Course Syllabus

Land Change Modelling: concepts and practice (1,5 credits)

Course leader: Ana Paula Dutra Aguiar and Francisco Gilney Silva Bezerra (INPE)

Brief Description

Spatially-explicit land change models (LCM) quantify in time and space the relationships between determining factors (biophysical, socioeconomic, cultural and institutional) and the spatial and temporal patterns of change in land use and cover. In this course we cover the basic concepts and types of models to represent land change through a combination of lectures and practical exercises. The practical exercises will use the LuccME/TerraME modelling framework (. LuccME/TerraME is an open source framework for spatially explicit Land Use and Cover Change (LUCC) modelling developed by the Earth System Science Center (CCST). Using LuccME/TerraME the modeler can easily create deforestation, agricultural expansion, desertification, forest degradation, urban sprawl models and other process models at different scales and areas of study, combining existing model components and/or creating new ones. Basic GIS (visualization) and multivariate statistical analyses skills are recommended (but not mandatory). No programming skills necessary.

Course Learning Outcomes

After taking the course, I expect the students will:

1. Acquire a general understanding about the different type of Land Change Models (LCM) and their applicability for different goals.
2. Be able to analyse the drivers underlying land change processes at different scales and conceptualize LCMs and scenarios.
3. Build alternative spatially-explicit models and scenarios using the LuccME/TerraME modelling framework.

Course Organization

The classes (20 hours) combine lectures, group discussions (in blue) and practical modelling exercises (in green). We will cover the content in three consecutive days, from **January 11-13, 2023** at the Stockholm Resilience Centre. The students will then have a week to prepare their final projects, which will be presented **on January 19, 2023** (in person or virtually, if necessary).

	Day 1 (Jan 11, Wed)	Day 2 (Jan 12, Thu)	Day 3 (Jan 13, Fri)	Day 4 (Jan 19, Thu)
09:00-12:00	**Topic: Land Change basic concepts** Lecture: - Land use and cover change concepts - Temporal and Spatial scales concepts - Land use trajectories - Drivers of change and examples - Feedbacks, SES, LUCC project to Land project - Perspectives of understanding, case studies and meta-analysis, archetypes, syndromes, theories Discussion in groups (applying the concepts to case studies): direct and indirect drivers of change for selected case studies at different scales	**Topic: Discrete and Continues land change models** Lecture: - Potential, Allocation and Demand components for discrete models - Potential, Allocation and Demand components for continuous models Practical exercise: - Building, calibrating and validating discrete LuccME models - Building, calibrating and validating discrete LuccME models - Running and analyzing alternative scenarios	**Topic: Building a spatial database and performing statistical analyses** Lecture: - Combining multiple raster and vector data sources in a common grid for spatial modelling - Basic multivariate statistical analyses concepts (exploratory analyses, linear, spatial and logistic regression) Practical exercise: - FillCell - Using R and GeoDA for regression analysis	**Presentation of final projects and course evaluation** Each student will present the final project and we will discuss it in plenary.
Lunch				
13:00-16:00	**Topic: LCM approaches and modelling process** Lecture: - Goals and approaches - Scenario concepts and typologies - Typologies of LC modeling approaches - Examples of different modeling approaches for the - From conceptual to quantitative modelling - TerraME and LuccME modeling frameworks	**Topic: Discrete and Continues land change models** (cont.)	**Topic: Discussion on projects** Each student will present the proposal for the final project and we will discuss it in plenary.	

Criteria for assessment

Grade is Pass/Fail.

Pass grade requires attendance and participation in practical exercises and discussions.

References

Basic reading

Bürgi, M. et al. (2022): Advancing the study of driving forces of landscape change, *Journal of Land Use Science*, DOI: 10.1080/1747423X.2022.2029599

National-Research-Council. *Advancing Land Change Modeling*. *Advancing Land Change Modeling* (National Academies Press, 2014). doi:10.17226/18385

van Vliet, J. *et al.* A review of current calibration and validation practices in land-change modeling. *Environmental Modelling and Software* **82**, 174–182 (2016).

Drivers

Lambin, E. F. et al. The causes of land-use and land-cover change: Moving beyond the myths. Global Environmental Change 11, 261–269 (2001).

Bürgi, M., Hersperger, A. M. & Schneeberger, N. Driving forces of landscape change - Current and new directions. Landsc. Ecol. 19, 857–868 (2005).

Hersperger, A.M. Gennaio, M. Verburg, P. H. Linking land change with driving forces and Actors: four conceptual models. Ecol. Soc. 15 (2010) (available at http://www.ecologyandsociety.org/vol15/iss4/art1/).

Bürgi, M. et al. (2022): Advancing the study of driving forces of landscape change, Journal of Land Use Science, DOI: 10.1080/1747423X.2022.2029599

Meta-studies and synthesis

Malek, Ž., Douw, B., Van Vliet, J., Van Der Zanden, E. H. & Verburg, P. H. Local land-use decision-making in a global context. Environmental Research Letters 14, (2019).

van Vliet, J. et al. Meta-studies in land use science: Current coverage and prospects. Ambio 45, 15–28 (2016).

Magliocca, N. R. et al. From meta-studies to modeling: Using synthesis knowledge to build broadly applicable process-based land change models. Environ. Model. Softw. 72, 10–20 (2015).

Magliocca, N. R. et al. Synthesis in land change science: methodological patterns, challenges, and guidelines. Reg. Environ. Chang. 15, 211–226 (2014).

Archetypes

Oberlack, C. et al. Archetype analysis in sustainability research: meanings, motivations, and evidence-based policy making. Ecol. Soc. 24, (2019).

Regime shifts

Müller, D. et al. Regime shifts limit the predictability of land-system change. Glob. Environ. Chang. 28, 75–83 (2014).

Land system science and theories

Turner, B. L., Lambin, E. F. & Reenberg, A. The emergence of land change science for global environmental change and sustainability. Proceedings of the National Academy of Sciences of the United States of America 104, 20666–20671 (2007).

Verburg, P. H. et al. Land system science and sustainable development of the earth system: A global land project perspective. Anthropocene 12, 29–41 (2015).

Meyfroidt, P. et al. Middle-range theories of land system change. Glob. Environ. Chang. 53, 52–67 (2018).

Nielsen, J. Ø. et al. Toward a normative land systems science. Curr. Opin. Environ. Sustain. 38, 1–6 (2019).

Meyfroidt, P., Abeygunawardane, D., Ramankutty, N., Thomson, A. & Zeleke, G. Interactions between land systems and food systems. Curr. Opin. Environ. Sustain. 38, 60–67 (2019).

P Meyfroidt, et. al. Ten facts about land systems for sustainability. PNAS (2022). https://doi.org/10.1073/pnas.210921711

Scale

Gibson, C. C., Ostrom, E. & Ahn, T. K. The concept of scale and the human dimensions of global change: A survey. Ecol. Econ. 32, 217–239 (2000).

Cash, D. W. et al. Scale and Cross-Scale Dynamics: Governance and Information in a Multilevel World. Ecol. Soc. 11.

TerraME/LuccME/GPM

Carneiro, T. G. S., Andrade, P. R., Câmara, G., Monteiro, A. M. V & Pereira, R. R. An extensible toolbox for modeling nature-society interactions. Environ. Model. Softw. 46, 104–117 (2013).

Moreira, E., Costa, S., Aguiar, A. P., Câmara, G. & Carneiro, T. Dynamical coupling of multiscale land change models. Landsc. Ecol. (2009). doi:10.1007/s10980-009-9397-x

Aguiar, A. P. D., Câmara, G. & Souza, R. C. M. Modeling Spatial Relations by Generalized Proximity Matrices. in GeoInfo 2003 - V Brazilian Symposium on Geoinformatics (ed. Casanova, M.) (2003).

Aguiar, A. P. D., Carneiro, T., Andrade, P. R., Assis, T. O. & Aguiar Carneiro, T., Andrade, P. R., & Assis, T. O., A. P. D. LuccME-TerraME: an open-source framework for spatially explicit land use change modelling. Glob. L. Proj. News 8, 21–23 (2012).

Selected examples of LuccME applications

Aguiar, A. P. D. et al. Land use change emission scenarios: Anticipating a forest transition process in the Brazilian Amazon. Glob. Chang. Biol. (2016). doi:10.1111/gcb.13134

Tejada, G. et al. Deforestation scenarios for the Bolivian lowlands. Environ. Res. 144, 49–63 (2016).

Guimberteau, M. et al. Impacts of future deforestation and climate change on the hydrology of the Amazon basin: a multi-model analysis with a new set of land-cover change scenarios.

Hydrol. Earth Syst. Sci. Discuss. 1–34 (2016). doi:10.5194/hess-2016-430

Gomes, Luciene. Impacts of land use and cover changes on soul nitrogen balance in the Brazilian Cerrado region. (PhD Thesis, INPE, 2017).

Dalla-Nora, Eloi. L. Modeling the interplay between global and regional drivers on amazon deforestation. (PhD Thesis, INPE, 2014).

Bezerra, F. G. S., von Randow, C., Assis, T. O., Bezerra, K. R. A., Tejada, G., Castro, A. A., Gomes, D. M. de P., Avancini, R., & Aguiar, A. P. (2022). New land-use change scenarios for Brazil: Refining global SSPs with a regional spatially-explicit allocation model. PLOS ONE, 17(4), 1–17. https://doi.org/10.1371/journal.pone.0256052

Assis, T. O., Aguiar, A. P. D., von Randow, C., & Nobre, C. A. (2022). Projections of future forest degradation and CO2 emissions for the Brazilian Amazon. Science Advances, 8(24). https://doi.org/10.1126/sciadv.abj3309

Modeling approaches examples

Combination of approaches

Verburg, P.H., Overmars, K.P. Combining top-down and bottom-up dynamics in land use modeling: exploring the future of abandoned farmlands in Europe with the Dyna-CLUE model. Landscape Ecol 24, 1167 (2009). https://doi.org/10.1007/s10980-009-9355-7

Schlüter, M., McAllister, R., Arlinghaus, R., Bunnefeld, N., Eisenack, K., Hölker, F., et al. (2012). New horizons for managing the environment: a review of coupled social-ecological systems modeling. Nat. Res. Model. 25, 219–272. doi: 10.1111/j.1939-7445.2011.00108.x

Grupo LuccME: Evaldinolia thesis (clue and agent-based): http://www.dpi.inpe.br/gilberto/teses/tese_eva.pdf)

Agent based (LUCC)

Filatova, T., Verburg, P. H., Parker, D. C., & Stannard, C. A. (2013). Spatial agent-based models for socio-ecological systems: challenges and prospects. Environmental modelling & software, 45, 1-7. https://doi.org/10.1016/j.envsoft.2013.03.017

Matthews, R.B., Gilbert, N.G., Roach, A. et al. Agent-based land-use models: a review of applications. Landscape Ecol 22, 1447–1459 (2007). https://doi.org/10.1007/s10980-007-9135-1

Grupo LuccME - Talita's thesis and Sergio Costa:

http://www.ccst.inpe.br/defesa-de-tese-da-aluna-talita-assis-do-ccst-inpe-com-tema-mudancas-de-uso-da-terra-e-o-processo-de-degradacao-na-amazonia-brasileira/

http://www.dpi.inpe.br/gilberto/teses/tese_sergio.pdf

Calibration/Validation

van Vliet, J. et al. A review of current calibration and validation practices in land-change modeling. Environmental Modelling and Software 82, 174–182 (2016).