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Participatory land use modelling, pathways to an integrated approach

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ABSTRACT

The increasing adoption of land use models in planning and policy development highlights the need for an integrated approach that combines analytical modelling techniques with discursive 'soft-science' methodologies. Recent scientific contributions to the discipline have tended to focus on analytical problems such as statistical assessment of model goodness of fit through map comparison techniques, while the problem of integrating stakeholder information into land use models has received little attention. Using the example of a land use model developed for the Guadiamar basin in South West Spain, location of the emblematic Doñana natural area, an integrated methodology for participatory calibration and evaluation of model results is presented which combines information from key stakeholders across a range of sectors with analytical model calibration techniques. Both discursive and analytical techniques are presented side by side to demonstrate that including participatory approaches is likely to improve both calibration results and model applicability. Integration of participatory methods into land use models is more likely to be successful if stakeholders are selected carefully so as to make best possible use of their time and knowledge, and are involved in the modelling process from the beginning of the project cycle.

1. Introduction

1.1. Research background

Over the past decades the adoption of land use models in planning and policy making has increased dramatically (Seaton, 2001; Oxley et al., 2004; Encinas et al., 2006; Engelen et al., 2007). This has required the deployment of methods that cross disciplines and research communities, linking "soft" (humanistic, discursive) and "hard" (analytical, natural) science approaches. Soft-science approaches try to take into account the inherent unpredictability of human behaviour and the capacity of human agents to change the system from within. Hard-science approaches assume the collection of beliefs and perceptions which make up our view of the world to be static for the purpose of investigating a particular theory or problem (Winder, 2004). Soft-science methods are useful in cases where human behaviour or interaction is important (e.g. land use policy), and may often involve participatory or social enquiry techniques which provide qualitative or approximate information (Lemon et al., 1994). Hard-science approaches are relevant to the study of natural phenomena (e.g. degradation of a natural resource), and involve mathematical and quantitative methods which provide precise, numerical data. In cases of human–environment interaction, as in a land use change model, both kinds of information are necessary and integrative approaches that combine hard and soft-science methodologies are therefore important.

As land use models have become more widely used, spatial modelling frameworks such as Metronamica (RIKS, 2011; Van Delden and Hurkens, 2011) and CLUE (Veldkamp and Fresco, 1996; Verburg et al., 2008) have been developed, obviating the need to design a new system every time. Apart from the clear advantage of time-saving, the principal benefit of applying existing modelling frameworks to new regions rather than developing models from scratch for each new research project is that the model concepts and mechanisms tend to become better tested over time.

Thus, the emphasis has come to rest on calibration, that is, the adaptation of these existing frameworks to a particular case study

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region and data, rather than on the development of new model suites. As policy support-oriented models making use of existing architecture have proliferated, so too has literature on calibration methods and techniques; the evaluation of the results of land use simulations through various kinds of spatial metrics has practically become a sub-discipline in itself (e.g. Hagen-Zanker, 2003; Pontius and Malanson, 2005; White, 2006), map comparison techniques such as cluster analysis, rank size metrics, and the kappa statistic have been developed from existing approaches in statistics, geography and remote sensing. However, the recent literature tends to be over-balanced towards 'hard-science' approaches to calibration with little or no consideration given to the role of stakeholders as genuine contributors of knowledge that helps to define model parameters. In general, land use models do not incorporate stakeholder information at the model development phase, but rather later, for scenario development (e.g. Hernández Jiménez and Winder 2006; Volkery et al., 2008; Van Delden and Hagen-Zanker, 2009; Kok and Van Delden, 2009) or evaluation of model results (e.g. Millington et al., 2011).

1.2. Aims of the research

The research takes place in the context of a wider project in which a land use model is applied in support of finding appropriate pathways to mitigate the problem of land use change in the vicinity of a natural protected area in Spain. This research focuses on the application and calibration of the land use model which will afterwards be used to simulate the potential impact of different change processes and land planning interventions through scenarios in the wider project (for a discussion of scenario development for the Doñana natural area see Palomo et al., 2011).

In developing a model for policy support the needs of both the stakeholders and the land use modelling community need to be addressed. A poorly calibrated model is likely to be less useful for discussion support purposes, since it is less easy to convince stakeholders of its intrinsic value (e.g. by showing that the model is able to simulate land use change at approximately the right locations given the appropriate rules). At the same time, calibration results need to be expressed in the language of the existing non-participatory land use modelling community (e.g. through statistical map comparison techniques) if peers are to be convinced that the approach offers advantages. The intention of this article is therefore to propose a methodology for applying and calibrating land use models in which analytical and discursive modelling steps are applied in parallel, and show that the approach presented can both improve model calibration in quantifiable terms, and contribute productively to understanding of land change dynamics in natural areas by bringing together stakeholders from different communities (scientists, conservationists, local authorities, natural park managers, farmers) and combining different disciplinary perspectives (soft and hard science).

In order to achieve this aim three sub-objectives have been defined:

1. To engage key local stakeholders in a process of reflection and discussion about land use change in Doñana and its hydrological catchment (the Guadiamar basin), in order to build and calibrate a model of land use change in which the stakeholder community identified is explicitly involved at all stages of the development process.
2. To review existing methods for applying and calibrating land use models and participatory approaches, combining these to develop a methodology that incorporates both hard and soft science elements; and to test this methodology.
3. To demonstrate that the approach described offers important advantages over traditional non-participatory land use modelling application and calibration approaches (e.g. Van Vliet et al., 2013a; Wickramasuriya et al., 2009) for use in planning policy context.

The first of these three research aims is addressed in detail in Section 3 of this paper (results), and provides the necessary foundation for achieving aims 2 and 3, as discussed in detail in Section 4 of the paper (discussion and lessons learnt).

1.3. Calibration

Rykiel (1996) defines calibration as "the estimation and adjustment of the model parameters and constraints to improve the agreement between model output and a data set".

To calibrate a land use model, a range of types of knowledge from different sources must be brought together. Unless the model is very simple, it seems unrealistic to expect a single actor or group of actors from a single domain (usually the scientist/s or researcher/s), no matter how knowledgeable, to have a complete understanding of all of these at the outset. Nonetheless, the possession of such knowledge on the part of the researcher is often tacitly assumed, leading to the misconception that discursive knowledge-sharing processes are superfluous or "value-added". A broader definition of calibration than that given above can therefore be proposed, incorporating knowledge from both hard and soft-science domains (Fig. 1).

The key, therefore, to adequate calibration of the model is likely to reside in finding the balance between knowledge domains, not only statistical goodness of fit to available data (analytical domain), but also acceptance among the relevant stakeholder community that the model incorporates the appropriate parameters for its intended use within the area of study considered (discursive domain). For this reason we have integrated participatory information with analytical–technical activities as closely as possible.

1.4. Cellular automata models of land use change

The model employed in this research is a Cellular Automata (CA) based land use model. CA models integrate mathematical theories of self-reproduction in automata (von Neumann and Birks, 1966) and stochasticity (Ulam, 1950) with the 2 dimensional cellular-grid or raster cartographic space familiar to present-day users of Geographical Information Systems (GIS). The concept of a dynamic geographical cellular automata was proposed by Tobler (1979) and developed during the 1990's by researchers interested in modelling urban growth and change (e.g. White and Engelen, 1993; Batty and Xie, 1994; Clarke et al., 1997; Phipps and Langlois, 1997).

Though land use change can in theory be attributed to particular agents, they are not normally directly represented in CA land use models, unlike in Agent Based Models (ABMs) or Multi-agent

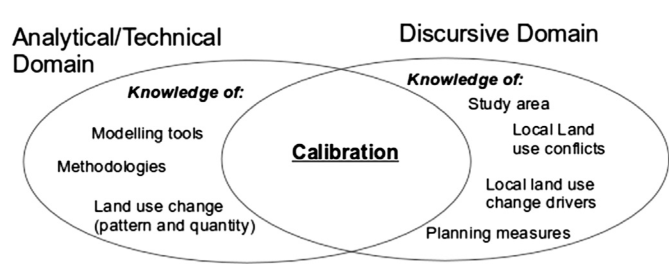

Fig. 1. Calibration of a land use model through knowledge sharing across domains.