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Dynamic modelling of future land use change under urbanization and climate change pressures: application to a case study in central Belgium

I. Jacquemin (1), C. M. Fontaine (2), N. Dendoncker (2), L. François (1), R. De Vreese (3), A. Marek (4), D. Mortelmans (3), A. Van Herzele (3,5), and G. Devillet (4)

(1) UMCCB, University of Liège, (ULg), Belgium (ingrid.jacquemin@ulg.ac.be), (2) Department of Geography and Namur Center for Complex Systems (naXys), University of Namur (FUNDP), Belgium, (3) Human Ecology Department, Vrije Universiteit Brussel (VUB), Belgium, (4) SEGEFA, University of Liège (ULg), Belgium, (5) Research Institute for Nature and Forest (INBO), Belgium

Projecting the future of the evolution of socio-ecological systems to analyse their sustainability under climate or other environmental changes is not straightforward. Current projections usually use process-oriented models describing the complex interactions within the physical/biological systems (ecosystems), while the socio-economic constraints are represented with the help of scenarios. However, the actual evolution can be expected to be much more complex, because of the mutual interactions between ecological and socio-economic systems. To represent these interactions, models must integrate the complex process of human decision at individual or society levels. Moreover, models must be spatially explicit, defining elementary spatial units on which can act both the physical factors and the human decision process. These spatial units (e.g., farm fields) must be described not only in terms of energy, water, carbon and nutrient flows, but also in terms of the flow of ecosystem goods and services (EGS) they provide to the society together with the management costs required to sustain them. The provision of EGS may be altered in the future in response to changes in the climate system and the environment, but also through various human pressures on the landscape such as urbanization, as well as through the reaction of human societies to these changes in EGS provision.

In the VOTES ("Valuation Of Terrestrial Ecosystem Services in a multifunctional peri-urban space") project, we attempt to model this coupled socio-ecological system by combining a dynamic vegetation model (DVM) with an agent-based model (ABM). The DVM (CARAIB; Dury et al., iForest - Biogeosciences and Forestry, 4:82-99, 2011) model describes the evolution of physical and biological processes in the ecosystems, i.e. the impact of climate change and land management on the energy, water and carbon budgets, as well as the productivity of each simulated plant species present on each land unit. The original version of the model developed for natural vegetation has been upgraded to include crop systems and pastures. The ABM (Murray-Rust, Journal of Land Use Science, 6(2-3):83-99, 2011) describes the management choices (e.g., crop rotation, intensive agriculture or organic farming, etc) for each land plot, as well as the possible change in their affectation (e.g., conversion of farm fields to residential areas in response to urbanization), under different socio-economic contexts described in the storyline of three scenarios depicting general societal orientations (business-as-usual; market oriented; sustainability oriented). As a result, the ABM produces a dynamic evolution of land use and management options to be passed on to the DVM for further analysis. The outputs from the DVM allow evaluating quantitatively the provision of EGS by each land plot. This DVM-ABM modelling tool is thus able to describe the future evolution of land use and land cover, as well as of EGS production, in the context of socio-economic scenarios. The model is applied to a case study area covering four municipalities located in central Belgium close to Brussels and Leuven. The area is mostly composed of agricultural fields (crops and meadows), residential areas and a large protected forest (Meerdaalbos) and is subject to intense urbanization pressure due to the proximity to Brussels.