CSS643: Land-Use Modeling Techniques and Applications /EVPP 741 - 005/GGS 531 - 001

Tuesday 4:30–7:10pm, 327 INNOVATION HALL

Qing Tian, 703-993-1405, qtian2@gmu.edu
Office hours: Tuesday 3pm-4pm, Room 374, Research Hall

Overview

This course surveys literature on empirical models of Land Use and Land Cover Change. We begin with an introduction to Land Change Science which provides a theoretical background for land-use modeling. The bulk of the course will be spent reviewing techniques for land-use modeling, including statistical models, cellular automata, optimization methods, agent-based models, and integrated models. Through discussions of case studies, we will learn the strengths and weaknesses and data requirements of each modeling technique as well as potential complementarities of the models to address complex research questions and acquire in-depth understandings of land use systems. Readings consist of peer-reviewed journal articles and some book chapters. Labs are included with a focus on agent-based modeling and cellular automata.

Objectives

Having completed the course, students should be able to critically review and interpret a land-use model, whether presented in a report or a scholarly article. They should have an understanding of the input data requirements, the ways in which the model output can be used, the spatial, temporal, and human scale over which the model operates, the disciplinary scope of the model, and the strengths, weaknesses, and limitations of the modeling technique used. Students should have an understanding of what empirical modeling techniques can be applied to a given data set. Finally, they should have an understanding of what modeling techniques are appropriate for particular research questions.

Recommended Prerequisites

It is helpful if students have a working understanding of spatial data structures, GIS, and statistical regression analysis, and are comfortable with simple optimization problems and systems of linear equations. However, motivated students without this prior knowledge have done very well in the past.

Course Work

Students are expected to actively participate in class discussions. Students should read all the required material before each class and write a brief note on two or three points from the readings that strike him/her (not a summary of the readings) to share with the class, and a list of questions (at least two) for further discussion in class.

Students are required to do a term project and write a report. You can work on a project individually or as a group (depending on the size of the project) using one land-use modeling

approach covered in class. Other options are possible but should be approved by the instructor beforehand. If you choose to do a CA or ABM, you may: 1) create and analyze a new model in ArcGIS, NetLogo, or another platform, or 2) modify and analyze an existing model. You will present your project in class. You should start thinking about the term project early.

There will be a lab session on agent-based land-use modeling using NetLogo. You are asked to explore the functioning of a very simple land-use model and make some changes to it. You are required to submit a report for this lab.

Grading

(1) Class discussion participation: 40%

(2) lab report: 20%

(3) Term project: 40%

Students will have a chance to evaluate his/her own performance. You are required to write a brief statement at the end of the semester to justify your grading. Students' self-evaluations will be taken into account the overall grade.

Disability Statement

If you have a documented learning disability or other condition that may affect academic performance you should: 1) make sure this documentation is on file with the Office of Disability Services (SUB I, Rm. 222; 993-2474; http://www.gmu.edu/student/drc/) to determine the accommodations you need; and 2) talk with me to discuss your accommodation needs.

Honor Policy

The integrity of the University community is affected by the individual choices made by each of us. GMU has an Honor Code with clear guidelines regarding academic integrity. Three fundamental and rather simple principles to follow at all times are that: (1) all work submitted be your own; (2) when using the work or ideas of others, including fellow students, give full credit through accurate citations; and (3) if you are uncertain about the ground rules on a particular assignment, ask for clarification.

Class Sessions

Week	Date	Reading
1	Jan 20	**Introduction to Land Change Science and Land Use Modeling** ***Required reading:*** Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., ... & Snyder, P. K. (2005). Global consequences of land use. science, 309(5734), 570-574. Turner, B.L., E.F. Lambin, A. Reenberg. 2007. The emergence of land change science for global environmental change and sustainability. *Proc. Nat. Acad. Sci.* 104 (52): 20666-20671. Geist, H.J., McConnell, W., Lambin, E.F., Moran, E., Alves, D., and Rudel, T. 2006. Causes and trajectories of land-use/cover change. In Lambin, E.F., and Geist, H. (eds.), *Land-Use and Land-Cover Change: Local Processes and Global Impacts*. Berlin: Springer, pp. 41-70. (Get an idea about the categories of drivers) ***Further reading:*** Ramankutty, N., Graumlich, L., Achard, F., Alves, D., Chhabra, A., DeFries, R.S., Foley, J.A., Geist, H., Houghton, R.A., Goldewijk, K.K., Lambin, E.F., Millington, A., Rasmussen, K., Reid, R.S., Turner, B.L. 2006. Chapter 2: Global land-cover change: Recent progress, remaining challenges. In Lambin, E.F., and Geist, H. (eds.), *Land-Use and Land-Cover Change: Local Processes and Global Impacts*. Berlin: Springer, pp. 9-40. Defries, R.S., Foley, J.A., and Asner, G.P. 2004. Land-use choices: Balancing human needs and ecosystem function. Frontiers in Ecology and Environment 2(5): 249-257. Turner, B. L., D. Skole, et al. (1995). Land-Use and Land-Cover Change Science/Research Plan. Stockholm and Geneva, International Geosphere-Biosphere Programm and International Human Dimensions Programme: 132.
2	Jan 27	**New Directions in land change science and land use modeling** ***Required reading:*** Seto, K. C., Reenberg, A., Boone, C. G., Fragkias, M., Haase, D., Langanke, T., ... & Simon, D. (2012). Urban land teleconnections and sustainability. Proceedings of the National Academy of Sciences, 109(20), 7687-7692. Verburg, P. H., Erb, K. H., Mertz, O., & Espindola, G. (2013). Land System Science: between global challenges and local realities. Current opinion in environmental sustainability, 5(5), 433-437. Müller, D., & Munroe, D. K. (2014). Current and future challenges in land-use science. Journal of Land Use Science, 9(2), 133-142. Verburg, P.H., Kok, K., Pontius, R.G. and Veldkamp, A. (2006), 'Modeling Land-Use and Land-Cover Change', in Lambin, E.F. and Geist, H. (eds.), Land-Use and Land-Cover Change: Local Processes and Global Impacts, Springer, New York, NY, pp. 117-135.
3	Feb 3	**Classic theoretical perspectives** ***Required reading:*** Lambin, E.F., Geist, H., and Rindfuss, R.R. 2006. Introduction: Local processes and global impacts. In Lambin, E.F., and Geist, H. (eds.), *Land-Use and Land-Cover Change: Local*

		Processes and Global Impacts. Berlin: Springer, pp. 1-8. (**pay attention to section 1.2 and 1.3**) Chomitz K.M., and D.A. Gray. 1996. Roads, land use and deforestation: A spatial model applied to Belize. *World Bank Economic Review* 103:487–512. (*in the tradition of von Thünen*) Perz, S. G., and R. T. Walker. 2002. Household life cycles and secondary forest cover among small farm colonists in the Amazon. *World Development* 30(6):1009–1027. (*in the tradition of Chayanov*) ***Further reading:*** Agarwal, C., Green, G.M., Grove, J.M., Evans, T. and Schweik, C. (2002), A Review and Assessment of Land-Use Change Models: Dynamics of Space, Time, and Human Choice, USDA Forest Service Northeastern Forest Research Station Publication NE-297, Burlington, VT, Available at http://www.nrs.fs.fed.us/pubs/gtr/gtr_ne297.pdf. McCracken, S. D., E. S. Brondizio, D. Nelson, E. F. Moran, A. D. Siqueira, and C. Rodriguez-Pedraza. 1999. Remote sensing and GIS at farm property level: Demography and deforestation in the Brazilian Amazon. *Photogrammetric Engineering and Remote Sensing* 65(11):1311–1320. (Chayanov) Nelson, G.C., and J. Geoghegan. 2002. Deforestation and land use change: Sparse data environments. *Agricultural Economics* 27:201–216. (von Thünen) Walker, R. 2004. Theorizing land-cover and land-use change: The case of tropical deforestation. *International Regional Science Review* 27(3):247–270. (von Thünen)
4	Feb 10	**Multilevel statistical models and mixed methods** ***Required reading:*** Pan, W., and R. E. Bilsborrow. 2005. The use of a multilevel statistical model to analyze factors influencing land use: A study of the Ecuadorian Amazon. Global and Planetary Change 47 (2):232–252. Overmars, K. P., and P. H. Verburg. 2005. Analysis of land use drivers at the watershed and household level: Linking two paradigms at the Philippine forest fringe. *International Journal of Geographical Information Science* 19 (2):125–152. Tian, Q., Brown, D.G., Zheng, L., Qi, S., Liu, Y., and Jiang, L. Manuscript in review. The Roles of Cross-Scale Social and Environmental Contexts in Household-Level Land-Use Decisions, Poyang Lake Region, China. Annals of the Association of American Geographers. ***Further reading:*** Jan Peter Lesschen, Peter H. Verburg, and Steven J. Staal. Statistical methods for analysing the spatial dimension of changes in land use and farming systems. LUCC Report Series No. 7 Mertens, B. and Lambin, E.F. (2000), 'Land-Cover-Change Trajectories in Southern Cameroon', Annals of the Association of American Geographers, 90(3): 467-494. Overmars, K. P., and P. H. Verburg. 2006. Multilevel modeling of land use from field to village level in the Philippines. Agricultural Systems 89:435–456. Muller, D. and Zeller, M. (2002), 'Land Use Dynamics in the Central Highlands of Vietnam: A Spatial Model Combining Village Survey Data with Satellite Imagery Interpretation', Agricultural Economics, 27(3): 333-354.
5	Feb 17	**Cellular Automata (CA)** ***Required reading:*** Batty, M. (1997), 'Cellular Automata and Urban Form: A Primer', Journal of the American Planning Association, 63(2): 266-274.

		Soares-Filho, B.S., Cerqueira, G.C. and Pennachin, C.L. (2002), 'Dinamica —A Stochastic Cellular Automata Model Designed to Simulate the Landscape Dynamics in an Amazonian Colonization Frontier', Ecological Modelling, 154(3): 217-235. Jantz, C.A., Goetz, S.J. and Shelley, M.K. (2004), 'Using the SLEUTH Urban Growth Model to Simulate the Impacts of Future Policy Scenarios on Urban Land Use in the Baltimore – Washington Metropolitan Area', Environment and Planning B, 31(2): 251-271. ***Further reading:*** Clarke, K.C., Hoppen, S. and Gaydos, L.J. (1997), 'A Self-Modifying Cellular Automaton Model of Historical Urbanization in the San Francisco Bay Area', Environment and Planning B, 24(2): 247–261. Deadman, P., R. D. Brown, et al. (1993). "Modeling rural residential settlement-patterns with cellular automata." Journal of Environmental Management 37(2): 147-160. Batty, M. and Xie, Y. (2005), 'Urban Growth Using Cellular Automata Models', in Maguire, D.J., Batty, M. and Goodchild, M.F. (eds.), GIS, Spatial Analysis and Modelling, ESRI Press, Redlands, CA, pp. 151-172. White, R. and Engelen, G. (1993), 'Cellular Automata and Fractal Urban Form: A Cellular Modelling Approach to the Evolution of Urban Land Use Patterns', Environment and Planning A, 25(8): 1175-1199.
6	Feb 24	**ABM I** ***Required reading:*** Brown, D.G. 2006. Agent-based models. In H. Geist, Ed. The Earth's Changing Land: An Encyclopedia of Land-Use and Land-Cover Change. Westport CT: Greenwood Publishing Group, pp. 7-13.*(an intro to ABM)* Parker, D.C., Manson, S.M., Janssen, M.A., Hoffmann, M.J. and Deadman, P. (2003), 'Multi-Agent Systems for the Simulation of Land-Use and Land-Cover Change: A Review', Annals of the Association of American Geographers, 93(2): 314-337. Deadman et al. 2004. Colonist household decision making and land-use change in the Amazon Rainforest: an agent-based simulation. Environment and Planning B: Planning and Design, volume 31, pages 693-709. Manson, S.M. (2006), 'Land Use in the Southern Yucatan Peninsular Region of Mexico: Scenarios of Population and Institutional Change', Computers Environment and Urban Systems, 30(3): 230-253. ***Further reading:*** Crooks, A.T., Castle, C.J.E. and Batty, M. (2008), 'Key Challenges in Agent-Based Modelling for Geo-spatial Simulation', Computers, Environment and Urban Systems, 32(6): 417-430. Manson, S. M. and T. Evans (2007). "Agent-based modeling of deforestation in souther Yucatan, Mexico, and reforestation in the Midwest United States." Proceedings of the National Academy of Sciences of the United States of America 104(52): 20678-20683. Berger, T. (2001), 'Agent-Based Spatial Models Applied To Agriculture: A Simulation Tool For Technology Diffusion, Resource Use Changes And Policy Analysis', Agricultural Economics, 25(2-3): 245-260. Jepsen, M. R., S. Leisz, et al. (2006). "Agent-based modeling of shifting cultivation field patterns, Vietnam." International Journal of Geographical Information Science.
7	March 3	**ABM lab in class** ***You may read:***

		Stewart Robinson 1997. SIMULATION MODEL VERIFICATION AND VALIDATION: INCREASING THE USERS' CONFIDENCE. *Proceedings of the 1997 Winter Simulation Conference*. Brown, D. G., S. E. Page, et al. (2005). "Path dependence and the validation of agent-based spatial models of land use." International Journal of Geographical Information Science 19(2): 153-174. Pontius, R. G., W. Boersma, et al. (2008). "Comparing the input, output, and validation maps for several models of land change." Annals of Regional Science 42(1): 11-37. ***Further reading:*** Grimm et al. Pattern-Oriented Modeling of Agent-Based Complex Systems: Lessons from Ecology. Science 310(5750): 987. Railsback and Grimm 2011. Agent-Based and Individual-based Modeling: A Practical Introduction ch IV on Model Analysis pp 271-308.
8	March 10	Spring Break
9	March 17	**ABM II** ***Required reading:*** Robinson and Brown 2009. Evaluating the effects of land-use development policies on ex-urban forest cover: An integrated agent-based GIS approach. *International Journal of Geographical Information Science*, 23:9,1211-1232. Brown, D. G., R. L. Riolo, et al. (2005). "Spatial process and data models: Toward integration of agent-based models and GIS." Journal of Geographical Systems 7(1): 1-23. Castella, J.-C., T. N. Trung, et al. (2005). "Participatory simulation of land-use changes in the northern mountains of Vietnam: The combined use of an agent-based model, a role-playing game, and a GIS." Ecology and Society **10**(1): 27.
10	March 24	**CA lab in class** Experiment with the SLEUTH urban growth model ***You may read:*** Clarke, K. C., and L. Gaydos (1998). "Loose coupling of a cellular automaton and GIS: Long-term urban growth prediction for San Francisco and Washington/Baltimore" International Journal of Geographical Information Science 12(7): 699-714.
11	March 31	**Economic models** ***Required reading:*** Anas, A., Arnott, R. and Small, K.A. (1998), 'Urban Spatial Structure', Journal of Economic Literature, 36(3): 1426-1464. Bell, K.P. and Irwin, E.G. (2002), 'Spatially Explicit Micro-level Modeling of Land Use Change at the Rural–urban Interface', Agricultural Economics, 27(3): 217-232. Lewis, D. and Plantinga, A.J. (2007), 'Policies for Habitat Fragmentation: Combining Econometrics with GIS-Based Landscape Simulations', Land Economics, 83(2): 109-127 An, Li, et al. "Variations in development of exurban residential landscapes: timing, location, and driving forces." Journal of Land Use Science 6.1 (2011): 13-32. (A case study using survival

		analysis) ***Further reading:*** Anselin, L. (2002), 'Under the Hood: Issues in the Specification and Interpretation of Spatial Regression Models', Agricultural Economics, 27(3): 247-267. Irwin, Elena G., and Jacqueline Geoghegan. "Theory, data, methods: developing spatially explicit economic models of land use change." Agriculture, Ecosystems & Environment 85.1 (2001): 7-24. Angelsen, A. and Kaimowitz, D. (1999), 'Rethinking the Causes of Deforestation: Lessons from Economic Models', The World Bank Research Observer, 14(1): 73-98. Mueller, J.M. and Loomis, J.B. (2008), 'Spatial Dependence in Hedonic Property Models: Do Different Corrections for Spatial Dependence Result in Economically Significant Differences in Estimated Implicit Prices?' Journal of Agricultural and Resource Economics, 33(2): 212-231. De Pinto, A. and Nelson, G.C. (2007), 'Modelling Deforestation and Land-Use Change: Sparse Data Environments', Journal of Agricultural Economics, 58(3): 502-516. Lewis, D. and Plantinga, A.J. (2007), 'Policies for Habitat Fragmentation: Combining Econometrics with GIS-Based Landscape Simulations', Land Economics, 83(2): 109-127.
12	April 7	**Optimization models** ***Required reading:*** Hazell, P. B. R., and R. Norton. 1986. Chapter 2: The Farm Model. Pages 9-32. In Hazell, P.B.R. and Norton, R. (1986), Mathematical Programming for Economic Analysis in Agriculture, Macmillan Publishing Company, New York, NY. (Concentrate on pages 9-14, 16-21, 28-31. You may also want to read Chapter 3.) Carpentier, C.L., Vosti, S.A. and Witcover, J. (2000), 'Intensified Production Systems on Western Brazilian Amazon Settlement Farms: Could They Save The Forest?' Agriculture, Ecosystems and Environment, 82(1-3): 73-88. Shiferaw, B. and Holden, S.T. (2000), 'Policy Instruments for Sustainable Land Management: The Case of Highland Smallholders in Ethiopia', Agricultural Economics, 22(3): 217-232. ***Further reading:*** Maatman, A., Schweigman, C., Ruijs, A. and van Der Vlerk, M.H. (2002), 'Modeling Farmers' Response to Uncertain Rainfall in Burkina Faso: A Stochastic Programming Approach', Operations Research, 50(3): 399-414 (Very technical in parts). Chuvieco, E. (1993), 'Integration of Linear Programming and GIS for Land-use Modelling', International Journal of Geographical Information Science, 7(1): 71-83. (Good introductory article).
13	April 14	**Integrated Models** ***Required reading:*** Engelen, G., White, R. and Nijs, T. (2003), 'Environment Explorer: Spatial Support System for the Integrated Assessment of Socio-Economic and Environmental Policies in the Netherlands', Integrated Assessment, 4(2): 97-105. Tang, Z., Engel, B.A., Pijanowski, B.C. and Lim, K.J. (2005), 'Forecasting Land Use Change and Its Environmental Impact at a Watershed Scale', Journal of Environmental Management, 76(1): 35-45. Verburg, P.H., Soepboer, W., Veldkamp, A., Limpiada, R., Espaldon, V. and Mastura, S.S.A. (2002), 'Modeling the Spatial Dynamics of Regional Land Use: The CLUE-S Model',

		Environmental Management, 30(3): 391-405. ***Further reading:*** Engelen, G. (2002), Xplorah: The Spatial Decision Support System for Puerto Rico, Research Institute for Knowledge Systems (RIKS), Maastricht, Netherlands.
14	April 21	**Students work on term projects** (Qing Tian in Chicago for the AAG meeting)
15	April 28	**Term project presentation**
	May 5	Term project reports due (must be submitted by midnight)