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Evolution of land use change modeling: routes to different knowledge schools

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Abstract

Although much has been published on land use change modeling (LUCM), no study has comprehensively dealt with the evolution of land use models based on knowledge schools. The primary objective of this paper is an explanation of the progress and growth of LUCMs considering their main ontological, epistemological, and methodological origins. Five main paradigms; i.e. positivism, post-positivism, constructivism, participatory, and pragmatism approaches are discussed in order to assess the current orientations of LUCMs. Given the complexities of the LUCMs components, the study concludes that one paradigm cannot adequately address all methodological aspects. Accordingly, it is necessary to combine quantitative and qualitative paradigms to create mixed method approaches within a systemic framework. Such systemic approaches could shape the most probable future generations of the LUCM, which would be able to cope with the complexity of various subsystems, including biophysical and socioeconomic.

Keywords: environmental planning; land use; land management; modeling; knowledge school; sustainable land use.

1. Introduction

Land use change models (LUCMs) can be developed with different goals in mind and in a variety of forms through the combination of models and due to their ability to understand and project land use change systems, represent human decision making, create links between human and environmental systems, and deal with questions about the challenges of environmental sustainability (Brown et al. 2013). When reviewing LUCMs, there are many criteria that can be found and used to classify the different models (Overmars et al. 2007). Based on Verburg et al. (2004), there are a significant number of models that outline land use from different backgrounds that have been developed by those that have researched and studied a variety of disciplines. They emphasize that the most important tasks for future research is to combine the strengths of all existing ideas, methods and tactics rather than expounding upon the method that belongs to the modeler's own field of study. Moreover, for modelers to further the traditions of their respective fields and build models that truly span different fields of study, it is necessary to increasingly integrate tactics and approaches that have been developed in various areas (Kooman et al. 2008; Witlox 2005).

The literature review revealed that there has been great advancement in developing models that outline land use change. Nevertheless, the new forms of land use modeling need to be made in order to create more dimensions of land use systems; such models are more likely to be successful when dealing with the multi-dimensional components of land use systems. They can better utilize new approaches when it comes to measuring neighborhood impacts, determining accurate responses to temporal changes and can more fully integrate various disciplinary methodologies as well as create more combinations of LUCMs for rural and urban areas. By gaining such advancements in the development of LUCM, researchers are able to evaluate land use changes and to better develop effective land use policies (Verburg et al. 2004).

There are many reasons that demonstrate the importance of understanding philosophy, especially when it comes to developing a proper LUCM. Philosophy gives the land use modeler the opportunity to clarify and identify the methods conducted within the model (Easterby-Smith et al. 1997). This would include the assorted collected data and its source, the explication of the data, and the way it responds to research inquiries.

Moreover, with a better understanding of philosophy, the land use modeler can become more inventive and imaginative when choosing or refining methods that s/he has never utilized before. The philosophical orientation of the land use modeler also has implications for the creation and application of preferred LUCMs, including the choice of the applied method. Working without being aware of the philosophical that underlie the situation does not necessarily signify that the modeler does not also hold such assumptions, rather, they in the process of developing a study that has resulted from assumptions that have not yet been examined or recognized. Therefore, it is crucial that the prevailing paradigms and that the basic philosophical assumptions are understood when creating and conducting LUCM and when contributing to the theoretical and methodological discussions in the model. During the last few decades, numerous LUCMs have been conducted to fulfill land management requirements, to improve the evaluation process, and to plan the future role of LUCCs in the natural system function (Veldkamp and Lambin 2001). Numerous literature reviews (Agarwal et al. 2002; Heistermann et al. 2006; Wainger et al. 2007; Mitsuda and Ito 2011; Wicke et al. 2012; Terry and Sohl 2013; Lee et al. 2015) regarding the approaches of land use modeling have been conducted over the last few years due to different views and the development of various typologies. According to Briassoulis (2000), both the epistemological basis and the contributing disciplinary characteristics critically influence the view of land and land use which, in turn, affect the methods of theorizing and modeling land use change. As a result, the role of knowledge claim schools in terms of land use change needs to be stressed.

One of the compelling reasons why there is a need for research on the philosophical routes of LUCMs is because the changes to land use occurs through the effect of many macro and micro factors, functioning within differing time frames and geographical space. Models are used to estimate and do not predict things precisely. Thus, the results that they produce should be considered with regard to the model's qualifications, assumptions, and limitations. Models depend on mathematical equations and data in order to simulate the "real world". Their reliability is mostly due to the quality of the data used and the principles that govern decision making and on the assumptions applied. Therefore, understanding the philosophical routes will help us recognize the ontological, epistemological, and methodological nature of LUCMs. Such an understanding directs thoughts concerning land use change, illustrates conceptual and operational expressions of change, its determinants and their relationships, and suggests explanatory plans for making sense of available empirical evidence; i.e. to support model building. Accordingly, understanding the philosophical routes could be an effective guide when predicting the future orientations/generations of LUCMs (determining which elements should be included or excluded in the next LUCMs). This would help us obtain a better understanding of the complex land use systems and to allow us to more efficiently interact with those that determine land use change (Verburg et al. 2004). Otherwise, according to Briassoulis (2000), inappropriate and inadequate awareness of the influence of the knowledge claim schools regarding land use change may mislead policy creation and create more challenges to deal with. This review paper aims to outline the evolution of LUCMs based on different worldviews (positivism, post-positivism, constructivism, participatory, and pragmatism). To meet the objective, we will first explain the different philosophical aspects (including ontology, epistemology and methodology) of each worldview and then try to compare the most known LUCMs against each aspect. Then, we will try to predict the most probable future of LUCM.

2. Knowledge claim schools

The definition of a worldview is "a basic set of beliefs that guide action" (Guba 1990, p. 17) or a common orientation of a researcher with regard to the universe as well as the content of a given study (Creswell 2009, p. 5). Ontological, epistemological, and methodological assumptions may belong to different worldviews. Setting a knowledge claim means that researchers launch a project with concrete assumptions about the subject under study as well as the way of learning (Creswell 2003). From the philosophical point of view, researchers mainly make claims about the definition of knowledge (ontology), the way we recognize it (epistemology), as well as the procedures of investigating that knowledge (methodology) (Creswell 1994). Table 1 and 2 respectively show a descriptive overview and a summary of the three main philosophical aspects and empirical dimensions of the five schools of thought about knowledge claims.

[insert Table 1]

[insert Table 2

Further clarifications of Table 1 and 2 are devoted to a brief discussion of the relationship between each of the five research paradigms and the main land use change models. However, prior to this presentation, it is necessary to discuss the need for and the uses of models within the context of a analysis of the changes to land use . LUCMs may have an effective role in evaluating different effects caused by previous human activities or those that would occur in the future within the nature and/or the socioeconomic contexts. All of which could provide useful information on possible future land-use configurations (Koomen et al. 2008). Lambin et al. (2000) recognized a number of categories of land-use change models, such as the empirical-statistical, the stochastic, the optimization, the dynamic (process-based) and the integrated models. Briassoulis (2000) distinguished the differences of statistical and econometric, spatial interaction, optimization, and integrated models, including a category of model types that incorporate and do not fall into any of these categories. Yet Heistermann et al. (2006) classify LUCC into geographically based (empirical-statistical or rule-based/process-based), economic, and integrated models. All inventories demonstrate that a group of heterogeneous model approaches that have noticeable differences within their theoretical backgrounds, the points where they start, their range of application and so on (Koomen et al. 2008). In this study, five categories of LUCMs have been considered in regard to the main research paradigms. Table 3 summarizes the most important features of each philosophical view of the LUCMs.

[Insert Table 3]

As shown in the table, there are often some common methodological, epistemological or ontological aspects for each model that may be attributed to one or more groups. Importantly, Fig. 1 illustrates how land-use change is understood has shifted from a simplistic (Positivism) to a more realistic and complex (Pragmatism) paradigm over time. Such new models have tried to better address land use systems and their multi-scale characteristics, and to integrate disciplinary approaches at a higher level

(Verburg et al. 2004; Courtney et al. 2015). The evolution of research questions, methods, and the scientific paradigm is reflected in this change (Lambin et al. 2003).

[insert Fig. 1]

3. Main land use change modeling

3.1. Linear models: pro-positivism?

In linear programming (LP), all mathematical expressions for objective functions and constraints are quantitative and linear. The inescapable underlying assumption that is made by modeling the real world via LP is that a linear model is suitable. Yet models constructed solely from linear relationships have certain limitations. The most obvious is that lines poorly model some real-world phenomena. A weakness common to all mathematical programming models is the assumption that input data are considered to be absolutely accurate (Chinneck 2001). Nevertheless, the main advantage of LP techniques is their capability to be managed, understood and computed.

The single and the multi-objective models are two major types of LP models. The first one is conducted in studies that only consider one goal when solving problems and the second one copes with more pragmatic conditions that deal with problems in which several objectives need to be optimized. In both situations, there are one or more objective functions as well as a range of limitations within the procedure to solve the problem. The objective function(s) of the problems of land use is displayed within a mathematical format, bringing about the question: "how much land to allocate to each of a number of land use types in order to optimize objective A (or, B, C, D)?" The objective is, for instance, to reduce the environmental effects and the development cost of land conversion to a minimum or to increase the advantages of such development to an optimum level, and the like (Briassoulis 2000). Two more important models in this group are the LRM (Linear Regression Models) (Chapin 1965) and CCAM (Canonical Correlation Analysis Model) (Briassoulis 2000). There are two groups of linear models, economic and mathematical, that apply statistical techniques in order to derive a mathematical relationship between the dependent and sets of independent (or predictor) variables. The study area is often split into several zones according to the selected density and the data gathered. They are usually cross-sectional, fixed models functioning according to the yearly-based data collection (Briassoulis 2000). In this type of situation, it is necessary to have rich datasets and elaborated statistical models (Agarwal et al. 2002). Economic models are produced through general or partial equilibrium sets of macro-economic equations that do not consider land as spatially explicit, rather, it is usually represented as a factor of production (Alcamo et al. 2006). The main goal in econometric modeling is to estimate the changes in some determinants of land use (such as: population density, retail and housing demand, employment, rates of salary, rents, earnings) and then through utilizing land use/activity factors and coefficients whose estimations are expressed in the form of land use type demands. The EMPIRIC model is one of the well-known econometric models (Hill 1965; Pack 1978) which represents a prototype model built in the 1960s and was used as a rather simple vehicle to model metropolitan structure (Briassoulis 2000). Other examples include the GTAP and the NEMESIS models. GTAP as an example of a general equilibrium model that deals with land-use change and represents the entire economy and the primary interactions between economic sectors of one or multiple regions (CBES 2009). These models are able to be used in order to define the global demand for various kinds of land-use (Mudgal, et al. 2008), NELUP (Natural Environment Land Use Program) (O'Callaghan 1995) and METROSIM (U.S. E.P.A. 2000).

While LP is a very effective method that is capable of taking care of problems that have very high dimensions (in terms of the number of variables, relations, and constraints). It also has the intrinsic drawback that all of the relations, constraints and objectives need to be formulated linearly. It is also necessary for the variables to be continuous (quantitative). This linear quality is not often applied within land-use planning due to the qualitative characteristic of the relations as well as the discrete characteristic of (a number of) the variables that have to be optimized (Loonen et al. 2007). Accordingly, land use linear modelers believe that they are able to control their biases and the environment sufficiently enough in order to identify a true objective which is able to, in turn, to become generalized into universal laws or principles (Coyle and Williams 2000; Greenfield et al. 2007). In order to test a specific part of a general theory, or principle, in order to determine a conclusion, they use deductive reasoning. As positivists, land use linear programmers usually put forth a hypothesis or prediction about a set of variables from a particular theory and then attempt to test and verify the relationship between these variables. Consequently, since land use linear modelers believe that such tests have a crisp methodology and trust that reality can completely be formulated, the biases of the researcher have no place in the model and they believe that the future can be fully predicted.

As a result, from the philosophical point of view and according to Table 3, linear models are oriented in a positivism worldview, but from the ontological aspect, they are more in line with post-positivism. Similar to positivism in which the researcher's job is mainly to discover the reality using quantitative and experimental methods that may not involve researcher's personal biases to influence the outcomes, the modelers also use such methods, mostly regression analysis, to describe the constant relationships between variables. In both positivism and LP approaches, the modeler and participants are supposed to be independent and should not influence each other (Lincoln and Guba 2000). However, similar to the post-positivists, LP modelers concur that they are able to discover the actuality of the situation within a certain realm of probability, only inhibited by the researcher's human limitations. Therefore, in LP models, the modeler may not be able to prove a theory, and primarily, they are able to make an even stronger case by getting rid of alternative explanations; a method that is in line with post-positivist principles.

3.2. Static models: pro-post positivism?

The static models (stationary, steady state or cross-sectional models) describe the state of the system as an equilibrium resulting from a long period of constant inputs. The static models do not simulate the transient behavior of the system for the time of interval that it is unstable, but these models give a description of the stable equilibrium of a system, which may be reached after a very long span of time. These models describe the structure of a system of distributed parameters as a set of qualitative physical fields. It consists of a distribution model for each individual field and an intersection model for each pair of fields that are to be combined in a composite field (Lundell 1996). One of the well-known static models is the multi-agent system model of changes in land-use/cover (MAS/LUCC) that can overcome certain important limitations of the existing techniques. MAS/LUCC models are particularly well-suited when representing complex spatial interactions within heterogeneous conditions and when making models of decentralized, autonomous decision making (Parkera et al. 2003).

Static models of land use are a function certain of fixed (unchanging) driving factors. These kinds of models are often strongly based in a statistical regression analysis that demonstrates past and present spatial developments. Static models are able to be used in order to test our knowledge of the driving factors regarding land-use changes, though this kind of model does not take into account temporal feedback and path dependencies (Verburg et al. 2006). Non-temporal static models, naturally, are not based in time, but rather, on the key ecological landscape attributes that are by the land's patch size and its connectivity. These models may be built within a variety of scenarios, ranging from static land use or from management decisions through the use of appropriate ecological indicators. The ecological impact of land use change is, essentially, a simple model that does not reference time.

Although these models predict the following phenomena of causal relationships, just as post-positivism, the fact is, they are not stable in all situations (unlike linear models and positivism); rather, it is constructed by those that are engaged in the study. They are of the opinion that the reality has a multiple (rather than singular) nature, is subjective, and that individuals mentally construct it, that our understanding of reality can be different depending on the context, and that reality cannot be fully understood otherwise. Although a great amount of effort and time is given to static models, the ability to generalize the results brings them in to question due to the studies focus on situational and conditional contexts; thus, just like post-positivism, making the conclusions all the more conditional and temporary (Tekin and Kotaman 2013). One of the strengths associated with static models is that, like post-positivism (Ponterotto 2005), these models recognize that not all knowledge is gained from one single method. Instead, the modeler aims to implement several measurements in the investigation process and rejects the notion that they are able to capture objective reality seamlessly. Indeed, idealism is disproved and critical realism and multiplism are accepted, which prove that the model can usually be considered from different dimensions. In-depth information from a variety of sources allow the complex web of interactions among variables to be understood, providing a greater chance to improve (Lor 2011). Static models as well as a post-positivist paradigm leans towards the predominant use of quantitative methods in order to collect data and analyze it, however, the increasing use of qualitative techniques is also recognized (Mertens 2005). The researcher interacts with the subject under consideration and the results in the static models are the consequences of this interplay that focuses on the concept and comprehension of the stance being researched. Consequently, in order to demonstrate valid research, a degree of proof that corresponds with the study's results, is necessary(Hope and Waterman 2003).

3.3. Dynamic models: pro-constructivism?

Transient or dynamic models describe the reaction within the system to dynamic inputs. They describe the transient state of the system, even if it is not in a state of equilibrium. But rather, they describe the behavior of the system during the time span needed to reach equilibrium. This approach is usually taken when a time varying input requires a response from the system. Time is one of the important variables in model algorithms and the results can be interpreted as the state of the system at a certain point of time. Dynamic models describe the behavior of a distributed parameter system in terms of processes acting on fields, the qualitative functional relationships between the parameters and the changes to the static model (Lundell 1996). Each of these works in junction with intermediate time-steps that could possibly become the starting-point calculations of the following situation. The case of dynamic modeling, therefore takes into account possible progress (throughout the time of the simulation) and tries to provide a richer model of behavior and the chance to more thoroughly mimic the real-life spatial developments (Koomen and Stillwell 2007).

Some of these models in LUCM consist of the General Ecosystem Model (GEM), the Patuxent Landscape Model (PLM), the Forest and Agriculture Sector Optimization Model (FASOM) (Agarwal et al. 2002), CLUE-s (Conversion of Land Use and Its Effects) (Verburg et al. 2006) and Cellular Automata (CA) (Voigt and Troy 2008). Dynamic models specifically concentrate on the dynamics of land-use systems that involve time as it is depicted by the competition between land uses, the path-dependence in system evolution due to irreversible past changes, and trajectories of land-use change that are fixed. Another category of LUCMs includes dynamic models that apply optimization methods that are presented by dynamic programming models which have been useful in dealing with constraints related to the land use analysis (Briassoulis 2000). Modelers of dynamic land use models conduct a mathematical form of programming that is usually beneficial in finding a suite of interconnected solutions. This technique provides the dynamic land use programmers with a systemic procedure that determines the composite decisions that maximizes the general efficiency of policies. Azadi et al. (2009a) and Azadi et al. (2007) used such approaches in their study of sustainable rangeland management. In contrast to LULPs, dynamic land use programmers do not use a standard mathematical formulation of programming on the problem. Instead, a tailored approach is developed to deal with the problem, and specific equations conducted by programmers need to be modified in order to adjust to different conditions (Briassoulis 2000; Hillier and Lieberman 1980).

Unlike constructivism, by using dynamic models as statics, the reality of the situation is external and is considered to come from outside of the researchers' minds and the researchers are unable to import their bias into the models. But like constructivism and unlike the static models, the modeler's background and experience have an important role when it comes to understanding the reality of the topic; such reality is not only different in different places, but also in different times. It means that the reality is not one singular facet, but multiple and socially constructed within these models and that how reality is perceived may change through or at any point during the process of study (Mertens 1998). In other words, studies where the modelers follow the constructivist view, in which those conducting the research interact with the participants of the study in order to get information and knowledge, are dependent on the context and the time of the study (Coll and Chapman 2000; Cousins 2002). In these models, like constructivism, inputs and independent variables are not fixed; they can be diverse and flexible in scale and type. The dynamic modelers as well as constructivist researchers are mainly in favor of methods that collect qualitative data and analyze them or a combination of the two methods, qualitative and quantitative (Mackenzie and Knipe 2006). For instance, Houet and Hubert-Moy (2006) utilized a time-series of aerial photographs and satellite imagery comprised of different spatio-temporal scales in order to identify landscape characteristics as well as the spatial features and the temporal changes of land-use/ -cover from 1950 to 2003. Furthermore, in the constructivism approach, quantitative data is able to be utilized in a manner that backs or elaborates upon qualitative data and efficiently enhances the description. Houet and Hubert-Moy (2006) also determined both biophysical and socio-economic drivers of existing dynamics by collaborating with members and organizations that are interested in sharing information and materials and were interested in conducting developed methods and tools as well as model outcomes. All of these input data were confirmed, examined, and evaluated in terms of applying spatial statistical methods in order to measure spatial associations. Furthermore, the modeling processes of cellular automaton are used to provide a spatially-explicit model according to the simulations of future trends of LUCC. As a result, in these models, the outcome of the inquiry is constructed through the joint effort of the researcher and respondents during the modeling process.

Dynamic models are clearly different from statistical models due to the way a phenomenon is represented and built with parts of a system that we can confirm occur in reality and describes input-output relationships. They do not depend on historical or cross-sectional data in order to reveal those relationships. Though, the advantage this provides also permits dynamic models to be utilized in further applications apart from empirical models (Agarwal et al. 2002). As shown in Table 3, from the methodological and epistemological aspects, these models can belong to post-positivism and pragmatism worldviews, both of which depend on the values of the researchers so that the research cannot be independent from them. These models rely on how reality is socially constructed in ways that the study can only be carried out through the interactions between the investigator and the respondents (Lincoln and Guba 2000). Since from an ontological point of view, dynamic models are related to constructivism and post-positivism worldviews, the aim of the modeler's is to comprehend the multiple social constructs regarding meaning and knowledge and that objective reality can be known.

3.4. Hybrid models: pro- participatory?

The participatory approach is a group of procedures that experts and stakeholders use to cooperate in order to produce different scenarios (Alcamo et al. 2006). Often, the hybrid approach is used as a means to overcome the boundaries of the previous approaches and to take advantage of their strengths (Rindfuss et al. 2004), trying to include the strengths of each representation (Bonan et al. 2004). The result is a hybrid model that usually is a mixture of other models (Wien et al. 2010).

Hybrid models of LUCC begin with an estimator model, but continue with simulation patterns. The patterns utilize the estimation model's parameters in order to predict the spatial drivers of LUCC that can possibly occur within various scenarios imposed exogenously (Irwin and Geoghegan 2001). Some examples of hybrid models are: LUS (Land Use Scanner) (Hilferink and Rietveld 1999), SELES (Spatially Explicit Landscape Event Simulator) (Haase et al. 2007), ProLand and UPAL (Sheridan et al. 2007), the Simulated Land Use Dependent on Edge-Effect Externalities (SLUDGE) (Verburg, et al. 2006), Dyna-CLUE (Verburg et al. 2008), and MOLAND (Monitoring Land Use Changes) (Engelen et al. 2007). Hybrid models try to combine some of these techniques together, every one of which is a moderately discrete approach in and of itself. A relevant example is the estuarine LUCC transition modeling which consists of an explicit, cellular model connected to a system dynamics model. Other similar combinations of these models include DELTA, which integrates sub-models that pertain to human colonization and ecological interactions in order to estimate the amount of deforestation that occurs in various immigration and land management scenarios. Further examples that utilize different statistical techniques in combination with cellular and system models consist of larger-scale models, such as GEOMOD2 (Hall et al. 1995) and the CLUE family (Veldkamp and Fresco 1996b). The latter is a cross-disciplinary approach, integrating both socio-economic and biophysical aspects that can be described as an integrated, spatially explicit, multi-scale, dynamic, and economy-environment-society-land use model (Briassoulis 2000). Gibon et al. (2010) noted that it is necessary that the socio-ecological processes in the modeling are taken into account and to elaborate the scenarios with a hybrid or integrated and participatory approach that regards the investigation of alternative futures inland change (Houet et al. 2010).

During the process of participatory research, participants actively create, modify, and test the different forms of knowledge in an iterative research process, validating the outcomes of the research (Hosseininia et al. 2013; Breu and Peppard 2001). Similarly, in hybrid models, modelers try to develop a combined method from two separate models in order to offer a useful method that optimizes the performance models that track land-use change. Such a combination can be found in the study of Soares-Filho et al. (2013), who developed a hybrid analytical-heuristic method for calibrating land-use change models. They constructed and applied a tool using a Genetic Algorithm in order to produce optimal deforestation probability maps of that are generated using the Weights of Evidence method in 12 different case-study sites in the Amazon in Brazil. The results showed that by modeling deforestation after the Genetic Algorithm tool was coupled with the Weights of Evidence method, was able to surmount fitting and improved the validation of the fitness scores at a computational cost that was acceptable . There also is an already established body of research that uses the participatory approach in developing LUCMs through the involvement of stakeholders in developing hybrids models. One good example of that is the participatory model of land use change that is agent-based, which is only one of a sequence of tools utilized in assessing integrated environmental situations (Hisschemoller et al. 2001). Varieties of participatory agent-based modeling are participant observation and 'companion modeling' (Barreteau et al. 2003), which consists of members of the study population that become actively involved in model design and its validation (e.g. Bharwani et al. 2005). For example, D'Aquino et al. (2003) applied the method of companion modeling regarding management issues of land use in Senegal. Ramanath and Gilbert (2004) reviewed different general methods to participatory agent-based modeling.

Perhaps linear, static and dynamic models cannot be attributed or related to a particular worldview, but according to some features, it can be claimed that the principles of these models are closer to a participatory worldview than any other. Those features are as follows:

- Using a combination of (usually two) methods,
- Believing that the complexity of the process is comparable to reality,
- The need for people with diverse expertise to participate in the process of designing a model,
- The methodological imperative that requires the researcher to engage in research with people rather than in doing research on people,

- Avoiding purely top-down methods in model design, and
- Attention to non-biophysical variables in addition to the biophysical in a model.

Accordingly, this group mainly has post-positivism, participatory and pragmatism worldviews regarding the methodological and epistemological aspects of models, while from an ontological view, they mostly take constructivism, participatory and pragmatism worldviews. Similar to pragmatism, hybrid modelers emphasize the creation of knowledge from lines of points of action directed toward the types of "joint actions" or "projects" that different people or groups are able to accomplish while working together (Morgan 2007). However, like constructivism, reality is socially constructed in hybrid models and how reality is perceived may change through and during the study's process as some of the perceptions may be in conflict with each other. Above all, hybrid modelers use a combination of approaches available to understand the problem. In these models, the effectiveness of the approach is becomes the criteria that is used to judge the worth of research, instead of the findings corresponding to a "true" aspect of reality.

3.5. Integrative models: pro-pragmatism?

Integrated models generally arose in the 1960s in a "quantitative revolution" in regional, urban, and geographic assessments. Integrated models, also called comprehensive or general models, are based on integrating different elements of modeling techniques more and more. Indeed, the most effective elements are put together in order to answer the specific questions in ways that are the most appropriate. Accordingly, in the pragmatic tradition, when we first face a problem, our first task is to understand our problem by describing its elements and identifying their relationship. Integrated models consider various environmental, social, economic, as well as institutional aspects of an issue (Rotmans and van Asselt 2001). Increasingly, these models are called integrated models. Even though in numerous cases, due to the fact that level that they are integrated is sometimes low, they are more fittingly described as hybrid models (Lambin et al. 2000). Numerous integrated models have been built since the mid-1960s. They are spatial models, meaning that they focus on the interplays between a range of dimensions within a spatial structure, but are not comprise of a spatially explicit reference (for instance, energy-economic, demographic-economic, environmental-economic, and so on). Some examples of these models are: IPDMSs (Integrated planning and decision-making systems), MEPLAN, TRANUS (Tranus Integrated Land Use and Transport Planning System) (U.S. E.P.A. 2000), CLUE-CR (Veldkamp and Fresco 1996a), PLM (Patuxent Landscape Model) (Voinov et al. 1999), UrbanSim (Waddell 2002), DSSM (Dynamic Settlement Simulation Model) (Piyathamrongchai and Batty 2007), LUMOS (Land Use Modelling System) (Beurden et al. 2007) and MAS (Multi-Agent Simulation) models (Loibl et al. 2007). Given the fact that values, aesthetics, politics, and social and normative preferences are an integral part of pragmatic research as well as how it is interpreted and utilized, it is noticeable that integrative models are in line with this integral principle of pragmatism.

One of the general features of integrated models is their large-scale, besides their integration characteristic discussed above. Considering the objective of the model, the concept of integration differs and is represented in the integrated system (Briassoulis 2000). The complex nature of the causes, processes, and impacts of land change has impeded the development of an integrated theory regarding land-use change (Lambin and Geist 2006). Integrative models have been suggested as a key method in order to improve how complex systems are managed and to provide information that is objective on the options decision makers have regarding policy (van Ittersum and Brouwer 2010).

Therefore, the goal of these modelers, like pragmatists, is to search for useful points and ways of connecting that also combine different techniques from different disciplines or models in order to improve their knowledge and practical understanding of reality. Both also believe that how we combine the different methods depends on the time, place and circumstances of their political, economic and social aspects, all of which can be mean different things from one another depending on time and place. Similar to pragmatists who clarify a hypothesis by identifying its practical consequences when applying integrated models, it is not necessary to combine all components of two or more models either. Additionally, depending on the situation, certain techniques can be chosen. The scientific method in integration models is similar to pragmatism, in which an experimental methodology is conducted, and the application of the pragmatist maxim reveals how hypotheses can be subject to experimental tests. Like pragmatism, someone who is knowledgeable of integrative models is an agent who obtains empirical support for his/her beliefs by making experimental interventions in her surroundings and by learning from the experiences that his/her actions elicit. Recently, many national and international programs have enforced the necessity to produce models that involve different processes, that ultimately aim to develop integrated models that are able to simulate the processes and consequences that are important for certain landscapes or societies (Janetos 2004). These models mainly have a pragmatism worldview of all the three ontological, epistemological, and methodological aspects. Although, the former may have some elements of the participatory paradigm.

4. Discussion and conclusions

As discussed in this paper, establishing multi-scale methodologies that lead to enhancing and conducting evaluations, on both a small and large scale, is a critical challenge that has not yet been addressed. Such development can provide the opportunity to identify various influential drivers at different levels. As such, out of all of them, the main obstacles is obtaining data of specific regional economies and policies. Information that would be relevant on regional or local levels in order to establish how land claims are allocated between different sectors (Azadi et al. 2011). Most modeling frameworks and tools utilize a top-down method, which takes different the national scale and two different spatially explicit scales, into account (Fig. 2). Consequently, driving social forces like quality of living, official and unofficial social regulations, and the priorities and manners of local people are usually not appropriately indicated in the majority of modeling methods (Mudgal et al. 2008). However, such drivers can pose substantial effects on the changes of land-use, especially at regional and local levels. In this regard, Azadi et al. (2009b), Ho and Azadi (2010) also emphasize that, unlike environmental factors, for example, socio-economic drivers are not usually used to assess the severity of degradation. Also, they argue that if socioeconomic factors were taken into consideration, the evaluation of degradation trends would relate more fully to real life.

[insert Fig. 2]

Therefore, land-use modelers will not only need to take into consideration of the relative importance of various drivers regarding land-use change (Agarwal et al. 2002), but also will need to integrate various drivers to be able to provide important improvements in land use models in the future. Issues like the integration of socioeconomic and biophysical drivers, improving agent-based decision-making models, enhancing the ability of modeling land-use decisions in terms of lag time and their thresholds, and using mixed methods in multi-source integration of data (e.g., the remote sensing using a census and data from household surveys) gain additional importance in this context. As a result, assessing different LUCMs based on different knowledge claim schools in this study showed that modelers have moved towards more qualitative approaches. Denzin (2001) also says that "the days of naive realism and naive positivism are over" and adds that "the criteria for evaluating research are now relative". Qualitative researchers are primarily concerned with the process, rather than outcomes or products. Yet, there is no escaping the reality in qualitative research that the researcher is an tool that screens data through their own respective paradigms. Those that conduct research cannot be objective and their research and intuition will be laden with values. It is significant that research design and the researcher are separated in terms of their paradigmatic, ontological, epistemological, and methodological aspects.

Therefore, evaluating different LUCMs according to their philosophical routes demonstrates that due to the complex nature of the LUCMs, there is no single paradigm that could satisfactorily deal with all of the required methodological aspects. As a result, it is necessary to combine the quantitative with qualitative paradigms in order to create mixed method approaches within a systemic framework. The blending of both paradigms can provide land use change modelers with the ability to cope with the limitation of the existing methodology of LUCMs. Thus allowing for the collection multiple sets of data that use different research methods, epistemologies, and methods in a manner that results in a mixture or combination that consists of complementary strengths and does not have any overlapping weaknesses (Johnson and Turner 2003). These models ought to rely on scales that are global, regional and local, and on digital databases. Not only on land-cover classes, but also on methods of land management (like fertilization, irrigation, etc.) that allow for increased participatory, open GIS and data sharing. Furthermore, researchers of change in land-use will need to diversify their portfolios of analytic methods further: not only with multiple regressions, but with narratives, system and agent-based approaches, network analysis, etc., as well. (Lambin et al. 2006). On the other hand, when LUCMs do not take the presence of nonlinearities and spatial and temporal lags into account, which exist in environmental systems, their ability to understand the mutual complexities between human and environmental systems may be significantly reduced.

All these reveal that there is a crucial necessity to produce a systemic framework in order to collaborate and develop models (Agarwal et al. 2002) that can cope with the complexities and interactions of various subsystems (biophysical as well as socio-economic). Systemic models are more complex than others and the difficulty lies in deciding how to incorporate such complexities. Nevertheless, once a systemic model is constructed, if-then scenarios are able to be more readily formulated in comparison to other modeling approaches that are not oriented systemically. Particularly, a systemic approach is able to examine the feedback that exists within socio-ecological systems. In this regard, many studies (Houet et al. 2010; Gaucherel et al. 2010; Valbuena et al. 2010; Sohl et al. 2010 and Verburg et al. 2010; Courtney et al. 2015) emphasize the need to combine modeling approaches and techniques in order to further reduce the uncertainties of the future landscape. In order to monitor, model, and assess the interactions among and in humans/nature, landscapes' temporal dimensions have to be considered as significant as its spatial dimensions. Communally, combining modelling approaches and techniques opens up new avenues of research in the science of LUCMs. The systemic perspective represents the dynamics of the links between the economy and environment that operate from regional to global scales (Azadi and Filson 2009). It concerns issues such as technological innovations, changes in policy and the institution, environmental conservation, ownership of collective land resources, physical geography, dynamics of rural-urban areas, and macroeconomic transformations (Briassoulis 2000). Hence, it appears more sensible to use a systemic approach, rather than to rely on a single theoretical schema, which will inevitably miss some dimensions of the case under study or will be too complex to be easily understood and useful. Nonetheless, to achieve this systemic model successfully, it is necessary to critically examine which paradigm is suitable for which study scale. To do so, research paradigms help modelers conduct the study in a more effective method. According to Johnson and Christensen (2005), research paradigms are perspectives that are based on a set of shared assumptions, values, concepts, and practices, which would indeed be helpful in developing a systemic approach when analyzing LUCMs. Most researchers agree that it is very important to begin the research process by identifying the researcher's own worldview (Creswell 2007) and the research paradigms that consist of different approaches and research philosophies. The combination of all this helps researchers come to an understanding and develop knowledge base regarding the topic being studied, which, in our case, is developing a systemic approach within LUCMs. In the research paradigms, there are different factors that affect the study's ability to effectively apply a certain approach, like time constraints, budget constraints, etc. By using the suitable research paradigm and philosophies, researchers help exclude these factors from the study. Moreover, the specialist needs more useful data in order to reinforce the utilization of LUCMs, the integration of models that work at various levels, and the coupling of models that address both positive and normative dimensions of land use and cover patterns, as well as its dynamics (Brown et al. 2013). In this regard, when a modeler understands the philosophy of a study, he is able to conceive the constraints of special methodologies. Which in turn will help him to assess the various approaches and techniques and will prevent him from making burdensome mistakes when selecting suitable methods or wasting his time performing non-essential tasks (Easterby-Smith et al. 1997). If a researcher, for instance, can evaluate the difference between a model constructed according to a positivist paradigm and a model that is based on a post-positivist worldview, the suitability to the model requirements will be noticable and selecting the most suitable approach can then simply be specified. This was confirmed by Brown et al. (2013), who emphasized that it is essential to select an appropriate modeling approach for scientific or decision-making goals under consideration. This paper also described the major paradigms so that new modelers can justify selecting and combining different paradigms that best fit their proposed systemic approach in LUCC studies. Since research is described as a systemic process (Wiersma and Jurs 2004), it would seem reasonable to make the future trend of LUCMs as systemic as possible. This study clearly discussed that the function of paradigms is more important than selecting an approach, yet does not effectively address developing LUCMs within a systemic framework.

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Fig. 1. Classification of the LUCMs based on different knowledge schools.

Fig. 2. Top-down allocation procedure (Adapted from Verburg et al. 2004).