FOREWORD
The Economics of Land Use Change: Advancing the Frontiers

Lori Lynch and Jacqueline Geoghegan

The pace and pattern of land use change in the United States drives many communities to demand new policies due to both the environmental and fiscal impacts associated with the increasing urban and suburban landscape as well as questions of food security and global climate change resulting from the loss of farm and forest land. Between 1982 and 1997, U.S. population grew by 17 percent, while total urbanized land area grew by 47 percent (Fulton et al. 2001). However, the total amount of resource land lost is not the only concern to society: the location, distribution, and pattern of the land use change also matter. The *pattern* of land use determines the local government costs of providing infrastructure such as roads, schools, sewer, water, and other public services; the amount and type of nonpoint source pollution into water bodies; loss of farmland, forest, habitat, and other open space amenities; how much time people spend commuting—commute times have increased and contributed to negative air quality as well as to global climate change; and ecological effects including hydrological disturbances and habitat fragmentation. In addition, the amount of land converted per each person for new housing has been trending upward—almost doubling in the past 20 years. Since 1994, housing lots greater than 10 acres accounted for 55 percent of total land developed in the U.S. (Heimlich and Anderson 2001). Understanding the threshold impacts of different patterns—whether they relate to the percentage of impervious surface in a watershed, the impacts of and alternatives to achieving TMDLs (total maximum daily loads), or the number of acres of interior forests—has also become more important, but these threshold impacts are difficult to analyze given the modeling methods currently available.

Numerous local, state, and federal regulations have the potential to affect land use patterns. Land use planning and regulation are usually functions of state and local governments, traditionally performed through zoning regulations and subdivision ordinances, as well as other related land use tools such as adequate public facilities ordinances, differential development fees, urban growth boundaries, and public provision of water and sewer. Local governments can also use market mechanisms such as transferable development rights to create incentives for development to occur in specific regions, or they can explicitly buy parcels of remaining open space. In addition, federal government activities can indirectly affect land use patterns. These include the allocation of resources for the transportation network and the deductions of mortgage interest and property taxes in the federal income tax code. However, in many cases, government policies can result in unintended consequences on the spatial pattern of land use and land use change, as they are not always implemented specifically to affect this pattern.

Given these as motivating policy issues, spatially explicit economic modeling focusing on the *pattern* of land use change has increased dramatically in recent years, with advances in theoretical modeling as well as with innovations in methodology. Empirical advances have been facilitated by the availability of spatially explicit social science data. Applied economists have become increasingly interested in these issues as the availability of spatial data (remotely sensed data, such as satellite data, as well as other geo-referenced

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data) and geographical information system (GIS) advances have made analysis possible. This "spatial revolution" in the modeling of land use change within environmental economics began with Bockstael (1996) and Geoghegan, Wainger, and Bockstael (1997). These papers helped establish the methodological framework for the use of spatially explicit and spatially disaggregate data in land use economics. They demonstrated how to creatively use GIS data in hedonic land value models and developed techniques that are now commonplace in the environmental economics literature.

Soon after these initial papers were published, Robert Deacon and colleagues wrote an article on research opportunities in environmental and resource economics. "The spatial dimension of resource use may turn out to be as important as the exhaustively studied temporal dimension in many contexts. Curiously, the profession is only now beginning to move in that direction" (Deacon et al. 1998, p. 393). In the dozen years since, this challenge has been taken up by a growing cadre of researchers and their students, and this area of specialization has come into its own, with quite a few graduate programs now offering specialized courses in it, often taught by the authors included in this special issue.

Examples of advances in the theoretical modeling of the interaction of land use agents over space can be found in Irwin and Bockstael (2002). In order to allow for the more realistic spatial variability and fragmentation that exists in land uses, they develop a model that allows for spatial interactions between features of the landscape and different land uses. They demonstrate that such a model offers a viable explanation of the fragmented residential development pattern found in many U.S. urban-rural fringe areas. The incorporation of spatial amenities within an urban economic modeling framework which can explain "leap-frog" development is a further theoretical advance (Wu and Plantinga 2003, Wu 2006, Wu and Irwin 2008).

Methodological advances have also been rich and varied, including the incorporation of spatial economics and further sophisticated uses of GIS technologies to create variables for models (e.g., Geoghegan 2002, Geoghegan, Lynch, and Bucholtz 2003, Lynch and Musser 2001, Lynch and Lovell 2003, Paterson and Boyle 2002, Lewis and Plantinga 2007), as well as advances in the application of spatial sampling for land use modeling (Carrion-Flores and Irwin 2004), the development of algorithms for the prediction of spatial land use attributes (Plantinga and Miller 2001), and analysis of spatial data for land use change modeling (Irwin and Bockstael 2007).

Finally, there has been a surge in applying these theoretical and methodological advances to investigate the consequences of different land use polices on the spatial location and pattern of land use change. For example, measurements of the impact of different residential land use controls can be found in Irwin, Bell, and Geoghegan (2003), Lynch and Liu (2007), and Bento, Towe, and Geoghegan (2007), while the impact of farmland preservation programs on land values and land use change were modeled in Lynch, Gray, and Geoghegan (2007) and Towe, Nickerson, and Bockstael (2008).

The papers in this special issue came out of a workshop we organized entitled "The Economics of Land Use Change: Advancing the Frontiers," held in Washington, D.C., in June 2009, with funding from the U.S. Environmental Protection Agency as well as from the Lincoln Institute of Land Policy and from the Center for Agricultural and Natural Resource Policy at the University of Maryland. The goal of the workshop was to bring together a critical mass of researchers who have been involved in land-related research projects to present and assess the state of the art in spatial land use modeling. We held a competitive call for papers. Each accepted paper was presented and then discussed by a land use expert and the workshop participants. Participation in the workshop was by invitation only. In addition, we were delighted that three luminaries in environmental and resource economics, with a special interest in the field of spatial land use analysis—Peter Berck, Nancy Bockstael, and Kerry Smith[1]—participated in the workshop. Their role in the workshop was to provide additional feedback and insights on the specific papers presented as well as to help inform discussion on the directions for future research in the field.

The breadth in papers in this special issue reflects the range of current applications, with cross-fertilization with environmental economics, urban economics, and development economics, and more

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broadly with regional science and geography. In addition, the articles demonstrate a broad range in analytical, statistical, and simulation modeling (in some cases, all within one paper), with many of the papers focusing on a particular policy question. Finally, the applications cross over urban, suburban, exurban, and rural land uses in both developed and developing countries.

The workshop began with an invited talk from Elena Irwin. The resulting paper (coauthored with Yong Chen and Ciriyam Jayaprakash) gives an overview of the different types of spatial complexity that have been incorporated into urban land use models (Chen, Irwin, and Jayaprakash 2011). They create a hierarchy of models of increasing spatial complexity, ranging from exogenous spatial heterogeneity to multiple sources, while also including the increasing complexity of endogenous spatial feedbacks. These range from the seminal, but aspatial, land model of Arnott and Lewis (1979) through the increasing complexity of the current state-of-the-art models with multiple sources of exogenous spatial heterogeneity and dynamic endogenous spatial interactions across spatial scales. Chen, Irwin, and Jayaprakash introduce and discuss these models in the second half of their paper.

Nikhil Kaza, Charles Towe, and Xin Ye (2011) introduce a complementary advance in spatial land use modeling. The authors bring together the economic theory of decision making with insights from geography and other fields that focus on spatial patterns. The authors develop a sophisticated econometric model that allows for the simultaneous selection of multiple types of land use conversion and the intensity of that conversion (e.g., square footage of new construction), using data from a three-county region in Maryland. Following the estimation of this model, the authors take the model a step further by developing a simulation mechanism for future land use change. They also propose methods for evaluating the outcomes from land use change simulation models.

Most papers in this special issue use land use models to analyze the impact of different policies that affect land use either directly or indirectly. David Newburn and Peter Berck (2011) focus on the impact of different growth management policies for suburban and exurban development, with an empirical application to Sonoma County, California. Similar to Kaza, Towe, and Ye (2011), the Newburn and Berck article develops a spatially explicit econometric model of residential development. They then use the estimated model to simulate the effects of specific government policies such as urban growth boundaries and sewer provision. The simulations demonstrate the effectiveness of different policy options for growth management.

Erik Lichtenberg (2011) focuses on the effects of zoning and forest conservation regulations on open space preservation and the control of sprawl. He extends previous theoretical models of suburban subdivision development to incorporate the constraints of a forest conservation policy on land development. The resulting theoretical hypotheses are tested using data from Maryland in a number of different econometric specifications. The modeling results suggest that a policy such as a forest conservation regulation can contribute to low-density sprawl development by requiring more forest land to be set aside, but at a lower rate than other zoning regulations, such as increasing minimum lot size.

Tatiana Filatova, Dawn Parker, and Anne van der Veen (2011) develop an agent-based land market model to examine the trade-offs involved with development in coastal zones that have high amenity values but are also at risk for flooding. While the specific application is to a province in the Netherlands, their model has applications in many coastal areas throughout the world. The authors include in their agent-based model information from a survey conducted in the Netherlands about the uses of coastal amenities and individual risk perception. Different scenarios are specified in the simulation model concerning the risk perception of flood damage. The modeling results demonstrate how differing risk perceptions impact the spatial pattern of land development. They suggest ways to assist the government design policies that improve social welfare.

Two additional articles focus on urban issues within a developed world context. Antonio Bento, Sofia Franco, and Daniel Kaffine (2011) develop a theoretical model that explicitly incorporates the potential feedback effects of anti-sprawl government policies, such as development taxes, on society's welfare in a declining urban area. In their model, there are two market failures: underpricing of open space at the urban fringe, and urban decline in the center of the city. They analyze the different impacts of recycling devel-

opment tax revenues. The authors find that given the benefits associated with recycling the revenues, the optimal development tax is higher than the traditional Pigouvian prescription.

John Brown and Jacqueline Geoghegan (2011) develop a regression discontinuity design econometric test to determine the timing and magnitude of the capitalization of a newly established high-performing urban high school into nearby housing prices. They test this using spatially explicit housing sales data for an inner-city neighborhood in Worcester, Massachusetts. Estimating both a hedonic approach and a difference-in-difference technique, they compare housing sales before and after the establishment of the school. The critical spatial feature is that the authors create different spatial buffers on either side of the school catchment boundary to create the samples for the estimation. They argue that other than the high school eligibility, the neighborhood is fairly homogenous and that as such the comparison of houses on either side of the border is a robust test of the capitalization hypothesis. Their results suggest significant capitalization into housing prices of the value of the high-performing high school, a few years after its establishment.

The final three papers (Albers and Robinson 2011, Klemick 2011, Caviglia-Harris and Harris 2011) focus on spatial land use modeling in a developing country context. In many developing countries, the institutional and modeling framework for spatial land use modeling is very different than in the developed world context. This is due to the lack of fully functioning land markets and the constraints facing subsistence agriculture. These three papers all investigate the causes and consequences of tropical deforestation as well as policy interventions to reduce deforestation. Two of the papers—one by Heather Klemick and the other by Jill Caviglia-Harris and Daniel Harris—focus on the Brazilian Amazon, while the paper by Heidi Albers and Elizabeth Robinson develops a theoretical model with applications to a number of different countries.

The spatial links between shifting cultivation and fallow cycle are investigated in Klemick (2011). She develops a spatial optimal control model that allows for fallow externalities, such as how an individual farmer's on-farm fallow decisions can affect both on-site and off-site biomass. In the empirical application, Klemick uses household data on 22 villages in the Brazilian Amazon. Earlier work demonstrated that upstream fallow improves downstream productivity. Therefore, she links the household data with GIS water flow direction data, which allows her to cluster the farms into 11 groups defined by a common drainage area and flow direction, with upstream farms affecting downstream farms. Using a suite of spatial econometric models, she finds that institutional economic constraints such as poor market access and lack of liquidity affect fallowing decisions to a greater extent than the fallow externality effect.

Caviglia-Harris and Harris (2011) also look at land use in Brazil. They investigate the impact of different spatial regime government settlement schemes on overall deforestation rates as well as the spatial patterns in resulting land cover. They have spatially explicit household panel survey data for six municipalities in the Brazilian Amazon, which they link to time-series satellite data. Estimating several econometric specifications, they show that the different settlement schemes do affect deforestation rates and that these rates vary over time. They find that some settlement schemes might increase social goals, such as family contact and greater access to markets; however, environmental goals such as keeping more land area under forest cover might suffer as a result.

Albers and Robinson (2011) develop a spatial theoretical model of the relationship between the location of villages and their spatial access to forest reserves. Building on their earlier work on the trade-offs for villagers between transportation costs to and from forest reserves and their impact on forest degradation, and forest manager enforcement activities to reduce that degradation, they include in their article the option of supporting poverty-reduction policies such as beekeeping, which depends upon healthy nearby forests. This framework provides insights to forest managers to help see the possibilities of reducing forest degradation not just through enforcement of forest access rules but also by providing alternative livelihood activities that depend upon healthy forests.

In summary, the papers presented at the workshop and published here in this special issue on "Economics of Land Use Change" offer robust analysis, new datasets, data collection methods, and new methodologies related to land use. They build on the expanding interest and improvements

in theoretical spatial models and empirical methodologies. Several papers demonstrate how advances in the availability of spatially explicit data, especially at the micro level, enrich our empirical applications. These papers advance the science on modeling land use change and the success (or unintended consequences) of policies aimed at helping society achieve the most optimal pattern of land use. For example, research was presented on land preservation to help society understand the spatial processes that result in changing land values and subsequently changing land use, and the impact of different policies on spatial patterns of land use. These research papers demonstrate the importance of understanding impacts on land use and land values in addressing issues such as air pollution and global climate change, clean and safe water, and strong and vibrant communities and ecosystems. This issue will help researchers enhance and improve upon the theories and empirical methods used in environmental and resource economics for the evaluation of policies that affect land use decisions. Space, with its multidimensional aspects, challenges us all to think more creatively to fully achieve a representation of the land use system. The numerous policies employed to address market failures, institutional structures, and natural ecosystems provide rich and interesting subjects for ongoing research and policy analysis.

References

Albers, H.J., and E.J.Z. Robinson. 2011. "The Trees and the Bees: Using Enforcement and Income Projects to Protect Forests and Rural Livelihoods Through Spatial Joint Production." *Agricultural and Resource Economics Review* 40(3): 424–438.

Arnott, R.J., and F.D. Lewis. 1979. "The Transition of Land to Urban Use." *Journal of Political Economy* 87(1): 161–169.

Bento, A.M., S.F. Franco, and D. Kaffine. 2011. "Welfare Effects of Anti-Sprawl Policies in the Presence of Urban Decline." *Agricultural and Resource Economics Review* 40(3): 439–450.

Bento, A., C. Towe, and J. Geoghegan. 2007. "The Effects of Moratoria on Residential Development: Evidence from a Matching Approach." *American Journal of Agricultural Economics* 89(5): 1211–1218.

Bockstael, N.E. 1996. "Modeling Economics and Ecology: The Importance of a Spatial Perspective." *American Journal of Agricultural Economics* 78(5): 1168 –1180.

Brown, J., and J. Geoghegan. 2011. "Spatially Delineated Public Goods and Spatially Located Public Bads: A Hedonic Approach to Measuring Urban Revitalization." *Agricultural and Resource Economics Review* 40(3): 360–374.

Carrion-Flores, C., and E.G. Irwin. 2004. "Determinants of Residential Land-Use Conversion and Sprawl at the Rural-Urban Fringe." *American Journal of Agricultural Economics* 86(4): 889–904.

Caviglia-Harris, J., and D. Harris. 2011. "The Impact of Settlement Design on Tropical Deforestation Rates and Resulting Land Cover Patterns." *Agricultural and Resource Economics Review* 40(3): 451–470.

Chen, Y., E.G. Irwin, and C. Jayaprakash. 2011. "Incorporating Spatial Complexity into Economic Models of Land Markets and Land Use Change." *Agricultural and Resource Economics Review* 40(3): 321–340.

Deacon, R.T., D.S. Brookshire, A.C. Fisher, A.V. Kneese, C.D. Kolstad, D. Scrogin, V. Kerry Smith, M. Wared, and J. Wilen. 1998. "Research Trends and Opportunities in Environmental and Natural Resource Economics." *Environmental and Resource Economics* 11(3/4): 383–397.

Filatova, T., D.C. Parker, and A. van der Veen. 2011. "The Implications of Skewed Risk Perception for a Dutch Coastal Land Market: Insights from an Agent-Based Computational Economics Model." *Agricultural and Resource Economics Review* 40(3): 405–423.

Fulton,W., R. Pendall, M. Nguyen, and A. Harrison. 2001. "Who Sprawls Most: How Growth Patterns Differ Across the United States." Center on Urban and Metropolitan Policy, the Brookings Institution, Washington, D.C.

Geoghegan, J. 2002. "The Value of Open Spaces in Residential Land Use." *Land Use Policy* 19(1): 91–98.

Geoghegan, J., L. Lynch, and S. Bucholtz. 2003. "Capitalization of Open Spaces: Can Agricultural Easements Pay for Themselves?" *Agricultural and Resource Economic Review* 32(1): 33–45.

Geoghegan, J., L. Wainger, and N.E. Bockstael. 1997. "Spatial Landscape Indices in a Hedonic Framework: An Ecological Economic Analysis Using GIS." *Ecological Economics* 23(3): 251–264.

Heimlich, R.E., and W.D. Anderson. 2001. **"**Development at the Urban Fringe and Beyond: Impacts on Agriculture and Rural Land." Agricultural Economic Report No. 803, Economic Research Service, U.S. Department of Agriculture, Washington, D.C.

Irwin, E.G., K.P. Bell, and J. Geoghegan. 2003. "Modeling and Managing Urban Growth at the Rural-Urban Fringe: A Parcel-Level Model of Residential Land Use Change." *Agricultural and Resource Economics Review* 32(1): 83–102.

Irwin, E.G., and N.E. Bockstael. 2002. "Interacting Agents, Spatial Externalities and the Evolution of Residential Land Use Patterns." *Journal of Economic Geography* 2(1): 31–54.

____. 2007. "The Evolution of Urban Sprawl: Evidence of Spatial Heterogeneity and Increasing Land Fragmentation." *Proceedings of the National Academy of Science* 104(52): 20672–20677.

Kaza, N., C. Towe, and X. Ye. 2011. "A Hybrid Land Conversion Model Incorporating Multiple End Uses." *Agricultural and Resource Economics Review* 40(3): 341–359.

Klemick, H. 2011. "Constraints or Cooperation? Determinants of Secondary Forest Cover Under Shifting Cultivation." *Agricultural and Resource Economics Review* 40(3): 471–487.

Lewis, D.J., and A.J. Plantinga. 2007. "Policies for Habitat Fragmentation: Combining Econometrics with GIS-Based Landscape Simulations." *Land Economics* 83(2): 109–127.

Lichtenberg, E. 2011. "Open Space and Urban Sprawl: The Effects of Zoning and Forest Conservation Regulations in Maryland." *Agricultural and Resource Economics Review* 40(3): 393–404.

Lynch, L., W. Gray, and J. Geoghegan. 2007 "Are Farmland Preservation Programs Easement Restrictions Capitalized into Farmland Prices? What Can a Propensity Score Matching Analysis Tell Us?" *Review of Agricultural Economics* 29(3): 502–509.

Lynch, L., and X. Liu. 2007 "Impact of Designated Preservation Areas on Rate of Preservation and Rate of Conversion: Preliminary Evidence." *American Journal of Agricultural Economics* 89(5): 1205–1210.

Lynch, L., and S.J. Lovell. 2003. "Combining Spatial and Survey Data to Explain Participation in Agricultural Land Preservation Programs." *Land Economics* 79(2): 259–276.

Lynch, L., and W.N. Musser. 2001. "A Relative Efficiency Analysis of Farmland Preservation Programs." *Land Economics* 77(4): 577–594.

Newburn, D., and P. Berck. 2011. "Growth Management Policies for Exurban and Suburban Development: Theory and an Application to Sonoma County, California." *Agricultural and Resource Economics Review* 40(3): 375–392.

Paterson, R.W., and K.J. Boyle. 2002. "Out of Sight, Out of Mind? Using GIS to Incorporate Visibility in Hedonic Property Value Models." *Land Economics* 78(3): 417–425.

Plantinga, A.J., and D.J. Miller. 2001. "Agricultural Land Values and the Value of Rights to Future Land Development." *Land Economics* 77(1): 56–67.

Towe, C.A., C.J. Nickerson, and N.E. Bockstael. 2008. "An Empirical Examination of the Timing of Land Conversions in the Presence of Farmland Preservation Programs." *American Journal of Agricultural Economics* 90(3): 613–626.

Wu, J. 2006. "Environmental Amenities, Urban Sprawl, and Community Characteristics." *Journal of Environmental Economics and Management* 52(2): 527–547.

Wu, J., and E.G. Irwin. 2008. "Optimal Land Development with Endogenous Environmental Amenities." *American Journal of Agricultural Economics* 90(1): 232–248.

Wu, J., and A.J. Plantinga. 2003. "The Influence of Public Open Space on Urban Spatial Structure." *Journal of Environmental Economics and Management* 46(2): 288–309.