Chapter 9
Theory, Data, and Methods:
A Review of Models of Land-Use Change

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ABSTRACT

Land-use change models are tools to support analyses, assessments, and policy decisions concerning the causes and consequences of land-use dynamics, by providing a framework for the analysis of land-use change processes and making projections for the future land-use/cover patterns. There is a variety of modelling approaches that were developed from different disciplinary backgrounds. Following the reviews in the literature, this chapter focuses on various modelling tools and practices that range from pattern-based methods such as machine learning and GIS (Geographic Information System)-based approaches, to process-based methods such as structural economic or agent-based models. For each of these methods, an overview is given for the advances that have been progressed by geographers, natural and economy scientists in developing these models of spatial land-use change. It is noted that further progress is needed in terms of model development, and integration of models operating at various scales that better address the multi-scale characteristics of the land-use system.

INTRODUCTION

Changing patterns of land-use development have significant implications for future changes in climate, land function, global food demand, biodiversity, and associated ecosystem services, and in return, these have implications on subsequent land-use change (de Groot et al., 2002; de Groot et al., 2010; FAO, 2016). During the past three centuries, almost 12 million km^2 of forest and woodlands were cleared, and 5.6 km^2 of grassland and pasture have been diminished on a global scale (Bryant et al., 1997; Ramankutty and Foley, 1999; Davidson, 2017). During the same period, cropland has increased by 12 million km^2 (Ramankutty and Foley, 1999; Davidson, 2017). These land-use changes have significant implications for future changes of global climate, and consequently, have implications for subsequent land-use change.

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Rapid changes in land-use development patterns increase uncertainties related to possible future trends and the effectiveness of policies. This is of importance for the studies of land-change science (Turner et al., 2007) and land-system science (Rounsevell et al., 2012) considering that land is a scarce resource where competing claims interact. This is also important to governments, planners and policy-makers to understand the interactions between human activities and natural resources. The long-term impacts of policy decisions on land-use change may cover many diverse issues such as transportation, zoning, water supply, air quality, natural resources, recreation and ecosystem conservation. In this respect, there is a growing need for forward-looking information and scenario-based policy analysis that addresses these issues through ensuring consistency among past, present, and future assessments.

Considering that land-use change is the outcome of human decisions, land-use patterns reflect the decision-making processes of those who control scarce land resources (Verburg et al., 2006a). Land-use policies such as tax regulations and subsidies, urban growth restrictions, setting aside of land in return for monetary compensation, schemes to encourage urban regeneration and brownfield development, and land-zoning policies on different land uses have caused significant changes in urban landscapes (Randolph, 2004). As such policies and restrictions are influential on spatial development, it is important for policy-makers to develop appropriate policies and take necessary actions to keep pace with continuous spatial development. In this regard, land-use modeling approach can be considered as a tool to examine changes of land-use and pattern and to support planners and policy-makers in developing more informed policies and decisions (Verburg et al., 2004). Models are useful for resolving the complexities stemming from socio-economic and biophysical factors that influence the spatial pattern of land-use change (Figure 1), and for estimating the impacts of changes in land-use (Veldkamp and Fresco, 1996a; Verburg et al., 2004; Meyfroidt et al., 2013).

The initial studies of land-use modeling applications have mainly focused on biophysical factors (e.g. aspect, topography, soil quality etc.) given vast availability of such data. However, incorporation of data that is based on a wide variety of socio-economic and political drivers is more valued (Wilbanks and Kates, 1999; Veldkamp and Lambin, 2001). The urbanization process accompanied by population growth and in migration to the urban centers is one of the major factors resulting in land-use change (Geist and Lambin, 2002). Other than population change, the increasing volume of international trade of agricultural products and remote urban demand also result in land-use change (e.g. deforestation) (DeFries et al., 2010). In Lambin et al.'s (2001) explanation, in migration is triggered by government policies to open the non-urban land for development through settlements schemes, development projects and construction of industrial plants or commercial centers. Government decisions may include *the goal to secure territorial claims and national political support, to attract international capital, to facilitate market opportunities, or to promote the interests of specific groups through exploiting natural resources controlled by the state* (Lambin et al., 2001, p. 263). The programs and policies on environmental protection such as Kyoto protocol also have important role in driving land-use change (Veldkamp and Lambin, 2001).

Further to this, the influence of remote markets, diffusion of technologies and political forces were shown to influence the land-use system. Urban centers have significant impacts on land-use change through *changing consumption patterns associated with urban lifestyles and their wider networks of influence* (Meyfroidt et al., 2013, p. 440). These objectives, policies and technology-related and external factors, and the settlement-infrastructure development have subsequent impacts on land-use and cover; and their impacts vary by different regions (Lambin et al., 2001). Veldkamp and Lambin (2001) stated that the inclusion of these socio-economic, political and technology-related factors in land-use modeling applications is hampered by lack of spatially explicit data and methodological issues in linking social