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

Tuesday 4:30pm–7:10pm, 205 Innovation Hall

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Office hours: Tuesday 3:00pm-4:00pm, 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 and planning, 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 to enhance students' hands-on modeling skills.

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, such as writing a review paper, but must be approved by the instructor beforehand.

There are three lab sessions with detailed instructions. You are required to submit a brief report for each lab.

Grading

(1) Class discussion participation: 20%
(2) Paper presentation (about 3 papers): 15%
(3) Lab reports (4 labs): 40%
(4) Term project: 25%

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.

Useful Resources

ArcGIS

http://infoguides.gmu.edu/c.php?g=120514&p=787824

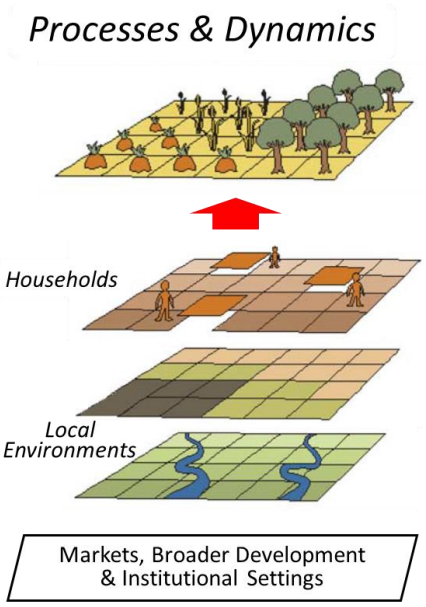
Raster package in R

https://cran.r-project.org/web/packages/raster/vignettes/Raster.pdf

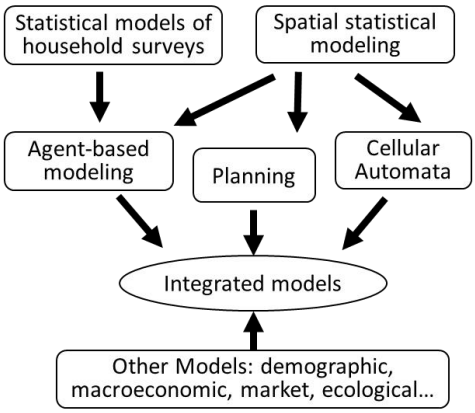
Netlogo

https://ccl.northwestern.edu/netlogo/download.shtml

Course Context



- **Explain, predict, plan, and evaluate consequences**
- **Rural, urban, suburban areas**
- **Labs using R, Netlogo, ArcGIS**



Class Sessions

Week	Date	Reading
1	Jan 24	**Introduction to Land Change Science and Land Use Modeling** ***Required reading:*** 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. 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. DeFries, R. S., Ellis, E. C., Chapin, F. S., Matson, P. A., Turner, B. L., Agrawal, A., ... and Lambin, E. (2012). Planetary opportunities: a social contract for global change science to contribute to a sustainable future. BioScience, 62(6), 603−606. ***Further 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. Brown, D. G., Verburg, P. H., Pontius Jr, R. G., & Lange, M. D. (2013). Opportunities to improve impact, integration, and evaluation of land change models. Current Opinion in Environmental Sustainability, 5(5), 452-457. 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. 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) 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.
2	Jan 31	**Classic theoretical perspectives and statistical models** ***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*) 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 **(*a good intro to statistical land use models*)**
3	Feb 7	**Spatial statistical modeling lab (LAB1) (due Feb 17 by 8am)**

4	Feb 14	**Statistical models and mixed methods** ***Required reading:*** 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. (2015). 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. 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 **(*a good intro to statistical land use models*)** ***Further reading:*** Yu, Q., Wu, W., Verburg, P. H., van Vliet, J., Yang, P., Zhou, Q., & Tang, H. (2013). A survey-based exploration of land-system dynamics in an agricultural region of Northeast China. *Agricultural Systems*, *121*, 106-116. 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 21	**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)* 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. 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. 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:*** 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 (*a good review on land use ABM*) 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. Jepsen, M. R., S. Leisz, et al. (2006). Agent-based modeling of shifting cultivation field patterns, Vietnam. International Journal of Geographical Information Science. 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.
6	Feb 28	**ABM lab (LAB2) (due March 3 by 8am)** ***You may read:*** Stewart Robinson 1997. SIMULATION MODEL VERIFICATION AND VALIDATION: INCREASING THE USERS' CONFIDENCE. Proceedings of the 1997 Winter Simulation Conference. 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.

7	March 7	**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. 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. Gargi Chaudhuri & Keith C. Clarke (2013) How does land use policy modify urban growth? A case study of the Italo-Slovenian border, Journal of Land Use Science, 8:4, 443-465 Zhang, R., Tian, Q., Jiang, L., Crooks, A., Qi, S., Yang, R. (In review). Predicting rice cropping patterns around Poyang Lake of China and policy implications: A cellular automata model. Land Use Policy ***Further reading:*** Manuel E. Ferreira, Laerte G. Ferreira Jr., Fausto Miziara & Britaldo S. Soares-Filho (2013) Modeling landscape dynamics in the central Brazilian savanna biome: future scenarios and perspectives for conservation, Journal of Land Use Science, 8:4, 403-4 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. Stephen J. Walsh , Barbara Entwisle , Ronald R. Rindfuss & Philip H. Page (2006) Spatial simulation modelling of land use/land cover change scenarios in northeastern Thailand: a cellular automata approach, Journal of Land Use Science 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. 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. 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.
8	March 14	Spring Break
9	March 21	**CA lab (LAB3) (due March 24 by 8am)**
10	March 28	**Optimization and planning** ***Required reading:*** 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. Xia Li , Xun Shi , Jinqiang He & Xaioping Liu (2011) Coupling Simulation and Optimization to Solve Planning Problems in a Fast-Developing Area, Annals of the Association of American Geographers, 101:5, 1032-1048 Hany M. Ayad, Dina M. Saad Allah & Hany S. Abd ElAzeem (2013) Investigating urban growth scenarios in Wadi El Natrun area, Egypt, using the UPlan land use allocation model, Journal of Land Use Science, 8:3, 304-320 ***Further 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.) (An intro to Mathematical Programming) Chuvieco, E. (1993) Integration of Linear Programming and GIS for Land-use Modelling. International Journal of Geographical Information Science, 7(1): 71-83. 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.
11	April 4	**Multi-criteria/multi-objective land allocation lab (LAB4) (due April 7 by 8am)**

12	April 11	**No class meeting** (Qing Tian out of town for US-IALE conference) Students work on term projects
13	April 18	**Integrated Models** ***Required reading:*** 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. Ross K. Meentemeyer , Wenwu Tang , Monica A. Dorning , John B. Vogler , Nik J. Cunniffe & Douglas A. Shoemaker (2013) FUTURES: Multilevel Simulations of Emerging Urban–Rural Landscape Structure Using a Stochastic Patch-Growing Algorithm, Annals of the Association of American Geographers, 103:4, 785-807. Yimin Chen , Xia Li , Shujie Wang , Xiaoping Liu & Bin Ai (2013) Simulating Urban Form and Energy Consumption in the Pearl River Delta Under Different Development Strategies, Annals of the Association of American Geographers, 103:6, 1567-1585 ***Further reading:*** Kristina A. Luus, Derek T. Robinson & Peter J. Deadman (2013) Representing ecological processes in agent-based models of land use and cover change, Journal of Land Use Science, 8:2, 175-198 (a review article) An, L., Linderman, M., Qi, J., Shortridge, A., & Liu, J. (2005). Exploring complexity in a human–environment system: an agent-based spatial model for multidisciplinary and multiscale integration. Annals of the Association of American Geographers, 95(1), 54-79. 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.
14	April 25	**Term project presentation and discussion (first round)**
15	May 2	**ABM II** ***Required reading:*** 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. Shipeng Sun, Dawn C. Parker, Qingxu Huang, Tatiana Filatova, Derek T. Robinson, Rick L. Riolo, Meghan Hutchins & Daniel G. Brown (2014) Market Impacts on Land-Use Change: An Agent-Based Experiment, Annals of the Association of American Geographers, 104:3, 460-484 Sara S. Metcalf (2014) Modeling Social Ties and Household Mobility, Annals of the Association of American Geographers, 104:1, 40-59
16	May 9	**Term project presentation and discussion** **Reports due May 12 by 8am**