ECONOMIC MODELS OF LAND EVALUATION: REGIONAL AND GLOBAL DECISION-MAKING

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Summary

This is the second of two papers that review the use of economic models in land evaluation. While the first paper introduced the subject and described the main steps in model construction and dealt with applications at farm and local level, the present chapter turns to models that deal with larger areas of study, at the watershed, regional and global level. It relates models' objectives, defined by the clients and the users, to model structure and data requirements. The paper concludes with an overview of the pitfalls of this class of models and identifies challenges for future research.

1. Introduction

This is the second of two papers that review the use of economic models in land evaluation. The first gave a general introduction and considered the embedding of economic models for land use evaluation within the wider field of land use planning. It also reviewed the main steps in model construction and discussed typical models at farm and local level.

The present paper considers applications at higher aggregation levels and distinguishes the following clients. First, *watershed authorities* who manage a clearly defined hydrological unit, and aim at an efficient allocation of water to the different demand sites and the monitoring of land use changes and their impact on water quantity and quality. They usually rely on hydrological models to follow the water flows and on crop models to quantify yield potentials Whereas the biophysical information for these components is generally available on a fine grid, the economic components need data from household surveys as well as aggregate information at district level. Recommendations are prepared on water trading prices, the impact of specific aspects of land use, urbanisation, and on the pattern and quality of water flows and possible hazards, say, floods.

Second, it refers to *regional authorities and national governments* who are interested in a spatial representation of agricultural production and production potential to explore the scope for rural poverty alleviation, and regional development. The models built on their behalf distinguish a limited number of zones per region; land quality characteristics are only represented at the aggregate level of the zone, usually after summation of the results from more detailed calculations with biophysical models. Recommendations may range from the (optimal) location of facilities such as schools, health posts, to the effect of national fiscal and trade policies on poor farmers in a particular area.

Finally, it deals with the *global community* which is nowadays mainly interested in land use because of its major role as driver of climate change. Agriculture and forests are important carbon sinks and also affect rainfall patterns directly. The models in this field are either stylised in their treatment of economic variables or in the representation of geographic diversity and biophysical processes. Recommendations mainly pertain to the effect of various measures to control the emissions of greenhouse gases.

2. Watershed Models

Watershed authorities seek to track and predict the interaction between land use and hydrological flows. Hence, they are natural clients for economic models of land evaluation. This section discusses two applications. One is the Patuxent Landscape Model that aims at an evaluation of the impact of future land use changes on water quantity and quality. The second application provides an example of an economic hydrological model that seeks an efficient allocation of water for different economic sectors in the Maipo river basin in Chile.

2.1. The Patuxent Model

Clients - The United States Environmental Protection Agency (EPA) aims with its "Watershed Protection Approach" at a strategy for effectively protecting and restoring aquatic ecosystems and protecting human health. This strategy has as its premise that many water quality and ecosystem problems are best solved at the watershed level rather than at the individual water body or discharger level. To implement this objective EPA funded ($1,000,000) jointly with the National Science Foundation the project entitled: "The Patuxent Landscape Model" (PLM), for the period 1995-1998. The Patuxent river watershed in Maryland is one of the best-studied tributaries of the Chesapeake Bay, and has often been used as a model of the entire Bay system.

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Team - The model is designed by the Institute for Ecological Economics of the Maryland University.

Objectives - The PLM addresses the following questions: First, what are the quantitative, spatially explicit and dynamic linkages between land use and terrestrial and aquatic ecosystem productivity and health; second, what are the quantitative effects of various combinations of natural and anthropogenic stressors on ecosystems and how do these effects change with scale; third, what are useful ways to measure changes in the total value of the landscape including both marketed and non-marketed (natural system) components; and, fourth, how effective are alternative mitigation approaches, management strategies, and policy options toward increasing this value.

Data - Biophysical data of the Patuxent watershed (app. 1500 sq. kms) are stored in grids of 200×200m. Soil data with their hydrological details (runoff, permeability, etc.) are based on a detailed soil survey, and the topographic details (elevation, aspects and slopes) are derived from a Digital Elevation Model. Land use data are available for five years in the period 1973-1994 and are aggregated according to their relation with ecological and hydrological processes. Modelling of the river network and water balances are based on a monitoring network of 15 climatic and 13 gagging stations with long-year time series, including records on nutrient concentrations. Economic data were derived from the Census Bureau which aggregates the data at county level (varying from app. 200-2500 sq. kms).

The Model - The PLM was designed to serve as a tool in a systematic analysis of the interactions among physical and biological dynamics of the watershed, conditioned on socio-economic behavior in the region. A companion socio-economic model of the region's land use dynamics was developed to link with the PLM and provides a means of capturing the feedbacks between ecological and economic systems.

Spatial interactivity - The landscape is partitioned into a spatial grid of square unit cells. An ecosystem-level "unit" model is replicated in each of the unit cells representing the landscape. While the unit model simulates ecological processes within a unit cell, horizontal fluxes link the cells together across the landscape to form the full PLM. Such fluxes are driven by cell-to-cell head differences of surface and ground water in saturated storage. Within this spatial context, the water fluxes between cells carry dissolved and suspended materials, determining the water quality in the landscape. Thus, when run within the spatial framework of the PLM, the landscape response to hydrology and water quality is effectively simulated as material flows between adjacent cells.

Economic component - As reported by Bockstael and Bell (1997), the land use conversion model was developed in two steps. First, statistical models were estimated that explain the value of land parcels in different uses. Second, a qualitative response model was estimated based on historical land use conversion decisions. Once the parameters of the two stages of the model are estimated for any given sub-market, the model is used to generate the conversion of different parcels in the landscape. Thus, a spatial pattern of relative development pressure is obtained as a function of

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characteristics of the parcels and their locations.

Simulation - The model has a recursive structure. It proceeds in consecutive iterations between the cells of the hydrological and the economic component. Since the explanatory variables used to predict the values in residential and alternative uses and the costs of conversion are all functions of ecological features, physical infrastructure, and government policies, the effects of changes in any of these variables can be simulated.

Validation - The model follows a modular structure. All modules were designed and tested independently, at several time and space scales, before the integrated version was run. The Model Performance Index (MPI) was used to integrate an array of variable-specific tests into a single score and expresses the overall fit between data and hypotheses.

Users - The PLM team undertook various activities to bring the model under the attention of the stakeholders of the Patuxent watershed. The PLM has been used by the Patuxent River Commission which also sponsored the Patuxent Watershed Scenario Development Workshop where a number of scenarios were discussed. The website http://iee.umces.edu/PLM/PLM1.html was developed to offer a platform for discussions.

Discussion - The model provides an example of how process-based hydrological models and micro-econometric models can be integrated in a decision framework at watershed level, and the results are presented in a spatially explicit manner. It highlights many spatial and dynamic external effects. As regards estimation and prediction, one may note the limitation that the spatial and temporal autocorrelation are not accounted for. Moreover, even though the external effects are mapped out, the simulation framework does not permit to derive dynamically efficient trajectories of decision variables.

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