INTEGRATING APPROACHES FOR NATURAL RESOURCE MANAGEMENT AND POLICY ANALYSIS: BIOECONOMIC MODELS, MULTI-AGENT SYSTEMS AND CELLULAR AUTOMATA

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Over the past decade a number of new simulation approaches geared towards the understanding and management of spatial, economic and ecological changes of agricultural systems have emerged. This is desirable because previous models appear to have taken a rather simplistic view of these issues, albeit because of limited computing power. There are two main approaches. The so-called 'bioeconomic models' (BEM) explicitly take into account interrelated socio-economic and biophysical processes. Second, there are models based on the view that agricultural reality rests on individual actions and interactions. These draw their inspiration from concepts of 'artificial intelligence' like cellular automata (CA) and multi-agent systems (MAS). The aim was to bring these different approaches together and to explore opportunities for integrating them.

Bioeconomic models and genetic algorithms

The paper by B. Barbier (Honduras), with Chantal Carpentier, gave examples of BEM for tropical countries, aimed at studying land use dynamics and farmers' reactions to changing external conditions such as population growth and price changes. Geographic information systems (GIS) maps were the basis for spatial representation and the methodology followed a top-down approach. Recursive linear programmes were built on a regional level to optimize land use patterns. Explaining the model results to farmers and officials in the countries studied was also a key objective.

H. Jansen (Netherlands) provided an overview of a toolbox for land use analysis on different scales as developed and applied by REPOSA (Research Programme on Sustainability in Agriculture, Costa Rica) in a long-term interdisciplinary setting. In particular, the SOLUS regional system was discussed. It follows a top-down approach combining the biophysical and socioeconomic aspects of land use on the basis of linear programming and GIS. The central objective of the research is policy analysis support.

The presentation from O.J. Cacho (Australia) addressed the application of optimal control problems in natural resource economics. These problems are conventionally solved using dynamic or non-linear programming techniques,

though some difficulties arise as the solutions obtained often only represent local optima. Genetic algorithms, alternatively, provide a mechanism for exploring the solution surface without sticking to local optima, even though they may converge to a global optimum very slowly.

Genetic algorithms were also the topic of the presentation by S. Geisendorf (Germany). She discussed their potential to depict bounded rationality in bioeconomic models. Her work interprets genetic algorithms as an adaptive learning process in which economic agents learn their behaviour in an environment. The simulation runs also show that the system's behaviour differs greatly if the agents are given different cognitive capacities. Therefore, she concluded, bounded rationality should not be neglected in resource use models.

Cellular automata and multi-agent systems

Alfons Balmann (Germany) presented a model of a fictitious agricultural region where farms are located on the grid of a cellular automaton. These farms are interpreted as agents interacting indirectly in the land market. Each agent's behaviour is determined on the basis of recursive linear programming. The model can be used to study structural change and the effects of different policy measures (transfer policy, price policy) on the system. The simulations used showed the impact of policies on endogenous structural change and hence on the evolution of farm sizes, efficiency and farmers' income.

Thomas Berger (Germany) extended the previous approach in several respects. Agents in his model follow heterogeneous decision rules, they communicate in information networks and they interact bilaterally over the land market. Furthermore, the model integrates the regional water resource system and considers tradeable water rights. Berger applied his model to a selected agricultural region in Chile to study the dynamic impacts of free trade-oriented policy options. The simulation runs help to predict the diffusion of specific innovations and the resultant resource use change under different scenarios.

The paper by E. Chattoe (UK) addressed general difficulties of building multi-agent models, and in particular the representation of social interactions. He identified three major difficulties. The absence of a sound data base for dynamic analysis, weak explanatory theories of social behaviour and lack of a general will to enhance the predictive power of social science.

Conclusions

The final discussion, opened by R.A.E. Mueller (Germany), dealt especially with the advantages of top-down and bottom-up approaches in the context of practical policy advice. Over the years, the more aggregate BEMs have become established as a good means of policy support. However, they fail to address certain research questions such as the role of externalities, the effects of interactions, self-organization and emergence, which are the strengths of MAS. Hence the participants of the mini-symposium agreed that bottom-up approaches can significantly extend the scope of economic analysis and should

be seen as complements to the standard tools. This gives rise to further need to explore their particular strengths and to integrate them with existing bioeconomic models in order better to serve the primary objective of managing tomorrow's agriculture in a sustainable way.