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From prediction to learning: the implications of changing the purpose of the modelling activity

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Abstract

During the last decades, there has been a growing interest in the use of models for natural resource management. While early models were theoretical representations of simple systems designed to predict, in time or space, the behaviour of a system, current modelling applications expand beyond prediction. Models, and particularly the whole model building process, have become useful tools to support dialogue, learning and negotiation processes in stakeholders groups. For example, models are currently being used to improve collaboration between expert and stakeholder groups, to facilitate the negotiation between conflicting parties, or as a tool for group reflection, just to mention few of a wide-ranging list of applications. Such a broadened scope in the use of models not only has implications for how models are applied, but also for how the modelling activity is addressed and the type of conclusions that can be drawn from a modelling exercise. It is well known that, the information requirements, the degree of involvement of stakeholders and the type of model evaluation performed, mostly depend on the reason for which a model is developed, despite the modeller's preferences for a particular modelling approach. This paper examines how participatory modelling building affects the modelling practice, specifically focusing on the implications to cope with model uncertainty. A set of strategies to guide the development of participatory models is presented.

Keywords: learning, prediction, participatory modelling, modelling process, uncertainty

1. Introduction

During the last decades, there has been a growing interest in the use of models for natural resource management. This, in combination with computation advancements, have led to a diversification in modelling approaches and applications. Particular attention has been given to participatory modelling, which combine modelling techniques with stakeholder participation. Participatory modelling offers the possibility to integrate local and scientific sources of knowledge, facilitating collaboration among stakeholder groups and promoting the co-generation of solutions. In this way, models, and particularly the whole model building process, can be used to support dialogue, learning and negotiations in collective decision making processes. This trend in the use of participatory modelling has been reinforced by new policies, like the Water Framework Directive in Europe, that claim that stakeholder integration should be considered as an essential prerequisite to management.

Such a broadened scope in the use of models not only has implications for how models are applied, but also for how the modelling activity is addressed and the type of conclusions that can be drawn from a modelling exercise. It is well known that, the information requirements, the degree of involvement of stakeholders and the type of model evaluation performed, mostly depend on the reason for which a model is developed, despite the modeller's preferences for a particular modelling approach. For example, Brugnach and Pahl-Wostl [2007] identified four major modelling purposes that are important for understanding and managing natural resources: prediction, exploratory analysis, communication and learning, where *learning* was identified as the main purpose of a participatory modelling activity. While each of these modelling purposes highlights

different model properties and ways of handling the modelling activity, *learning* implies an extreme shift in the role of the model and the role of those who guide the process of model building. Building on these ideas, here I examine the participatory modelling building practice. I pay particular attention to the role of uncertainty in this process and provide a set of strategic options to guide the development of participatory models.

2. Prediction and Learning: Two Distinctive Modelling Purposes

Following Brugnach and Pahl-Wostl [2007], *Prediction* refers to the use of a model to forecast the behavior of a system over time and/or space. When modeling natural systems, prediction is not necessarily focused on the temporal or spatial trajectory of a single variable, but also on the understanding of overall system properties. For example, the effect of increasing diversity on the adaptive capacity of a system (e.g., Levin, 1998). Hence, the results of predictive models can generate general insights and support the development of guidelines for integrated system design.

Differently, the purpose of *learning* refers to the use of a model, and the whole model building process, as a tool that supports the process of social learning and reflection in a group of stakeholders. In this case, both the model building process and the resulting model, are used as a discussion support tool, creating an opportunity to exchange ideas and knowledge among participants, and when possible the creation of a shared construction of reality. This is carried on using participatory approaches to uncover the mental models and frames of the participants (Hare and Pahl-Wostl, 2002).

3. How Does a Model Built for *Prediction* Differ from One Built for *Learning*?

A model –conceptual or implemented in a computer- constitutes an abstraction of a system existing in reality that is built for a particular purpose. When built for prediction, a model reflects the objective understanding of the modeller, or scientists, about the system being modelled. Generally built based on scientific facts, a predictive model tries to capture as close as possible the characteristics of the real system, so it can be used as a surrogate of it. Differently, when built for a learning purpose, as it happens in a participatory modelling exercise, a model reflects the interpretations that the participants have about the reality been modelled. In this case, during the process of model development, the participants (e.g. stakeholders) bring their experiences and know-how and, together with the modeller, integrate this information into the model.

As a large amount of scholarly research has already shown, the interpretation of reality is influenced by many factors (e.g. biases, heuristics, expectation, attitudes), which can in a participatory modelling exercise far outweigh the contribution of scientific understandings. For example, it is well known that our information processing capacities are limited and our perception is selective (e.g. confirmation bias). This means that in a participatory modelling exercise, the interpretation of reality goes beyond scientific evidence, and is partly constructed by the expectations, previous information, experience, values and beliefs of those who participate. As such, a participatory model becomes situation specific, drawing upon details related to particular places and local realities.

Table 1. *Main differences between a model developed for prediction and for learning purposes.*

	Prediction	Learning
What is a model?	A objective description of a real system	A reflection of the view points that different stakeholders have on a real problem
Goals of the model	To closely mimic the behaviour a real system	To exchange ideas and knowledge in a group
Focus of the model	Model results	Modelling processes
Role of the modeller	External observer	Facilitator/Mediator
Knowledge used	Factual knowledge	Factual knowledge + Value based knowledge

4. Modelling Activities

The development of a model can be summarized in three main activities: *conceptualization*, *implementation* and *evaluation*. Conceptualization is the process through which the modeler generates a description of a real system, based on scientific evidence when it refers to a predictive model. In the case of the complex set of interactions and processes that characterize most natural resource systems, conceptualization consists of identifying the specific component subsystems needed to describe the system adequately, formulating a model for each subsystem, and defining the interactions among these subsystems. To this end, the modeller uses scientific information, such as theories, field measurements, observed data which can serve to capture the essential characteristics of the system that is being modelled.

In a model built for learning, *conceptualization* is carried on differently than in a model built for prediction, since the model has to capture the different views on reality of those that participate in the modelling exercise. To this end, stakeholders take active part in the conceptualization activity, providing knowledge that reflects their interpretation of the situation being modelled, based on their experience, expectations, disciplinary background, values and beliefs (Van den Belt, 2004). In addition, the modeller adopts the role of facilitators participating in a process of co-production of knowledge, rather than being "external observers" who reveal an objective reality (Vennix, 1996; Checkland, 1999; Sterman, 2000; Pahl-Wostl, 2007).

There can be different levels at which stakeholders participate, ranging from individual contributions to a team modelling building effort (Van den Belt, 2004). In the later case the stakeholders have complete control over the modelling process and they are the ones that determine the type of content to include in the model. However, achieving a satisfying level of participation, both in terms of number and involvement of participants is not obvious. A participatory modeling exercise in its own is not a guarantee for equal participation, since there are many factors that determine who gets to participate and how. Power differentials among participants, cultural barriers and differences in resources and skills can hamper the participation of some individuals, filtering the knowledge content including into a model. It is the the responsibility of the modeller to mediate these problems, determining the level of participation that can be achieved in each particular situation.

Further on, *implementation* is the construction process that transforms the conceptual model into the actual physical model, for example the computer program. This involves writing the computer code and algorithms that render the conceptual model into an executable computer representation. This activity will vary greatly depending on the type of model built, being very different when a model is implemented through, for example, a card game,

than when it is a system dynamic representation of a river system. The final step, *evaluation*, tests the behavior of the simulation model for adequacy and quality. Evaluation comprises mainly of the activities of validation and uncertainty analyses, and is of fundamental importance in both the development of a predictive or learning purpose model. I address them in more detail below.

While these activities can be carried on in sequence, many natural resource problems require an iterative process of model formulation; a trial and error approach, where modules at different levels of detail are considered in conjunction with different assumptions and hypotheses; a series of cycles of conceptualization, implementation, re-conceptualization, code modification, implementation, etc. This iteration typically occurs over the course of time as new information and ideas are generated and subsequently used to modify existing code. In a participatory model built for learning, these iterations can parallel the development of knowledge construction and shared understanding that are underlying participatory processes.

5. Model Evaluation: Validity and Uncertainty

When a model is developed for prediction, it should be in close match with the system to be modelled, since it is expected to generate behaviour that is similar to the real system. The validity of a predictive model is determined by the agreement between observed and modelled system behaviour. To this end, any uncertainties that can prevent this goal should be identified and eventually eliminated, reduced or explicitly considered in the model outputs. In models used for prediction, uncertainties in data stemming from measurement errors and the possibility of having different model structure are of key importance. There are several methodologies that can be applied to quantify uncertainty, determining which are the most important factors affecting model results and which the uncertainty associated with model outcome (see Refsgaard et al. 2007 for a review, Saltelli et al. 2000). This information is important to decide what type of action, if any, needs to be taken (e.g. collect more data, test different model structures, etc.) as well as to communicate the effects of uncertainty in predictions and derive the boundaries within which model results are valid.

Differently, when developing a model for learning purposes, the focus is not on model results but on the modelling process and the validity of the exercise is given by assessments by stakeholders, who determine whether or not their view points are well reflected in a model (see Table 2). Thus modelling becomes the activity that is used to bring together different view points and opinions about a problem that different actors may hold, engaging individuals in a dialogue with the aim of developing a solution. During this process the simultaneous presence of multiple and sensible ways of framing a problem is unavoidable, resulting in ambiguities: it is not clear what the problem, or its solution, is about. Ambiguity has been identified as one of the main causes of uncertainties in collective decision making processes (Brugnach et al. 2008), playing a key role in marking the differences, commonalities and points of conflict among the participants of a modelling exercise. For this reason, in addition to the uncertainty associated with factual knowledge (data, parameters, theories), participatory modelling requires the ability to resolve the ambiguities that result from the different, and sometimes contradicting, views on a problem participants may have. In the next section, I outline some strategies for doing so.

Table 2. *Differences between validity and uncertainty in models developed for prediction and for learning purposes.*

	Prediction	Learning
Validity	The validity of the model is determined by the agreement between observed and modelled system behaviour	The validity of the exercise is given by assessments by stakeholders who determine whether or not their view points are well reflected in a model

Uncertainty	It indicates the limits of knowledge. It needs to be quantified or eliminated as much as possible.	Uncertainty indicates the differences, commonalities and points of conflicts among participants.

6. Strategies to Cope with Ambiguity

A participatory modelling exercise can facilitate handling ambiguities by making explicit the different mental models held by the participants, and ultimately, by including knowledge generated in a participatory setting that reflects a common understanding on a problem. However, doing so implies the capacity of the participants, as well as the modeller leading the exercise, of knowing how to deal with differences. This does not necessarily imply reaching consensus in a group, but being able to create a shared definition of the problem, from which a solution can be derived. In practice, this goal can be achieved in different ways. For example, on occasions a solution can be negotiated through mutual activities, while at other times actors can focus on changing the way in which they frame a problem. Bouwen et al. [2006] have identified four basic deliberative approaches to deal with ambiguity:

6.1 *Persuasive communication*: consists of trying to convince others of their own frame of reference, not by imposing it, but by presenting it as attractive and worthwhile (see e.g., Bouwen and Fry, 1991).

6.2 *Dialogical learning*: aims at understanding each other's frames better through open dialogue and encourages learning on all sides (see e.g., Argyris and Schön, 1978).

6.3 *Negotiation:* aims at reaching a mutually beneficial and integrative agreement that makes sense from multiple perspectives or frames (see e.g., Leeuwis, 2000). The negotiation can have a dominantly 'integrating' quality when actors develop synergetic win-win outcomes. Less integrative are negotiations that are 'distributive' where the actors take a win-loose position and distribute profits and gains in an antagonistic way.

6.4 *Oppositional modes of action:* cold conflict means that distancing and avoiding each other is a dominant mode of operating (see e.g., Gray, 2003). Hot conflict refers to heated opposition and adversarial actions. Parties try by force to impose their frame of reference upon the others.

In a participatory modelling exercise conflictive values and perceptions can transform the modeling process into a controversial and futile activity. The strategies presented above, even though are not exhaustive, provide the modeller with a broad set of possibilities to cope with different situations in which ambiguities can arise. In doing so, the process of model building can be seen as an opportunity for exchange and learning, where differences and commonalities can be worked out.

7. Conclusions and Recommendations

In this paper I have examined the differences between predictive models and models that are built for learning purposes, paying particular attention at the management of model uncertainty. Here, I claim that uncertainties cannot be understood in isolation, but only in the context of a particular modelling activity and their importance is relative to the purpose a model is designed for. For example, in a predictive model, uncertainty needs to be eliminated or reduced as much as possible; while, in a model developed for learning purposes, uncertainties can be useful to indicate the differences and points of conflict among participants. This means that handling uncertainties can imply engaging in very distinct and diverse activities depending on the model purpose. While a lot has been said in the literature about how to handle uncertainties in predictive models, not much has been said about how to manage uncertainties in models developed for learning purposes. Here, I

have explored various strategies based on learning and negotiation that can be applied to cope with ambiguities in participatory modelling. Failing to make the distinction between modelling purpose and uncertainty management can lead to a downplay of uncertainty, or to invalidate model results.

8. Acknowledgements

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