Land Use Policy 39 (2014) 403–411

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Viewpoint

Why have land use change models for the Amazon failed to capture the amount of deforestation over the last decade?

Eloi Lennon Dalla-Nora[a,*], Ana Paula Dutra de Aguiar[a], David Montenegro Lapola[b], Geert Woltjer[c]

[a] National Institute for Space Research – INPE, Earth System Science Center – CCST, Avenida dos Astronautas, 1758, Jardim da Granja, 12227-010 São José dos Campos, SP, Brazil
[b] São Paulo State University – UNESP, Biosciences Institute of Rio Claro, Avenida 24-A, 1515, Bela Vista, 13906-500 Rio Claro, SP, Brazil
[c] Wageningen University and Research Centre – WUR, Agricultural Economics Research Institute – LEI, Alexanderveld, 5, P.O. Box 29703, 2585 DB The Hague, The Netherlands

ARTICLE INFO

Article history:
Received 9 July 2013
Received in revised form 5 February 2014
Accepted 8 February 2014

Keywords:
Brazilian Amazon
Land use models
Land demand

ABSTRACT

Land cover change in the Neotropics represents one of the major drivers of global environmental change. Several models have been proposed to explore future trajectories of land use and cover change, particularly in the Amazon. Despite the remarkable development of these tools, model results are still surrounded by uncertainties. None of the model projections available in the literature plausibly captured the overall trajectory of land use and cover change that has been observed in the Amazon over the last decade. In this context, this study aims to review and analyze the general structure of the land use models that have most recently been used to explore land use change in the Amazon, seeking to investigate methodological factors that could explain the divergence between the observed and projected rates, paying special attention to the land demand calculations. Based on this review, the primary limitations inherent to this type of model and the extent to which these limitations can affect the consistency of the projections will also be analyzed. Finally, we discuss potential drivers that could have influenced the recent dynamic of the land use system in the Amazon and produced the unforeseen land cover change trajectory observed in this period. In a complementary way, the primary challenges of the new generation of land use models for the Amazon are synthesized.

Introduction

Land cover change is one of the major drivers of global environmental change (Turner II et al., 2007). Concentrated in tropical regions (Gibbs et al., 2010), such changes raise great concern about the sustainability of the goods and services provided by these ecosystems (Carpenter et al., 2005). The growing demands for food, fiber and energy along with market globalization could also further pressure the dynamics of tropical land use systems in the coming decades (Lambin and Meyfroidt, 2011). In this context, a number of models have been proposed to explore future trajectories of land use and cover change in tropical forests, particularly in the Amazon (Aguiar, 2006; Soares-Filho et al., 2006; Wassenaar et al., 2007; Malhi et al., 2008; Lapola et al., 2011; Davidson et al., 2012).

The future of the Amazon rainforests may never have been as heavily discussed by the scientific community as over the last decade since the advent of these models (Laurance et al., 2001; Nepstad et al., 2008). The scientific literature today has accumulated numerous projections derived from several models, scales and resolutions (Soares-Filho et al., 2004; Aguiar, 2006; Sampaio et al., 2007; Lapola et al., 2010). However, despite the significant improvement of these models through the adoption of more sophisticated analysis methods and expansion of the processes and factors considered, projections of land cover change in the Amazon are still surrounded by uncertainties.

None of the change projections currently available in the literature plausibly captured the overall trajectory of land use and cover change that has been observed during the last decade in the Amazon (Laurance et al., 2001; Aguiar, 2006; Soares-Filho et al., 2006; Nepstad et al., 2008; Lapola et al., 2011). After a long period of projections of massive deforestation, Amazon forest loss dropped

* Corresponding author. Tel.: +55 12 32086779.
E-mail addresses: eloi.dallanora@inpe.br (E.L. Dalla-Nora), ana.aguiar@inpe.br (A.P.D. de Aguiar), dmlapola@rc.unesp.br (D.M. Lapola), geert.woltjer@wur.nl (G. Woltjer).

http://dx.doi.org/10.1016/j.landusepol.2014.02.004
0264-8377/

dramatically to levels never previously recorded (INPE, 2013). A combination of regional policies to combat illegal deforestation along with a period of decrease in agricultural commodity prices, also marked by pressure from civil society on the government and productive sectors, have been suggested as the primary drivers for the deforestation slowdown observed since 2004 (Assunção et al., 2012; Macedo et al., 2012; Boucher et al., 2013) – 84% through 2012 – (INPE, 2013).

Such inconsistency between trajectories and reality may be directly linked to the ways that these trajectories have been simulated, especially with regard to the quantity of change. In this sense, it is appropriate in this moment to analyze what exactly we have learned about land use models during the last decade, what went wrong and what we still need to do to add relevance, credibility and legitimacy to this type of tool (Alcamo, 2008). For this purpose, a synthesis of the scientific knowledge that has been accumulated through the development of different models and projections is still missing in the literature on land use science.

Therefore, in the present study we seek to review and analyze the general structure of the land use models that have been used most recently to explore future change trajectories in the Amazon, focusing on those with regional coverage (Amazon basin or Brazilian Amazon). This review initially discusses the functional structure on which most of the spatially explicit land use models are based, paying special attention to aspects related to the estimated quantity of change. Based on this discussion, the primary limitations inherent to this type of model will be analyzed, as will the ways in which these limitations can affect the change trajectories projected for the Amazon. Finally, the authors discuss potential drivers that could have influenced the recent dynamic of the land use system in the Amazon and produced the unforeseen trajectory of land cover change observed in this period. In a complementary way, the primary challenges of the new generation of land use models for the Amazon are synthesized.

General structure of spatially explicit land use models

Despite the diversity of land use models found in the literature (Laurance et al., 2001; Aguiar, 2006; Soares-Filho et al., 2006; Wassenaar et al., 2007; Lapola et al., 2011), it is possible to identify a common functional structure that is valid for most of the available cases. As illustrated in Fig. 1, the main similarity is related to the partition between the land demand calculation (the magnitude or quantity of change) and the land allocation (the spatial distribution of change, including the potential calculation). In both cases, these projections are computed based on a number of driving factors, a portion of which are related to the quantity of change, and others of which are related only to its spatial distribution (certain factors can be important for both the demand calculation and the allocation process).

Based on the interpretation of one or more driving spatial factors, assumed to be determinant for the location of land use and cover change, suitability maps or transition probability maps are produced (Fig. 1). These maps indicate the suitability or propensity of a given location for a specific land use type in relation to other regions. There are several established approaches to performing this procedure; however, suitability maps based on empirical analyses and multi-criteria analysis (MCA) are the most frequent ones observed in the literature (Laurance et al., 2001; Aguiar, 2006; Soares-Filho et al., 2006; Wassenaar et al., 2007; Lapola et al., 2011).

In addition to the suitability map, the pattern of land use and cover change is also influenced by the land demand projected for each land use type in a given time period. Several methods have been used to perform such estimates, most of them following a top-down approach in which the amount of change is based on the interaction of a specific set of land use drivers (Soares-Filho et al., 2006; Lapola et al., 2011). However, the assumptions involved in each method, as well as the drivers considered in the land demand calculation may differ significantly from one application to another, as discussed in the next section. The attention devoted to the land demand calculation in this review is justified by the fact that this calculation is one of the most uncertain components or modules and therefore the most discussed output in regard to land use models produced for the Amazon.

Quantity of change in Amazon land use models

The land demand calculation is one of the most critical aspects of land use modeling exercises in the Amazon. As illustrated in Fig. 2, none of the previous studies were able to plausibly capture

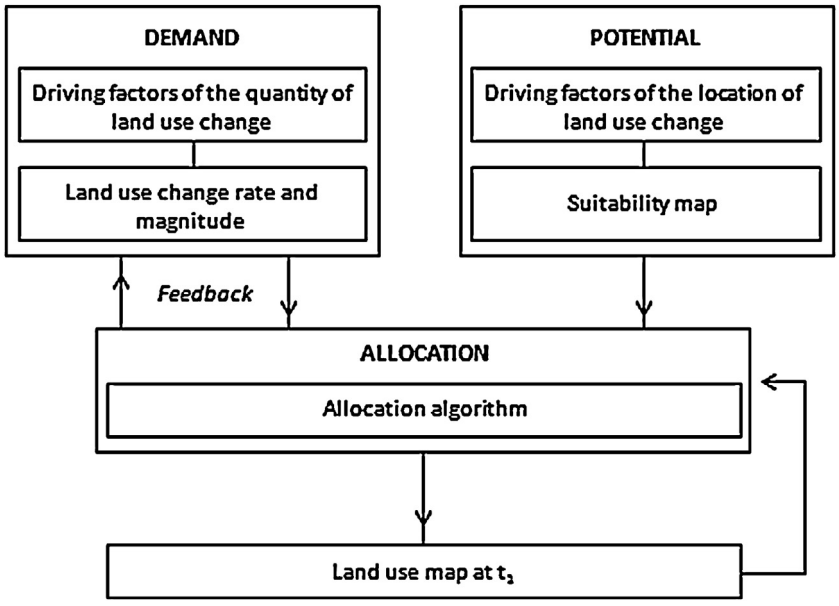

Fig. 1. General structure of spatially explicitly land use models.

Adapted from Verburg et al. (2006).