Tools for Land Use Analysis on Different Scales with Case Studies for Costa Rica

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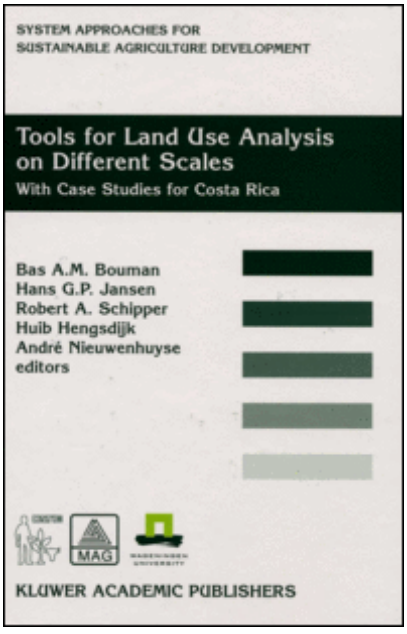

This is an edited, multi-authored volume reporting the results of a decade-long interdisciplinary research project (1990-1999), the Research Program on Sustainability in Agriculture (REPOSA). The project was undertaken by the Wageningen Agricultural University (WAU), based in the Netherlands, and conducted in Costa Rica with two resident partner agencies, the Tropical Agricultural Research and Higher Education Centre (CATIE) and the Ministry of Agriculture and Livestock (MAG). REPOSA was a joint exercise in research and education largely focused on

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techniques designed to link understanding of land-use and land-cover change to sustainability and development. Project disciplines ranged from agronomy, physical geography and soil science to economics and rural sociology. The book chapters focus on case studies that highlight various research methodologies across these disciplines.

Chapter one introduces the case studies by apportioning them into five categories according to the intent underlying use of the model: projective, exploratory, predictive, generative and prototyping. I note these classifications where pertinent. The chapter also introduces the study region and situates the methodologies relative to the REPOSA project's goals.

Chapter two establishes the socioeconomic and biogeophysical setting necessary to understanding subsequent chapters. This includes large-scale phenomena such as geology, climatology and agricultural policy as well as smaller scale considerations of soils and land-use practices. The one disconnect in this chapter is that it limits itself to just one region in Costa Rica, centred on the northern Atlantic coast, while other chapters consider the country as a whole. Nonetheless, the chapter provides a good overview of the basics.

Chapter three explores the CLUE (Conversion of Land Use and its Effects) model, which constitutes the sole projective methodology offered by the book. CLUE is designed to indicate the most likely locations for future land use and land change at the regional and national scales. It offers scenarios based on driving forces such as climate, soil quality and population growth. An economic model develops projections of land demand, which in turn feed into a statistical regression model that relies on data provided by a geographic information system (GIS). As with other statistical models, there is an implicit assumption of statistical stationarity that allows the user to modify independent variables and assess the effect on the dependent variable - in this case, land use. CLUE remains one of the best examples of a statistically driven land-use and land-cover change model.

Chapter four concerns the REPOSA project's Spatial Equilibrium Modelling (SEM) approach, a national-scale effort that draws on general spatial equilibrium theory. In essence, the approach uses a short-term economic optimisation model to assess the policy implications of actions such as movement towards free trade in given commodities or changes in

technology. These implications are visited in terms of land use, agricultural production, trade, consumption and consumer welfare. The model is spatial insofar as it divides Costa Rica into six zones joined by a seventh, the world at large. The SEM approach is econometric, and as such, is based on empirical data for one time period (1995) that allows the authors to estimate key supply and demand variables. It also draws on linear programming to carry out what the editors of the volume term a predictive role. The key distinction drawn between the terms projective (applied to CLUE) and predictive is that SEM attempts to explain the underlying trends instead of merely extrapolating them.

Chapter five explores two expert systems that design land-use regimes, such as agricultural production systems, at the farm or field level. The editors term these systems generative because they identify important biophysical and socioeconomic factors that define feasible land management strategies. The importance of these factors and their values give rise to the moniker Technical Coefficient Generators (TCGs) for the expert systems. The meaning of 'expert' does not extend to farmers or data from field research, but instead to the elicitation of knowledge from agronomic specialists. TCGs consider the inputs and outputs of land-use systems in order to optimise current land-use configurations and shed light on possible, alternative production systems. The TCGs act as building blocks for models considered in the following chapters.

Chapters six and seven concern development of the SOLUS model (Sustainable Options for Land Use), which is essentially an optimising linear programming framework designed to conduct cost-benefit analyses of varying configurations of biophysical, socioeconomic, and policy factors at the regional scale. This model is termed explorative because varying factor configurations are considered in terms of trade-offs over relatively long time scales of twenty to thirty years. The model is based on, and constrained by, technological options for land use generated by the expert systems considered above (TCGs). These land-use profiles are fed into a linear programming model that optimises objectives subject to biophysical and socioeconomic constraints. These bounds in turn are considered either fixed, such as biophysical characteristics, or policy related, such as biocide taxation or the potential for agricultural development as a function of labour demand and supply. Chapters six and seven are detailed and include the formulae necessary to understand the linear programming system.

Chapter eight describes UNA-DLV (Autonomous National University - Sustainable Land Use and Food Security), which joins SEM (chapter four) in being considered a predictive model by the editors. The UNA-DLV methodology incorporates the decision-making behaviour of four different kinds of farms in order to make short-term (i.e., less than five years) predictions of the effect of policy on land use. The model ties farm-level decision making to the regional scale by incorporating market equilibrium conditions given by a separate economic model, which facilitates analysis of farmer reactions to regional policy changes. Farm decision making is modelled using a linear programming framework. Case specific resource endowments and technical coefficients of different agricultural production systems (given by TCGs) bound the objective functions for each farm type. These production systems include alternatives not found in actuality, which allows for generation of sustainable agriculture scenarios.

Chapter nine concerns the BanMan (Banana Management) model, and is termed a prototyping methodology because it is used to design new types of land-use systems. This case study is situated at the micro scale of a single banana plantation. The model is classified as prototyping because it is used to develop new management regimes with the support of information systems that evaluate agronomic decisions and project the economic and ecological consequences of these decisions.

Chapter ten looks back on the previous ones and examines how the various project methods complement one another. There are many interconnections between the models, such as the reliance on shared technical coefficient generators. The methods also compensate each other's weaknesses, such as when the statistical stationarity of CLUE is offset by the theoretical depth of SEM, the exploratory nature of SOLUS, or the specificity of the expert systems. The methods also share a policy focus that ranges from what is expected to happen (projective) to what could happen (explorative/predictive). Finally, the chapter notes how the methods presented in this volume address land use across scales, which seems increasingly necessary for dealing with the myriad facets of land use as it relates to local vulnerability, regional sustainability, and global change.

The end papers are home to the book's sole technical problem: a poorly constructed index that offers little indication of the importance of pages to a given concept. The terms 'Pasture', 'Banana', and 'Biocide', for

instance, each have close to one hundred page entries in a book of fewer than three hundred pages. Otherwise, the volume has a list of concepts and definitions that is quite useful. The extensive bibliography is shared by all chapters and offers a good sampling of works of interest to anyone working in the fields of agriculture, land use, development or modelling. The included compact disc is quite handy because it offers basic data, programs, and importantly, a full listing of documents available from the project.

The chief drawback of the work as a whole - and this is not actually a problem as such - is the paucity of actual land-use outcomes. Throughout the book there are detailed examples of model construction, but few examples of models being validated against reality. What were the effects of the models on policy outcomes? Do the projections, predictions, explorations, generations and prototypes address what happened in reality? The authors devote several tantalising pages in the final chapter to describing a test application of the SOLUS framework to an actual policy context but offer only general conclusions on issues of knowledge transfer. While reading the work I was hoping for more results of what is ostensibly policy-focused research; this, however, may await another volume, which I look forward to reading.

The only other potential shortcoming of this work - from the perspective of JASSS readers - is the modest range of modelling techniques considered. Every method falls into the categories of statistics, systems model, and linear programming. While certainly valid and valuable, these approaches rely on assumptions of linearity and mechanistic linkages among key relationships and variables in the modelled systems. These approaches are increasingly joined by methods such as cellular automata or agent-based models that relax or contextualise these assumptions in light of complexity theory and complex systems.

The volume does a great job of demonstrating that established and tested techniques continue to be used in new and exciting ways. The strength of this volume lies in its thorough treatment of a number of land-use and land-cover change modelling topics from a policy-oriented view. The models are designed to answer questions that guide decisions on the ground. This work also highlights how an interdisciplinary approach is necessary to understand some of the most pressing problems humans face in the often competing realms of development and sustainability. This book is therefore valuable to professionals working in the field and

useful to researchers embarking on their own land-use or sustainability projects. Finally, it offers one of the relatively few examples of research projects that successfully use technology to integrate across academic disciplines at multiple spatio-temporal scales.

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