Simulating climate change adaptation and structural change in agriculture using microsimulation and agent-based modeling

Christian Troost and Thomas Berger

Land Use Economics Group, Institute of Agricultural Sciences in the Tropics, University of Hohenheim

We present MPMAS, a software package for agent-based modeling and microsimulation in agricultural economics. The modeling package uses mixed integer programming to represent farm and farm household decisions and is designed for *ex ante* policy analysis in the context of agricultural production. We present the internal modeling sequence, our approaches to parallelization and case studies that use the software in the context of the analysis for climate change adaptation in agriculture.

1 Introduction

Originally developed for the analysis of innovation diffusion and the effects of trade policy on irrigation agriculture in Chile [1], the MPMAS software has developed into a versatile modeling package for agent-based modeling (ABM) in the context of agricultural production and land use decisions that has been used in a variety of case studies around the world [2, 3]. It is targeted at scientific applications that specifically require taking into account heterogeneity of farms and farming households (microsimulation) and/or interactions between farms (ABM). Farm management is modeled as a sequence of pre- and post-production-season decisions. Management decisions have consequences on the farm and its social, natural and economic environment. These effects are evaluated using internal or externally coupled biophysical, social and market models and feedback recursively on the next decision steps (cf. Fig. 1).

2 Uncertainty analysis and parallelization

Recent development of MPMAS focused on improving the options for uncertainty analysis with MPMAS. Uncertainty in MPMAS simulations stems from epistemic uncertainty due to incomplete knowledge on decision parameters and population characteristics and the uncertainty of future climatic and socioeconomic development, but also from aleatory uncertainty due to the inherently stochastic nature of certain farm events (e.g. death and birth of household members). Robustness of simulation results is assessed using sampling-based sensitivity analysis. Experimental designs (Latin-hypercube sampling, Sobol' sequences, elementary effect screening) are

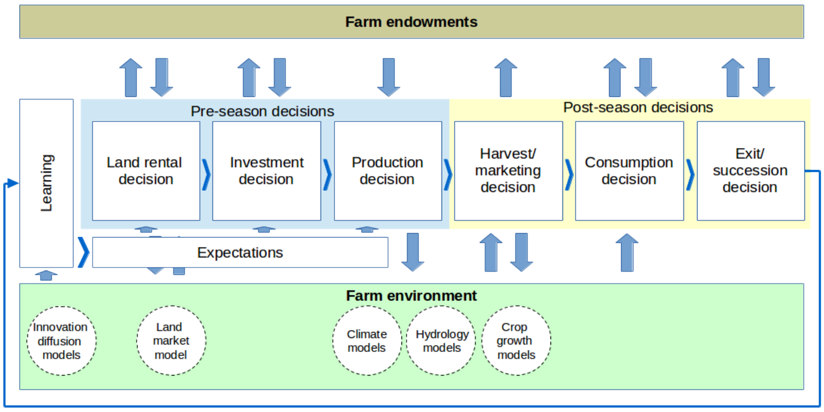

Figure 1: Sequencing of farm agent decisions in MPMAS

used to keep the number of model repetitions feasible. Still, considerable numbers of repetitions are necessary [4]. Two approaches to parallelization are used: With smaller applications, where the runtime of each individual repetition remains within acceptable time limits, trivial parallelization, i.e. running each run on one processor, is most efficient as it avoids the overhead of multiple processes/threads. For larger applications (e.g. with many land market interactions), MPMAS uses MPI to parallelize agent decisions. A common random numbers scheme has been implemented to ensure consistency of stochastic events across repetitions and parallel processes [5].

3 Applications

Scientific application of MPMAS currently has a strong focus on agricultural policy analysis in the context of climate change adaptation and mitigation. For example, Troost & Berger [4] demonstrated the importance of taking farm-level processes into account when assessing the consequences of climate change adaptation in agriculture in Southwest Germany.

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