Both during the MM and the MCA processes new (and hopefully better) alternatives can be formulated, which will be considered in the whole process in an iterative way.

In summary, MM and MCA can be used in a participatory decision-making context adopting the following stages:

1. identification and invitation of stakeholders to join the process—here issues of representation should be carefully taken into account—institutional analysis and social research methods can play an important role at this stage;
2. formulation of the problem and development of a system dynamics model describing it by the group of stakeholders with the support of a facilitator in a series of modelling workshops (scoping model);
3. identification of the relevant evaluation criteria by the stakeholders. Integration of the criteria in the adopted model structure (this stage runs in parallel with stage 2);
4. refinement of the model by the facilitator/modeller adding relevant data and conducting consistency and validation tests/procedures;
5. collaboration of the stakeholders in workshops aimed at the identification of scenarios, i.e. images of how the future might unfold, and the development of the corresponding storylines;
6. simulation of the model in a participatory setting to obtain possible trajectories of evolution of the relevant evaluation criteria for each of the different scenarios selected in the scenario building workshops;
7. discussion and analysis among the stakeholders of the outcomes obtained and of the resulting trade-offs among objectives for the different alternative courses of action (supported by MCA methodology).

This way mediated modelling and multi-criteria evaluation are embedded in each other allowing the MCA process to benefit from the problem structuring and participative characteristics of the MM exercise, which, in turn, gains a new operationality and usefulness for decision making with the analytical capabilities of MCA methodologies.

This approach therefore combines the advantages of deliberative procedures, while providing a framework to apply a formal appraisal technique. Moreover, it allows for the consideration of issues such as multiple dimensions, uncertainty, time and space, which are essential in most sustainability decisions.

Conclusions

In this paper, we presented the potential of MM as a tool to support the implementation of participative multi-criteria decision-making methodologies. MM is particularly useful to study ill-structured problems, for which there are several different views, exhibiting a dynamic behaviour and multiple feedbacks.

Although, so far, MM has been used mainly as a tool for participation in scoping and consensus building exercises, we argued that it can be successfully applied in a broader decision-making context.

The use of MM does not preclude the use of a formal assessment method for decision making in sustainability issues. Rather, we think that it can be used as a tool to support problem structuring with the contributions of the different stakeholders and to provide basic insights about how the future might unfold in the face of a given set of assumptions and policy decisions.

The use of a combined approach, as was suggested in this paper, can have synergetic effects, improving the potential of both tools to contribute to more sustainable decision-making processes.

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