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# Common Concepts to Development of the Top-Down Models of Land Changes

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**Abstract.** Land change models describe the complexity of the biophysical and socioeconomic process. This work presents the common concepts and proposes an early meta-model to top-down models developed in TerraME modelling environment. The major motivation of this extension is to help model replication, code sharing, and developing theoretical foundations. However, the complexity of this process is a great challenge to development of a common meta-model. Therefore, we believe that is possible the development of meta-models to specific cases.

**Key words:** Land change, modeling, gis, TerraME, TerraLib

## 1. Introduction

Land changes are results from complex social and biophysical systems and their interactions (Turner et al., 1995). Nowadays, processes related to these changes have become a major topic in several works (Castella and Verburg, 2007), (Aguiar et al., 2007), (Almeida et al., 2003), (Verburg et al., 2008) and (Nepstad et al., 2001). Interest in land changes is due mainly to the important implications for future changes in the Earth's climate and, in return, great implications for the resulting land change (Agarwal, 2002). Land change models are a common tool for the analysis of the causes and effects of land changes and to support land use planning and policy (Verburg et al., 2004).

There are a great variety of land change models in the literature, with different objectives, techniques, theoretical basis and modelling traditions. Briassoulis(2000) presents an extensive review of land use theories and modelling approaches. However, it is possible to distinguish two major approaches to land change models: *top-down* and *bottom-up*. *Top-down* models have influences from landscape ecology; they are pattern-oriented and based on remote sensing and census data. In this approach, it is possible to distinguish three major submodels: a demand change submodel, a transition potential submodel, and a change allocation submodel. On the other hand, *Bottom-up* models describe explicitly the actors of land changes as heterogeneous and variable actors in time and space. This approach uses agent-based modelling theory, which consists of autonomous entities (agents), of an environment where the agents interact and of rules that define the relations between agents and their environment (Parker et al., 2002).

Recently, researchers in land change models have argued about the advantages of *bottom-up* models for land change studies, but many studies still use the *top-down* models. The *top-down* models present common concepts and some are parameterized, which makes these models easier to apply than *bottom-up* models. In our work we propose an early *meta-model* to top-down models developed in TerraME modelling environment. The major motivations of this *meta-model* are facilitate model replication, code sharing, and development of theoretical foundations. This work is organized as follows. Section 2 presents major concepts of top-down models. The section 3 presents our early extension. The section 4 presents our final remarks.

## 2. Top-down Modelling

Top-down models consider in general land-uses/covers as a set of discrete states. Land changes are transitions from one state to another (Walker, 2004). Raster or cellular space, subdivided in pixels or cells represent each discrete state. This approach uses an empirical, mathematical, statistical or econometric equation to describe the transitions among states. There are different models in the literature: CLUE (Veldkamp and Fresco, 1996; Verburg et al., 1999), CLUE-s (Verburg et al., 2002), Dinamica (Soares-Filho et al., 2002), RIKS (White and Engelen, 1997, , 2000), CA_Markov (Eastman, 2003). The structures of these models present some similarity, as discussed in (Eastman et al., 2005) or (Verburg et al., 2006). Eastman (2005) argues that models generally consist of three major parts: a demand change submodel, a transition potential submodel, and a change allocation submodel, as shown in Figure 1. In the next sections we present each one of theses submodels.

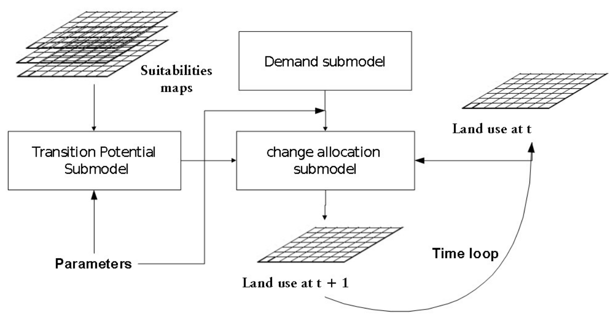


**Figure 1. Basic structures of top-down models.**

The *demand submodel* calculates the rate and magnitude of change, usually based on economic model, trend analysis, or scenario analysis to quantify the change (or demand). This demand is then allocated in a spatially explicit grid by the *change allocation*. This submodel uses suitability (or change transition potential) maps representing the suitability/or potential for change of each cell for a given land use/or transition. This map is produced by the *transition potential submodel*, given a set of input driving factors and a method to relate these maps as a multivariate statistical relation. Then, the change allocation produces a new land use map that can be use to next model iteration.

## 3. A TerraME extension to land change model

The land change models are complex and need an effort of several disciplines, such as geography, sociology and computer science. Some authors propose meta-model or data flow to support and help model replication, to share code, and to develop theoretical foundations, for example. (Parker et al., 2006) and (Soares et al., 2008). Parker proposed a conceptual design pattern specific to agent based modelling for land change. With similar motivation, in this work we propose a *meta-model* to *top-down* models developed in TerraME modelling environment (Carneiro, 2006). This extension must consider some common concepts of the *top-down* approach presented in the Section 2. TerraME is a development environment for spatially explicit dynamical modelling. It can deal with heterogeneous applications and processes, and allows multiscale and model integration. Thus, to be able to handle multiple scales in a flexible way, a land change model must be organized into distinct and independent dimensions (Carneiro, 2006).

- *Spatial dimension:* describes the different extents and resolutions of the spatial scales used in the model.
- *Temporal dimension:* describes period and frequency of execution of processes and agents in each temporal scale.
- *Behavioural dimension:* includes the variables and rules that describe the behaviour of agents and processes that include the *top-down* and *bottom-up* approaches.

TerraME proposes a set of components to each one of these dimensions. For example, a *Cellular Space* that represents the spatial dimension and a *Scheduler* that controls the flow of execution of the model represents the temporal dimension. However, TerraME was developed to support a great variety of spatial dynamic models. Thus, in the *Behavioural dimension* only two general components were proposed: *Automaton* and *Agent.* Another relevant issue is that TerraME uses the *Environment* concept to encapsulate the behaviour, spatial and temporal submodels, but it does not describe the link among these concepts, which is done by the model developers.

The structure of the TerraME modelling environment includes some advantages. TerraME use LUA (Ierusalimschy et al., 1996) (an extensible programming language) as the modelling language. TerraME uses TerraLib (Câmara et al., 2000) (library for geographic applications) to support spatial database management. Considering these characteristics we propose an extension to TerraME in LUA programming language, as shown in Figure 2.

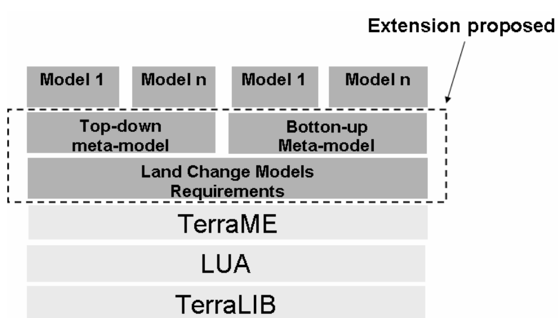


**Figure 2. Extension proposed to TerraME.**

This structure enables the use of several resources of each layer (TerraLib, LUA and TerraME) in the development of land change models. The main goal of this extension is to provide a *basic template* or *meta-model* and some common functions specific to land change models, as shown in Figure 3.

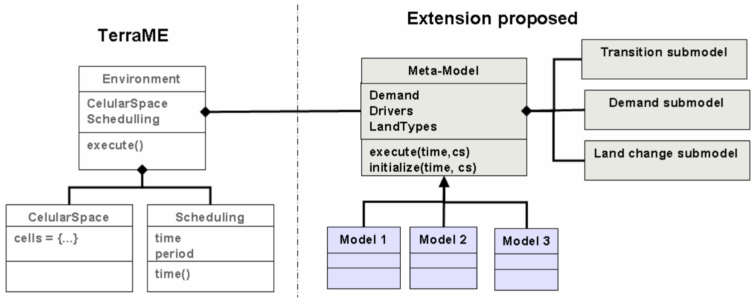


**Figure 3. The main components of the extension.**

Figure 3 presents the main proposed component, *template* or *meta-model* that supports the development of new land change models. This *meta-model* is supported by the one presented in Section 2 and the TerraME *Environment* links the spatial and temporal dimensions to land change model. Some models (in preparation or submitted) have been implemented using these early concepts (Moreira et al., 2008), but a better definition and adjustments are necessary so that it can be applied in more cases.

## 4. Final remarks

Many works propose the use of the models as tools to study land change process. In this work, we present some common concepts of land change models and an initial extension is presented. The definition of these concepts is challenging, but we believe that the development of the *meta-model* to some specific models is feasible.

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