Methodology to couple multi-scale LUCC models

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Abstract. *This work presents a methodology to couple multi-scale LUCC models using the TerraME modeling framework. The approach is illustrated in this article by a two-scale deforestation model in the Brazilian Amazonia, based on a modified version of the CLUE framework. These two scales could in turn be linked to more scales, using other types of models, as appropriated in different contexts. Results show the potential of our approach in LUCC applications in which intra-regional, bottom-up and top-down interactions need to be understood.*

1 Introduction

LUCC (Land Use and Cover Change) computational models, especially if done in a spatially-explicit, integrated and multi-scale manner, are an useful technique for the projection of alternative pathways into the future, and for conducting experiments to test our understanding of key processes in land use changes [Veldkamp and Lambin 2001]. Although some multi-scale modeling approaches have been developed, specially the CLUE (Conversion of Land Use and its Effects) modeling framework [Veldkamp and Fresco 1996; Verburg, Koning, Kok et al. 1999], there is still the need of a generic framework in which diverse modeling approaches can be chosen and combined according to the need of each scale, and dynamic linked into a multi-scale and multi-locality model composition, as appropriated to different contexts.

This work presents a methodology for dynamic coupling LUCC models at several scales (from macro to micro studies) using the TerraME (Terra Modeling Environment) framework [Moreira, Costa, Aguiar et al. 2007]. TerraME is a development environment for spatial dynamical modeling that provides a high level modeling language, a set of spatiotemporal data structures for model representation and simulation, direct access to geographic database management system, and provides support for multi-scale modeling, thorough the concept of Scale [Carneiro 2006].

This paper is organized as follows. Section 2 presents our methodology. In Section 3 presents results and Section 4 presents the final comments.

2 Methodology

The methodology we propose enables any independently developed model, defined to run in a particular Scale, to be coupled to higher our lower hierarchical level Scales, as Figure 1 illustrates.

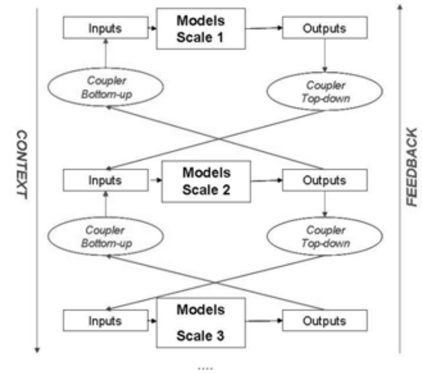

Figure 1. Model coupling.

The coupling between scales based on the definition of two *Model Couplers*: *Spatial Coupler*: defines the relationship between cells in different Cellular Spaces, for down-scaling and up-scaling, as illustrated in Figure 2. The *Analytical Coupler*: defines how to couple the analytical dimensions of different models at different Scales, i.e., how the output of a given Scale (in a certain time step) is used as input to another. In the coupling process, each Scale is independently specified in its spatial, temporal and analytical dimensions.

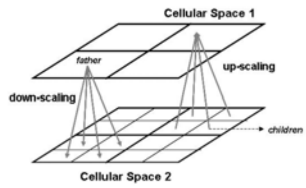

Figure 2. Relationship between cells in different Cellular Spaces.

The proof of concept of our approach is the re-implementation the multi-scale CLUE framework. The original CLUE model includes two spatially explicit scales rigidly coupled through the code implementation. The CLUE allocation model was adapted from the original to allow single scale application. The coupling is performed at run time by the Analytical Couplers (see, Figure 3). The down-scaling *Analytical Coupler* corresponds to the computation of a matrix of relative change calculated using the result of the coarse resolution. This relative change influences the suitability to change of each cell. In a single scale application, this suitability to change is influenced only by the determinant factors, and by the demand push. In a multi-scale application, it is also influenced by relative change factor. The bottom-up *Analytical Coupler* corresponds to an (optional) aggregation from the land use patterns resulting from the finer resolution to the coarser one. Results may be compared using or not this feedback mechanism.

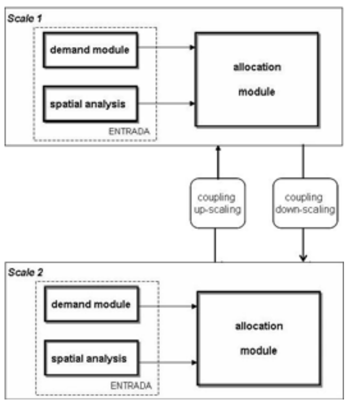

Figure 3. CLUE dynamic coupling in TerraME.

3 Model results

The results of applying the new version of the CLUE model with two Scales dynamically coupled: the whole Amazônia, in a resolution of 100 x 100 km^2 and 25 x 25 km^2 (Figure 4. Simulation results for coupling two scales.). The spatial determinant factors and regression coefficients are based on Aguiar [2006].

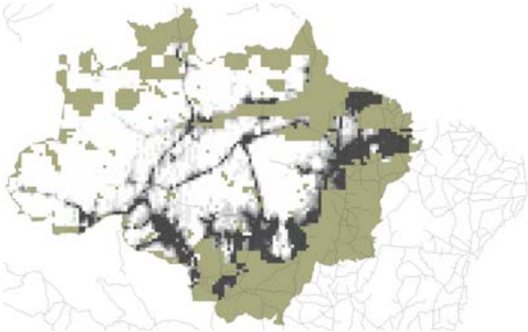

Figure 4. Simulation results for coupling two scales.

4 Conclusions and future work

This paper presented a methodology for dynamically linking multi-scale models in TerraME environment through the definition of *Analytical and Spatial Couplers*. We tested our methodology in a real application, using a modified version of the CLUE framework for the Amazonia. Using this methodology, previously developed models can be combined in a multitude of ways, according to the need of different applications and case studies. In future works, we will explore the use of heterogeneous modeling approaches in different scales, such as agent based and cellular automata models.

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