Land use is a critical and increasingly important component of climate change analyses and studies of water management. It plays a key role as a driver of climate change and a component of mitigation strategies, and many adaptation strategies involve changes in land use or land management. Models take a variety of approaches to representing land use decisions, but there has been no organized comparison of these approaches to understand their relative strengths and weaknesses for use in climate and water assessments.

A group of land use, integrated assessment, and earth system modelers (representing the GLP, iLEAPS and AIMES communities, among others) met in July 2012 in Snowmass, Colorado, to discuss alternative approaches to modeling land use decisions across scales and to evaluate current knowledge of climate-related consequences of land use change. This article summarizes the principal workshop findings.

Spatial land use modeling: simulating decisions and their consequences for climate, carbon, and water

Land use modeling includes a number of research communities that address land use with different approaches and at different scales. For example, scholars interested in understanding social and environmental sustainability within communities have gravitated towards micro-economic and agent-based models (ABMs), and empirically focused case-based analyses, to represent decision making and governance in land change processes; regional-scale assessments of land-change patterns and interactions with social and environmental processes have tended to rely on cell-based allocation models based on expert knowledge or econometric estimation; and global integrated assessment models (IAMs) have used general or partial equilibrium models to represent demands for and allocation of land to various uses within different world regions.

A principal aim of this meeting was to bring these communities together to help develop a common understanding of the state of knowledge across the different communities and stimulate the transfer of methods and ideas to improve current approaches. The two-day workshop was part of a longer two-week conference on integrated assessment of climate change held annually in Snowmass, and therefore had a principal focus on how spatial land use components of global IAMs might be improved or evaluated by drawing on methods, models, or insights from the land change community, and on assessing what we know about the sensitivity of climate and biogeochemical consequences to spatial patterns of land use change.

This workshop built on a previous Snowmass workshop that focused on interactions between the IAM and earth system modeling (ESM) communities in studying climate change and on a recent GLP workshop (jointly supported by CSIRO) held in Lake Crackenback, Australia, that explored approaches to modeling land use decisions across scales. All these are contributing to the IGBP synthesis activity on “Impacts of land-use-induced land-cover changes on the functioning of the Earth System.” Key questions addressed at the workshop were: How sensitive are regional land use outcomes to the representation of decision-making that is employed in land change models? Are large-scale IAMs missing important processes concerning land change? How can we best connect regional land use modeling and data to global scenarios? How sensitive is climate and biogeochemistry to the pattern of land use at the regional scale? How can validation of spatial land use modeling be improved?

The workshop concluded that, unfortunately, the state of knowledge is not sufficient to answer these questions satisfactorily at this time, and we are not yet able to judge whether current representations in global assessments are sufficient. However, a number of steps were identified that would enable progress to be made in the short term. For example, it would be useful to build further on the initial exploration in this workshop of what approaches to modeling land use decisions are available, what their relative strengths and weaknesses are, and whether it is feasible to scale them up for global

1Climate and Global Dynamics (CGD) Division & Integrated Science Program National Center for Atmospheric Research (NCAR) boneill@ucar.edu
2Institute for Environmental Studies (IVM) Amsterdam Global Change Institute, VU University Amsterdam peter.verburg@vu.nl
application. Several examples of both agent-based and global-scale integrated assessment modeling approaches were presented at the workshop, and substantial discussion occurred of what the key differences between approaches are. Methods clearly differ in practice, in terms of the processes typically accounted for and the scale at which alternative models are typically applied. It is less clear whether the approaches differ in terms of fundamental principles and under what conditions each approach is valid. An understanding of the degree to which differences in alternative models lead to differences in simulated land change patterns, and how such differences affect the earth system and climate assessments, is lacking. It was also concluded that while clearly not enough is currently known about how and why ABMs and IAMs differ from each other when applied to land use questions, we also lack knowledge of how and why models differ within each category.

A number of possible activities and approaches were identified that could help in this regard. Model comparison activities (across ABMs, IAMs, or both) focused on spatial land use issues would be valuable, particularly if focused on possibilities for validation of models against historical data. Such an exercise would also benefit from better use of econometric results to inform model parameterization and evaluation. National case studies in which large historical shifts in spatial land use patterns have occurred, such as in the US or Brazil, could make useful foci. A number of presentations sketched ways in which studies could bridge regional and global scales. These included a higher resolution and more comprehensive representation of the resource base (including water as well as land), new land system representations that move beyond land resource base (including water as well as land), new and more comprehensive representation of the global scales. These included a higher resolution and more comprehensive representation of the resource base (including water as well as land), new land system representations that move beyond land resource base (including water as well as land), new and more comprehensive representation of the global scales.

Participants agreed that a number of follow up steps would be useful, particularly targeted activities leading to new modeling results aimed at directly addressing the questions raised in the workshop. Model development, ABM-IAM model comparison activities, additional ESM exploration of consequences, and data initiatives would all be valuable. A near-term goal would be to identify a national case study of historical land use change that might serve as an organizing activity. Plans are in place for joint proposal writing and for possible future forums in which to continue the fruitful dialogue between communities. The participants would like to thank the Energy Modeling Forum (EMF) and its sponsors for supporting this workshop.

Acknowledgments
The participants would like to thank the Energy Modeling Forum (EMF) and its sponsors for supporting this workshop.

References


