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Urban land-use change: The role of strategic spatial planning

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ABSTRACT

To date land-change science has devoted little attention to spatial policy and planning in urban landscapes despite the widely accepted premise that planning affects urban land change. This is primarily due to lack of relevant data and an underdeveloped theoretical understanding regarding the impact of spatial planning on urban land change. To be able to better analyse the role of spatial planning in urban development we need to distinguish: 1) the intentions expressed in the plans; 2) the means of implementation of the plans through governance processes and 3) the role of external conditions influencing implementation. Based on a synthesis of the current literature on how spatial planning is implemented in land-change models, and drawing from the literature on planning evaluation, we sketch a research agenda to further develop the understanding of these three components and their interconnections as well as their application in quantitative land-change modelling approaches for urban regions.

1. Introduction

Land change is one of the key processes of global environmental change (Magliocca et al., 2015; Turner II et al., 2007; Verburg et al., 2015). The studies on the topic have gradually advanced from a focus on patterns of land-use and land-cover change to an analysis of dynamic interactions within socio-ecological systems and the resulting impacts on, for example, ecosystem services and biodiversity (Rindfuss et al., 2004; Rounsevell et al., 2012). In this context, land change is understood as the result of interacting political/institutional, economic, cultural, technological and natural/spatial driving forces and the respective actors (Bürgi et al., 2004; Hersperger et al., 2010). Whereas data on economic and natural conditions have a long tradition in being used to explain land changes, researchers only recently started to pay attention to policies, plans, and regulations on land use, within their specific institutional and governmental contexts. Meta-analytical studies have emphasized the role of land-use policies and spatial planning as a major underlying driving factor for many different land-use change processes (van Vliet et al., 2016).

Compared with forest and agricultural related research, studies on land change in urban regions are so far a small part of land-system research (Geist et al., 2006; Magliocca et al., 2015; Seto et al., 2011). However, urban regions, which are also broadly defined as cities or metropolitan regions, are some of the most dynamic land-change systems worldwide. With strong further urbanization expected over the coming decades they will cover increasing areas of the earth surface and host the majority of the human population (Seto et al., 2012). At the same time, urban land change is not restricted to the core city, but includes many new urban-rural spaces functionally tied to the city (Brenner and Schmid, 2015) and has many impacts on rural hinterlands (Bren d'Amour et al., 2016) and hence deserves more attention in land-change science (Müller and Munroe, 2014).

A widely accepted premise is that, especially in urban regions, spatial planning - a multifaceted activity with many purposes, including project planning, master planning, land-use planning and strategic planning - influences patterns of land use and land cover (Couclelis, 2005). Amongst the many purposes of spatial planning, spatial planners and governments have been trying to steer urbanization processes with the aim of developing sustainable cities and regions (Albrechts et al., 2017; Collier et al., 2013). However, conceptualizing the role of planning in guiding land change is a great challenge (McNeill et al., 2014). This is partly due to the fact that research on the contribution of planning to land change is at the interface of two paradigms (Briassoulis, 2008; Hillier, 2007): planning scholars tend to stress contextuality and social construction of space; whereas land-change scientists incline to assume the existence of realities that can be objectively described and measured and lend themselves to generalizations. The difference between the two paradigms can be illustrated

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through how they position themselves in respect to the concepts of space and uncertainty. Many urban geographers and planning theoreticians conceive space as a social construct (Harvey, 2006; Lefebvre, 1991) and expect future urban development to be open ended. Uncertainty is inherent; to be expected and subject to exogenous factors (Graham and Healey, 1999). Land-change scientists quantify and model space by identifying correlation or causality between drivers and outcomes, and strive to identify sources and levels of uncertainty in land-cover projections (Alexander et al., 2016). Research to bridge the two paradigms is sparse. Consequently, planning is not well integrated in quantitative land-change assessments.

In this paper we aim to provide a way forward to better link the planning and land-change domains and thus to enable the assessment of the impact of spatial planning on land change. While recognizing that there are many kinds of spatial planning, it remains unclear which planning is best suited for developing this link, and the answer likely depends on the questions under study. We refer in the text in a general manner to spatial planning whenever possible, but when we discuss examples and illustrate our points we focus on strategic spatial planning. Strategic spatial planning commonly practiced in urban regions is suitable for exploring the link between planning and land-change domains because of (1) the territorial extent of most strategic spatial plans covers functional urban regions; (2) the strong focus on a strategic mission in these plans, often 20–50 years into the future; and (3) the fact that strategic spatial planning has consolidated over the last decades in many urban regions around the world. However, in most planning cultures, strategic spatial plans do not influence land management and allocation directly but are defined as frameworks for action (Albrechts, 2004; Hermelin, 2009). Their role is, thus, to help planners frame practical judgments about the pursuit of multiple purposes in changing local situations and to facilitate discussions with citizens and other actors (Albrechts, 2010; Walsh, 2012; Healey, 2009). The outputs of strategic planning processes are the plans, consisting of a written report and often a cartographic representation of the envisioned regional development. Key strategies typically refer to (1) how much growth is expected and/or desired to fulfil the region's need for economic development and housing, (2) where distinct types of urban development (e.g. dense housing, single family homes, mixed uses, industrial facilities) should unfold, and (3) which areas should be protected in order to assure the long-term persistence of natural and cultural assets.

To pursue the aim of linking planning and land-change, we present a conceptual framework based on three interrelated components that help disentangle the role of spatial planning in land change. We start with an analysis of how planning is operationalized in current land-change studies and models and a review of factors crucial for successful plan implementation as discussed in planning-outcome evaluation literature. Based on that, we sketch a research agenda on how to further develop the three interrelated components (i.e. land-change intentions as expressed in plans, territorial governance, and external conditions) in the context of land-change science.

2. Planning in land-change studies and models

In land-change science, spatial planning is often classified as a political driver (Geist and Lambin, 2006), whereas in political science, planning is considered a public policy (Sabatier and Jenkins-Smith et al., 1999). For illustration purposes, Fig. 1 shows on the left-hand side a simple model of explaining land change: Five groups of driving forces determine the actor's autonomy and motivations in taking decisions and subsequently actors cause change (Hersperger et al., 2010). Political and socio-economic drivers are strongly interlinked and mediated by technological forces. These drivers act within a background set by cultural and natural drivers and feedbacks are omnipresent (e.g. Brandt et al., 1999; Bürgi et al., 2004; Rounsevell et al., 2012). When the policy cycle is applied to spatial planning as shown in Fig. 1, the following steps are commonly identified: problem definition, goal formulation, regional and local analysis of past, current and future socio-economic trends and environmental conditions, plan design, implementation, and evaluation (Steiner, 2008; Steinitz, 2012; Hersperger et al., 2015).

Planning thus entails the processes of plan making (designing the plan) as well as plan implementation and is affected by local socio-economic factors and external processes. However, plans are rarely implemented as they are. For example, urban development can occur as informal development in areas that were not foreseen for development or development can be partially lacking in areas that were intended for development (e.g. due to a lagging economy) (Loh, 2011). This incomplete implementation is an issue of governance and poses a mayor challenge for conceptualizing the role of spatial planning in urban development.

2.1. Qualitative and quantitative assessments of planning in land-change studies

Much research on political drivers so far has been in the form of qualitative assessments of policy and planning effects on land change in case studies around the world (Plieninger et al. 2016). A number of studies focus holistically on landscapes and aim to distil a historical description and explanation of land change (e.g. Seabrook et al., 2006; Thapa and Rasul, 2006; Bieling et al. 2013). Such studies highlight how policy and planning shape the changing landscape in interplay with the other driving forces (Fig. 1). For example, Santana-Cordero and colleagues (2017) studied land change, driving forces, as well as actors and institutions in three costal landscapes of the Canary Islands and identified case-specific development models. They found that socio-economic, political and natural driving forces were especially important to explain the very different developments in terms of land cover and land-change processes (e.g. resource extraction and urbanization) in these three landscapes. Other qualitative studies take a slightly different approach and focus on the contribution of planning and policy to land-change (e.g. Bicík et al., 2001; Hersperger and Bürgi, 2010; Zhu, 2013; Hersperger et al., 2014; Pagliarin, 2017). Such studies address the influence of policy and planning, as interplay of drivers and actors, relative to other influences. For example Mu and colleagues (2016) studied the contribution of planning to urbanization. They conclude that national policies favoured urbanization in the hinterlands and that the effect of these policies, reinforced by regional and local planning policy, caused the observed transformation of the study area Zhenghzhou (China) from an agricultural to an urban centre.

Quantitative assessments often use regression models (e.g. Hu and Lo, 2007; Liu et al., 2011; Kasraian et al., 2017), but also other methods such as AHP (Osman et al., 2016) or ANOVA (Warren et al., 2011) to investigate the relative contribution of planning and policies to land change. Typically, planning is represented in a rather simplified approach by a binary variable for conservation (e.g. Hu and Lo 2017) and/or designated growth areas (e.g. Kasraian et al., 2017). Such quantitative assessments have confirmed the role of conservation policies in keeping areas open (e.g. Kasraian et al., 2017 for the Randstadt in The Netherlands) and for guiding growth (e.g. Liu et al., 2011), but also pinpointed the limited effects of plans in certain contexts (e.g. Osman et al. 2016 for Cairo, Egypt). Overall, there are rather few quantitative assessments which might be due to the fact that they build upon a rather simplistic conceptualization of planning, unsuitable to do justice to complex land-change situations.

Qualitative and quantitative assessments, as outlined above, show for locations across the world to what degree political drivers, together with other relevant drivers have affected land change. However, generalizations regarding the role of planning remain difficult because of the diverse and complex socio-economic and natural contexts. Indeed, meta-studies that synthesize case studies and provide more comprehensive results are scarce for urbanization (van Vliet et al., 2016). This

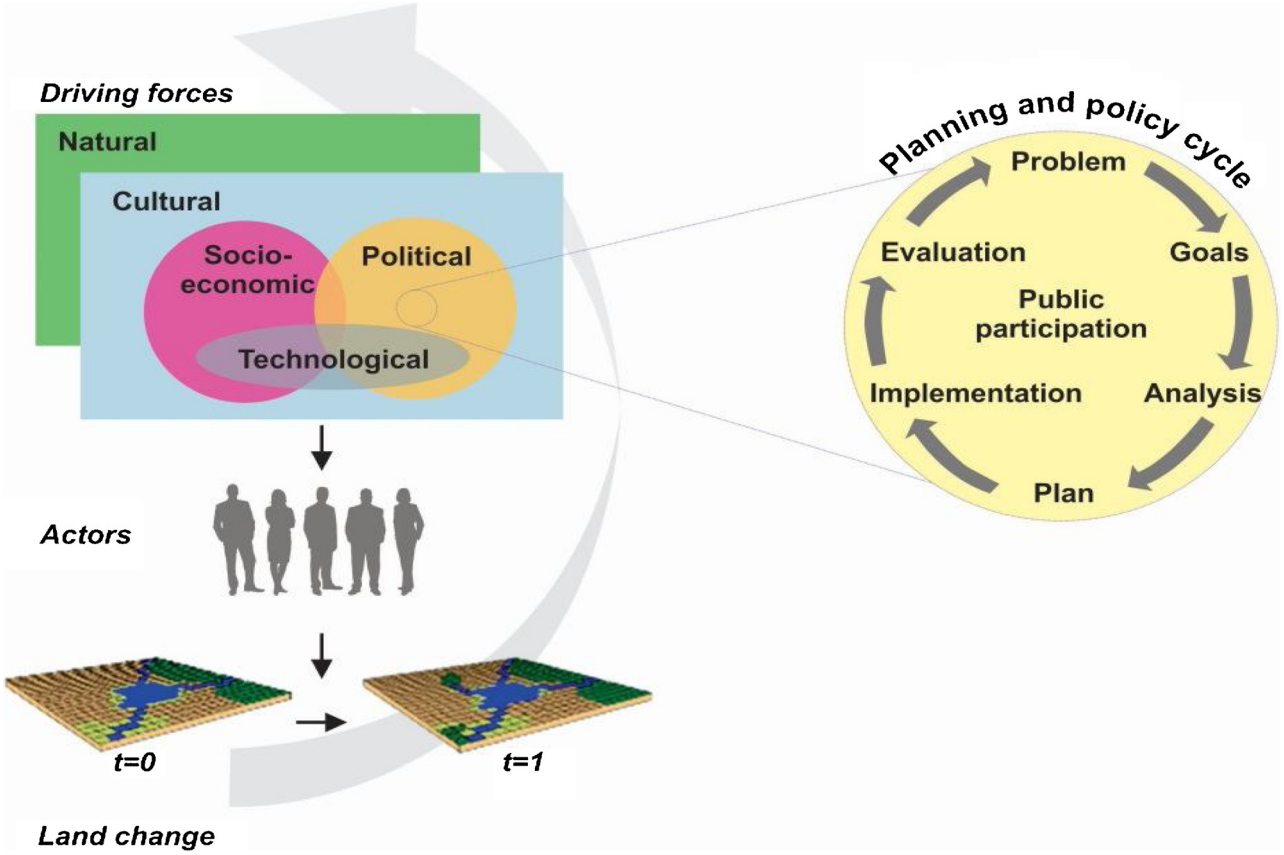

Fig. 1. Planning as a public policy to guide spatial development in urban regions.

leads to the current situation where there is a serious lack of theories on the mechanisms through which policies and planning affect land-change.

2.2. Current implementation of spatial planning in land-change modelling

Given the limited knowledge, current approaches to implement spatial planning as a driver of land change in land-change modelling often rely on rather rough approximations of planning instruments and policies. Furthermore, current approaches are very diverse as they are influenced by model choice and the spatial scale considered.

A meta-analysis of published studies showed that cellular automata (CA) are the prevailing modelling technique for urban land change, followed by regression models, artificial neural networks, fractals, and agent based models (Triantakonstantis and Mountrakis, 2012). CA and regression-based models use suitability layers and exclusion layers to simulate urban development. Planning may be implemented in the suitability layers and/or exclusion layers. These layers can operationalize positive planning (guiding) or negative planning (restricting) in either a dichotomous (hard) way or a gradual (soft) way. Often the choice between hard and soft is rather arbitrary and based on model structure. In terms of hard implementation, for instance, Poelmans and van Rompaey (2010) integrated planning as a binary layer - discerning zones where urban development is permitted versus only partially permitted - into logistic regression models; Geneletti (2013) integrated zoning policy in models by generating layers that specify the regulation of certain land-use transitions (prohibited, disfavoured, indifferent and preferred). Mahiny and Clarke (2012) softened the hard exclusion layer of SLEUTH by integrating the 15 parameters driving urban development in the Iranian context; and Mitsova et al. (2011) integrated an open-space conservation layer in a CA model to represent the policy that environmentally significant areas can contain urban development. If soft implementation is chosen, there is often not much empirical evidence to justify the weights in relation to other suitability factors. Sometimes the weight is derived from regressions based on past data (e.g. Schneider and Pontius, 2001); other cases rely on expert input (e.g. Lippe et al., 2011) or the history of policy implementation (Poelmans and van Rompaey, 2010). Furthermore exclusion and suitability layers are often fixed in time, not allowing for dynamic behaviour.

Some of these issues can be illustrated with the study by Onsted and Chowdhury (2014), who implemented zoning into a CA, with the goal to assess if a CA-model with zoning performs better than a model without. With zoning they refer to the goal of protecting agriculture in Redland, South Florida (USA) through the designation of three different zones, i.e. agricultural zoning, development zoning and interim zoning. Though they do not provide details on the zoning regulations, it is clear that agricultural zoning is used to implement policies geared at agricultural preservation. They test the performance of four scenarios, one where zoning is ignored and three others where it is incorporated through “excluded” layers that denote the cells’ resistance to growth. These layers approximate planning intention and its implementation. Onsted and Chowdhury develop these layers by measuring urban growth in each zoning category for the entire study area, and by measuring urban growth in each zoning category only in those areas more likely to experience growth based on past land changes. They found that the final condition generates the highest model performance and concluded that zoning, when implemented appropriately, improves model performance. Most other CA-modelling studies are less sophisticated and use a dichotomous variable for urban/non-urban land-use derived from planning documents (e.g. Cheng and Masser, 2003; Park, 2013; Price et al., 2015; Pazur and Bolliger, 2017) or protected/non-protected land use where delineation of protected areas are often readily available and publicly accessible on relevant geoportals (e.g. Bolliger et al., 2011; Mitsova et al., 2011). In addition, planners are still

rarely consulted as experts during development and calibration of the models (but see Silva, 2010 on the cases of the Portuguese cities of Lisbon and Porto).

Even more rudimentary to non-existent is the implementation of spatial planning in models for large urban regions up to global assessments, when modellers normally cannot rely on zoning (see e.g. Straatman et al., 2004). In one of the few models that include policies to explain global urban land expansion, Seto and colleagues (2011) accounted for policies by including, as a proxy for the strength of planning, the binary variable of whether the country has or has not national polices favouring the use of cars. Important recent large scale modelling studies lack planning factors completely (e.g. van Vliet et al., 2017; Mertes et al., 2015).

Major areas in need of future development to eventually achieve a solid implementation on planning in land-change modelling relate to conceptual issues and data, both in regard to planning intentions and their implementation. Regarding planning intentions, nuanced spatial data on envisioned future development including function and intensity of urban land use (e.g. industrial; service and commerce; single family and multi-family housing; and mixed uses) need to be available in a form that can be incorporated into models. Regarding implementation, models should be able to incorporate governance processes to overcome simplified rational procedures in planning and policy implementation. We are thus turning to the field of planning evaluation, to gain insight on factors crucial for successful plan implementation and on approaches to understand the causal connections between planning and land change.

3. Research in evaluating the outcome of spatial planning

In the classical planning approach, monitoring and evaluation steps are an integral part of the spatial planning process (Fig. 1) to track and assess the implementation and effects of plans (Alexander, 1992; Laurian et al., 2010; Steiner, 2008). However, these steps are rarely conducted (Waldner, 2009) and therefore there is little empirical knowledge on how plans are implemented and which factors hinder or foster their implementation. This is partly due to the fact that even today there is little agreement on the definition of planning "success" (Kinzer, 2016) and only a small and scattered, though increasing, body of scientific literature on how to theoretically carry out and methodologically approach a systematic evaluation of plans (Brody and Highfield et al., 2005; Oliveira and Pinho, 2010; Guyadeen and Seasons, 2018; Rudolf and Grădinaru, 2017). Furthermore, many evaluation studies focus on plan performance and planning process performance, rather than actual material outcomes that are of pertinent interest to land-change science. The ascertainment of causal connections between planning and outcomes (effects on socio-ecological systems, including changes in the built environment) is indeed extremely difficult and controversial, and some researchers consider it an almost impossible task (Wong and Watkins, 2009). Moreover, the neo-liberalist policy agenda in place worldwide since 1980s resulted in urban planning being more about promoting economic development and less about regulating land and guiding future development (Fainstein, 1991; Gerber, 2016).

While it is acknowledged that spatial planning is rarely implemented as designed due to the influence of political constraints, governance arrangements, informal processes, and competing administrations within and beyond municipalities (Forester, 1989; Tudor et al., 2014), there is little empirical knowledge that would allow a generalization regarding how and when planning is implemented. Studies on evaluating planning outcomes are often based on GIS-based comparison of planned versus actual land use. Some studies assess the effectiveness of distinct policies, such as Green Belts (Bengston and Youn, 2006; Siedentop et al., 2016) or Urban Growth Boundaries (Gennaio et al., 2009). Others are conducted to identify if and where there are discrepancies between planned and actual land use and to discuss these discrepancies to better understand the flaws in the planning and implementation process (Chapin et al., 2008; Tian and Shen, 2011; Long et al., 2012; Abrantes et al., 2016; Alfasi et al., 2012; Padeiro, 2016; Grădinaru et al., 2017). Researchers also use interviews to identify factors that can determine planning outcomes (Waldner, 2009 in Atlanta, USA) and document-analysis to explain the role of planning and policies in narratives of land change (Gallardo and Martínez-Vega, 2016). Studies show that successful planning implementation depends largely on public and political support, input of financial and human resources and a clear legal framework for implementation (van Rij et al., 2008; Bengston and Youn, 2006). Other studies found a large discrepancy between plans and actual development (e.g. Waldner 2009; Alfasi et al., 2012; Ali, 2008). Factors identified for such implementation divergence were property rights issues, political support (or lack of it), departmental structure and decision processes, highly dynamic socio-economic processes straining the capacity of government, strong local and national powers for economic development and the emergence of entrepreneurial opportunities. Overall, the balance between firm land management and flexibility for future development remains an issue particularly in cities with strong population and economic growth (Ali, 2008; Fertner et al., 2016). Regarding strategic spatial plans for urban regions, studies on plan evaluation are even sparser and focuses to our knowledge exclusively on process performance, i.e. plans are considered successful when they are useful for supporting decision making regardless of whether they influence planning outcomes (e.g. Abis and Garau, 2016).

Since the current state of knowledge in planning evaluation research is not much more than a good start for understanding the role of spatial planning in urban development, in the remainder of the paper we thus sketch a research agenda on how to develop a solid understanding of how planning impacts urban land change. The pursuit of such a research agenda is expected to provide a way forward to better link planning and land-change domains, but also to advance the fields of land-change modelling and planning evaluation.

4. Conceptualizing the role of spatial planning in urban land change

Based on the policy cycle (Fig. 1) and the available theoretical and empirical literature, we propose to conceptualize the impact of spatial planning (including both plan making and plan implementation) on land change by disentangling these complex processes into three important components: (1) during plan making, *land-change intentions* are expressed in the plans in form of spatial information (text and cartographic representations); (2) these intentions are largely sustained by *territorial governance* processes so that plan implementation eventually leads *to land change*, and (3) the effects and efficiencies of plan implementation are subject to *external conditions* acting in combination with, and differently elaborated by, the actors involved in territorial governance (Fig. 2). In line with these three components we here sketch a research agenda to conceptualize spatial planning as a prominent driver of land change.

Land change intention: Land change intentions refer to spatially explicit information in maps and/or text that visualize and describe the development visions. Commonly, plans contain information regarding location and extent of envisioned built-up development in various densities and land-use mixes, extension and consolidation of green infrastructure, growth of transportation infrastructure, and strategic projects.

Territorial governance: Territorial governance refers to "the formulation and implementation of public policies, programmes and projects for the development of a territory" (van Well and Schmitt, 2016, p. 13). It is, thus, the activity through which plans are made and implemented. Key aspects for successful territorial governance are the coordination of interests, involvement of key players and the public, recognition of various types of knowledge, adaptability of governance

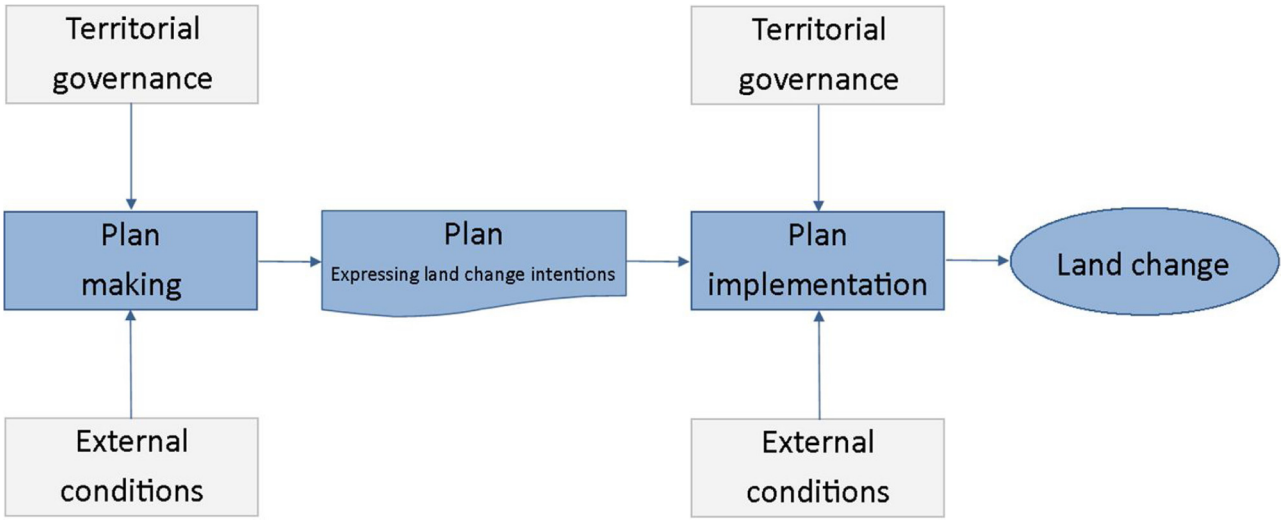

Fig. 2. Conceptualizing the impact of spatial planning on land change through spatial information expressed in plans, territorial governance, and external conditions.

processes, accountability and recognized leadership (e.g. Schmitt and van Well, 2016; Rivolin et al., 2014; Stead, 2014) as well as an emphasis on the interplay of governmental institutions from national to local scales, private actors (e.g. firms), educational institutions (e.g. universities) and citizenry (Davoudi et al., 2008). However, territorial governance as an activity reflects/encompasses also conditions emerging within the region that can hamper the formulation and implementation of plans.

External conditions affecting plan making and implementation: Actors involved in regional territorial governance are embedded in higher-level political, legal, economic, social and cultural contexts. Therefore, even if a region has good territorial government arrangements in place, the guidance through territorial governance towards the development goals as envisioned in planning intentions might be hampered by events and developments from beyond the region. For example an instable political situation nationally might provide a context in which local actors favour short-term reactive policies and neglect long-term perspectives. Such forces affect the unfolding of plan making and implementation and consequently plans might not have their anticipated effects. External conditions can enforce path-dependent developments or lead to spontaneously emerging patterns. The importance of such accidental events has for example been stressed by Batty (2005) who proposed to consider historical accidents as a driver of urban change.

For illustration purposes, we show how these three components have interacted in the complex transformations of the Quartier Confluence in Lyon (France). External conditions, for example the Europe-wide de-industrialisation of economic activities during the 1980s, led to the exodus of the wholesale market and other industrial activities and subsequently this working-class neighbourhood turned into a poor, socially segregated and run-down area suffering population decline. During the 1990s, the visionary idea of the strong leader Raymond Barre, socialist mayor of Lyon between 1995 and 2001, facilitated the functional redevelopment of the area into a service-oriented district. In terms of territorial governance, his leadership enabled the coordination of diverse strategies, interests and actors for the renewal of the neighbourhood, based on a joint working agenda (Vidal, 2004). His successor, Gérard Collomb, «inherited» the redevelopment project and maintained Barre's governance arrangements to realise the urban strategy envisioned by his predecessor (Carpenter and Verhage, 2014). Concerning the intentions on land change, the Quartier Confluence was not fully foreseen as such in the 1992 strategic spatial plan of Grand Lyon, but was rather part of the "Confluent Porte-Sud" strategic development area. However, it now holds a distinct and prominent role in the more recent 2010 *schéma directeur* (SCOT) of the urban region, being one of the key poles of urban development of Lyon metropolitan region. The Quartier Confluence is considered one of the most successful examples of urban renewal in Europe, and is characterised by a high architectural and urban quality.

The example illustrates that it is possible to pinpoint the three components in a specific transformation process. However, we are far from a systematic understanding, quantification and operationalization of these components in land-change processes, which is necessary for developing the envisioned link between spatial planning and land-change science. Therefore, we discuss in the remainder of the paper some specific challenges and propose a research agenda on how to further develop the three components in the context of land-change science.

4.1. Challenges and research prospects regarding spatial information as contained in plans

The challenges researchers face when they set out to understand land-change intentions and to operationalize them for land-change modelling are mostly associated with the fact that plans are generally less specific than one would need them for modelling (and implementation in actual decision-making alike). Many plans are sketchy rather than concrete and spatially explicit (Fig. 3). They are framed in a rather visionary discourse, presenting the aspirations of the urban region in the international context. For example in the strategic plan of Helsinki the direction and amplitude of envisioned land-use changes or the expansion of infrastructures is depicted in flow maps through arrows or highlighted through dot symbols (Fig. 3b). Even more, the plan of Barcelona metropolitan area assumes an open-end spatial trajectory of the urban region and limits the plan`s goals to social and economic aspects and includes no maps. Only few plans of urban regions are framed in a pragmatic discourse, i.e. express goals and objectives quantitatively and territorially explicit. One example is the strategic plan of Greater London that sets quantitative goals in terms of housing supply and indicates its spatial distribution within the municipalities of the urban region. Though in such plans it is straightforward to identify selected spatial information such as planned transportation hubs, it remains an enormous challenge to derive the entirety of land change intentions from a plan. A comprehensive representation of urban development plans as data quickly leads to overly complicated data models (e.g. Hopkins et al., 2005), whereas a simple representation, for instance in the context of the European project Plan4all, did not reach the land-science community since it was mostly designed for planning practitioners (Camerata et al., 2012). A more promising method to

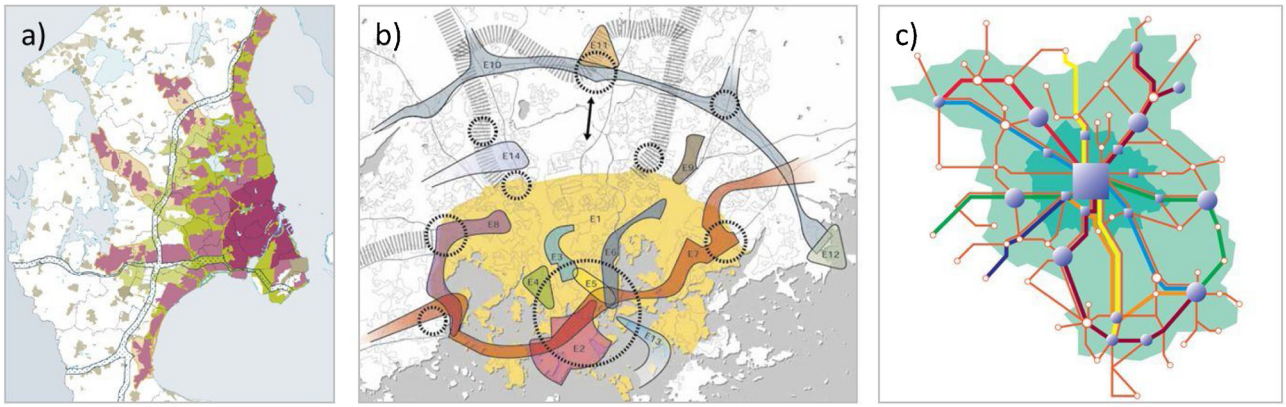

Fig. 3. Graphical illustration of planning intentions as geographically accurate maps with (a) clear and (b) fuzzy borders, or as (c) diagrammatic representation. a) Copenhagen Fingerplan (2007); b) Helsinki Strategic Vision "From city to city region "(2009); c) State Development Plan Berlin Brandenburg (2009).

derive and synthetize information from plans framed in a pragmatic as well as in a visionary discourse might be the systematic content analysis of plans (Hsieh and Shannon, 2005). Data collection could be conducted by following predefined assessment protocols that target specific policies (e.g. Norton, 2008; Berke and Godschalk, 2009; Rudolf et al., 2017 in contexts of plan quality assessments). Protocols could be designed to identify the intended land changes in terms of uses, patterns and locations. Information derived from applying the protocols could be coded and analysed qualitatively or quantitatively. Grounded theory methods such as theoretical sampling and constant comparison (Corbin and Strauss, 2008) could also be used, particularly for deriving data on the diversity of planning intentions in comparative studies.

In addition, the way planning intentions for land change and persistence are portrayed in the plans varies greatly from plan to plan. For example, some plans contain maps with a high geographical accuracy and clear boundaries; whereas other plans are diagrammatic or lack a visual representation all together. There is clearly no standardization of representation in practice and the choice of graphic representation, degree of accuracy and scope of information is largely a political one (Dühr and Müller, 2012; Soria-Lara et al., 2015). Local contexts as well as planning cultures are furthermore reflected in the way spatial information is included in the written report and/or depicted in the maps. In addition to the diversity we find in representation, there are no general agreements on associations between representation and meaning: the same planning intention can be visualized in several ways and, even more challenging, the same type of graphic representation can refer to different planning intentions. Future research, including comparative case study research across large samples of urban regions, should address these issues and eventually develop a systematic body of knowledge on representation and meaning.

In geographically accurate or only slightly generalized maps the graphic differentiation of line, point and area symbols are territorially rather precise (Fig. 3a). Methods for the conversion of these maps into data can rely on rasterization or vectorization to generate data such as probability distribution maps. Deriving spatial information from diagrammatic representations (Fig. 3b and c) will be more challenging. The most important element that needs to be addressed is the territorial model for built-up development and/or conservation of open and green spaces found in most plans. Territorial models are for example aiming at developing *polycentric urban systems* as in Stockholm (Sweden) or Dusseldorf (Germany); reorienting settlement development towards a *decentralized concentration*, as promoted in German urban regions; and fostering a transit-oriented spatial approach as in Copenhagen (Denmark). These models contain locational as well as relational information on a rather abstract level. Methods developed for translating narrative scenarios into quantitative data (see Mallampalli et al., 2016 for a synthesis) might provide a good starting point for approaching this challenge if we understand territorial models as narratives for future urban development. Specifically, role playing games (e.g. Castella et al., 2005) or semi-structured interviews could be used to simulate and understand decisions taken to conceive these territorial models. Fuzzy cognitive mapping (Kosko, 1986; Kok 2009; Gray et al. 2015) is a promising method to quantify, in a dialogue among experts, the relationships between the planning intentions depicted by the diagrammatic representations. This method seems particularly appropriate for translation purposes when both, planning intentions and their relationships are ambiguous.

Another challenge is the fuzziness of most borders in cartographic representation. Fuzziness can be an endeavour to avoid conflict in the planning process or a way to represent a relational understanding of interconnected social, political and economic relations manifested in space (Davoudi and Strange, 2009). It is crucial that methods can be developed that do allow for these meanings inherent in territorial models and fuzzy borders to be accounted for when converting the maps to spatially-explicit data suitable for land-change modelling. Suitable for such situations are integrated methods that address the interplay between urban processes, administrative competences which condition the implementation of planning intentions, and relational aspects which define the main actors within the borders.

Finally, research is needed to address the development of methods for translating textual content into land-change allocation rules. For example, in the written report there are often intentions regarding shifts in development patterns (e.g. from urban sprawl to densification), preferred and to-be-avoided neighbourhood adjacencies, or details on certain development projects which need to be converted into some sort of allocation rules in land-change models.

4.2. Challenges and research prospects regarding territorial governance

Territorial governance - as a means through which spatial plans are prepared and implemented - is a complex web of interactions rather than a clear process. Territorial governance happens in a more or less coordinated manner, through partially overlapping and mutually enforcing, and partially conflicting, practices. Furthermore, territorial governance in spatial planning varies greatly among urban regions, primarily because of the type of planning system, the degree of institutionalization of regional governments and the legal power of plans (statutory or mere guidelines).

During plan implementation, choices are made and decisions are taken on spatially explicit actions that eventually lead to urban land change. Often these actions are driven by the pursuit of public or private investments. Territorial governance processes thus sustain a translation, i.e. a meaningful interpretation and prioritization, of the plans' rather broad goals plans into regulations and building permits

which are then related to land-change. Spatial plans are often implemented through projects rather than through a concerted implementation effort (e.g. Savini and Aalbers, 2016; Oosterlynck et al., 2011; Albrechts, 2006). This is for example the case in Cardiff (Wales, United Kingdom), Dublin (Ireland), and Stuttgart (Germany). Consequently plan implementation depends on the availability of funding as well as on the dedication of leaders and the involvement of interested groups (Oliveira and Hersperger, 2018). For example, green infrastructure improvements envisioned in the Strategic Regional Plan 2009 of the Verband Region Stuttgart (VRS) are implemented through landscape projects in which the regional authority of VRS, various municipalities and environmental non-governmental organizations are involved. Funding schemes made available by the VRS are the financial backbone of these environmental-oriented projects.

With a broad understanding of governance arrangements in mind, territorially-based governance studies (e.g. Schmitt and van Well, 2016; Nuissl and Heinrichs, 2011; Davoudi et al., 2008) and literature on planning practice (e.g. Albrechts et al., 2017) can be summarized to identify components that are crucial to understand how spatial plans are prepared and implemented. Current debates highlight especially the importance of governance components such as interest groups involvement, multilevel coordination, negotiations, citizen participation and integration of expert knowledge. For example, in the Stuttgart region, coordination among VRS, its municipalities and representatives of various interests is the core characteristic of the strategic planning process. Groups representing housing and environmental concerns as well as industrial and retail interests are involved in the overall planning process. The strong political and decision-making capacity of VRS brings effectiveness to strategic spatial plans and enriches the multilevel engagement among VRS and various actors. In the Stuttgart region, negotiations mainly focus on locations of new housing developments and industrial sites and improvements in the public transport networks. While research on the above mentioned governance components is rather solid in the context of plan-making, little is known regarding the implementation phase of plans. However, for linking plans with land change it is critical to better understand the interrelationships among these components in processes of plan implementation (see Fig. 2).

More case-study research in urban regions is clearly needed to consolidate the emerging understanding of key components of territorial governance and to trace governance processes. Future research should especially address the role interest groups, leadership and negotiation are playing in the plan implementation phase. In this regard, leadership has been recognized to be pivotal in bringing multiple interests and perspectives for future development together. Of particular relevance is a better understanding of (1) how a well-defined leadership at the regional level (i.e. a regional government with decision making capacity) affects the effectiveness of regional plans and how leadership can support a unified plan implementation; (2) which are the reasons that favour the implementation of plans through projects (e.g. limited financial resources and lobbying from private interested groups); and (3) who are the main initiators and carriers of projects (exclusively public driven, the result of multilevel government cooperation or developed through public-private partnerships).

This type of research is best conducted in the context of planning-outcome evaluation. Though very challenging, the goal is to eventually develop clear links between territorial governance, plans, development projects and urban land-change. Comparative case studies might be the most promising method to advance this linkage (e.g. Fainstein, 2008). Such studies could compare and contrast, for example, urban regions in which urban projects led to measurable land change and identify the role of various private versus public actors therein. Furthermore, systematic meta-studies can be used to synthesise the findings across a larger number of case studies to identify general patterns (a method suggested by van Vliet et al., 2016 for land-change science). Specifically, meta-studies could be used to develop conceptualized models synthesising how actors work together in different governance and planning settings, for instance development-led versus plan-led planning systems, in producing land changes.

However, for land-change science it is important to go beyond the mere understanding of territorial governance arrangements and reach some kind of relative quantification of influences and key components. It is also crucial to develop a method to help quantify the full process. A promising way to achieve a quantification might be the use of Multi Criteria Analysis (MCA) (see e.g. Langemeyer et al., 2016), combined with a solid case study understanding and input of local planning practitioners. Causal loop diagrams, fuzzy cognitive maps, Bayesian networks, and role playing games (all described by Mallampalli et al.,) might present alternative options.

4.3. Challenges and research prospects regarding external conditions

Many external conditions can affect plan making and plan implementation in urban regions. Examples are economic changes ensuing from de-industrialization and the rise of the service economy; international city competition and the strengthening of an own market niche; migration; demographic pressure or decrease; the changing relationships among national states, regional and local authorities; an increasing environmental awareness and also environmental challenges such as floods. The distinction between “internal” and “external” conditions is heuristic, however the literature on co-evolutionary policy-making (Gerrits, 2012) and on proximate and remote influences for land change (Lambin et al., 2006) can serve as theoretical references.

In spatial planning practice, the identification of such external conditions is crucial because territorial governance actors need to take them into account when developing and implementing plans, identifying key strategies to make the most of them or counteract their effects. These influences are often perceived as external challenges by regional and local actors, and typically addressed through a territorial governance process. External factors can also be perceived as chance events (Gerrits, 2012), whose effects can consolidate past arrangements or can even initiate path-breaking developments. These conditions are generally (and as consensually as possible) identified by actors through SWOT analyses and exercises of scenario-making during plan making processes (Healey, 2009).

In the current literature, reference to external conditions is acknowledged, but it is often limited to general statements in setting the context for case studies analyses (e.g. Albrechts et al., 2003; Albrechts and Balducci et al., 2017; Healey, 2009) or for theoretical and conceptual elaborations (e.g. Albrechts, 2004; Graham and Healey, 1999). For example, Graham and Healey (1999, p. 623) talk about “tumultuous economic, social, cultural, technological and physical change”, “economic and cultural globalization”, and “current societal transformations”. Albrechts and Balducci (2013, p. 17) identify, among other factors, global competition and “economic vocations” of urban regions, the increasing reduction of state funding to local authorities, and new forms of multi-level governance that make decision-making processes on plan making and implementation more complex. In case study analyses, external conditions are generally considered background information stimulating actors’ decision-making processes for plan-making and for local urban change (e.g. Healey 2009; Albrechts and Balducci et al., 2017). For example, Healey (2009, p. 6) refers to “wider forces” such as political, economic, social and environmental factors creating the setting where (certain) urban governance actors take decisions on how to steer urban change according to a selective strategic vision included in the plans. However, an explicit consideration of external conditions in affecting the formulation and implementation of spatial plans and projects is, to our knowledge, left unexplored.

The impact of external conditions on plan making and implementation can be illustrated with the construction of the Zuidas (“South Axis”) area as the new central business district of Greater Amsterdam during the 1990s and early 2000s. Amsterdam Zuidas has

been the result of a development strategy proposed by a powerful financial actor from outside the region, as compared to the more locally-oriented planning proposal by Amsterdam municipality to re-develop part of the northern harbour (Majoor, 2006). The presence of a powerful private actor, coupled with a favourable (pre-2008 crisis) economic situation of the urban region and the high accessibility of the area to Amsterdam Schiphol international airport hub influenced Amsterdam city council's decision to eventually modify their previous plans. The combination of these three external conditions affected the municipality's decision, considerably influencing the long-term development of the Amsterdam urban region so that the Zuidas is now presented as its new "(business) centre".

Future research should focus on the identification of the most important external conditions, the analysis of how they affect plan making and plan implementation, and eventually the quantification of these influences. The time-dimension is also particularly relevant: external conditions change over time and are perceived differently over the course of, for instance, the implementation of large-scale urban projects that can span over several years or even decades. More case study research on how actors in urban regions perceive external conditions to affect their decisions on plan making and implementation is clearly needed, followed, in due course, by systematic meta-studies to synthesize findings across multiple cases.

Especially regarding project implementation, it is reasonable to assume – by taking stock of the international literature - that only certain (combinations of) external influences can lead to certain urban outcomes. Future research should therefore also account for which combinations of external conditions can describe and explain different trajectories of development in different contexts, including the consolidation of urban transformations (path-dependency). Methodologically, set-theoretic methods for the social sciences (Ragin, 2008), with their focus on conjunctural causation and multiple paths to the same outcome, appear to be particularly appropriate to examine how combinations of external influences affect plan making and implementation (Rudel, 2008). This method has already been applied to land change (e.g. Scouvart et al., 2008); however further applications to urban development in cities and spatial planning remain unexplored.

5. Discussion and conclusions

To conceptualize and study the role of spatial planning in urban land-use change along the three components has consequences for planning evaluation research and for the implementation of spatial planning in modelling. This we discuss in the subsequent sections. Thereafter, we present a succinct list of priority issues in form of a research agenda and some concluding remarks.

5.1. Implications for planning evaluation research

The proposed way to disentangle spatial planning into the intentions expressed in the plan, the territorial governance processes and external conditions influencing planning, is expected to facilitate the design of future evaluation studies. The outlined research priorities suggest the need for a stronger focus on planning outcomes than planning outputs and to complement the performance with a thorough conformance approach. Specifically, conformance approaches, which are indeed suitable for evaluating plans of urban regions, could be improved to overcome current simplistic land cover/land use analysis and integrate assessments of functions attributed to urban land. This is even more important as planning generally addresses land uses as well as functions. Good illustrations thereof are many European urban centres which plan to continue their traditional multi-functionality, typically combining housing, commerce, and service. Other examples are urban parks that, in addition to providing places for recreation and social activities, play a key role in supporting local biodiversity and climate change mitigation.

Planning evaluation might further benefit from system thinking. A socio-ecological systems approach, a topic that has been debated in this journal (e.g. Challies et al., 2014; Ebbesson, 2010; Young et al., 2006), might be particular useful for evaluating the role of planning in land change because of the feedbacks between components of territorial governance, external conditions and spatial intentions. Furthermore, in today's strategic planning practice socio-ecological systems are already a relevant topic (Frank and Marsden, 2016), due to the recognition that sustainability concerns, such as climate change adaption and resilience, are central to the development of urban regions.

Furthermore, the territorial governance concept can stimulate empirical research on spatial planning with the aim of understanding the motives behind, as well as the outcomes of, actual planning processes (e.g. investigating the territorial governance arrangements behind the implementation of plans through projects). In addition, knowledge on the key components of territorial governance in plan making and plan implementation is expected to facilitate reflections on the potential impact spatial plans can have at the ground level, bringing thus more certainty to understanding urban land change (Nuissl and Heinrichs, 2011).

5.2. Implications for implementation in modelling

As the previous sections point out, the lack of data on planning - which often hinders land change modellers to include planning in their models - is in fact due to a serious lack in theoretical understanding of how spatial planning effectively shapes land change. In order to facilitate an efficient implementation of new knowledge into models, a close cooperation between the domains of planning and land-change modelling in future theory and data generation is needed. This is especially necessary since planning intentions (as specified in a plan) might be translated by modellers into many potential land changes. For instance, the rather general statement in a spatial plan of "limit urban sprawl" can be implemented by constraining the development of urban edge areas (higher density of buildings) or by creating a green belt. Tools to translate planning intentions into land changes would be very valuable to homogenize the expression of spatial planning in models. The tools could consist of a set of spatial analysis routines to compute distance-dependent relationships as they are expressed by planning intentions, e.g. new built-up developments nearby existing public-transport routes. Similarly, spatial analysis routines could address other spatial features such as neighbourhood configurations. Once developed, sets of such routines could even be assembled into a GIS-software-extension. Although these types of tools will never capture the full range of planning intentions, and especially not the planning intentions without an explicit spatial dimension, they are expected to be useful for prevalent land-change intentions (e.g. densification).

Modelling needs to pay attention to many aspects for integrating more realistic understandings of planning implementation. We highlight here a few, for which the development of standardized approaches would be especially beneficial: non-spatial features of spatial planning such as funding schemes or coordination of interests between multiple interested groups; area-specific development projects which start and end at a certain time versus continuous development such as urban sprawl; various degrees of fuzziness in planning intentions and projects; and approaches to deal with land-use functions and intensity.

The development of relevant data on spatial planning for modelling of large geographical extents will remain a challenge in the near future. As in most countries land use is planned primarily locally, i.e. by municipalities and cities, data on planning intentions and implementation is often available only in local geoportals, and not in a standardized format. Even if more and more plans are getting digitized, discussions are needed to clarify, for example, how much of the plan content is represented in the plan's digitalized form. Modellers will furthermore need guidance on how to select appropriate information from the diverse and detailed contents of plans and on how to address conflicting

planning intentions. It is of eminent importance that methods will be developed to quickly collect data on spatial planning in many urban regions with instruments like standardized questionnaires and data collection protocols. We envision that protocols for plan-content analysis can be developed to derive much needed data on land change intentions. Ideally, the results would be cross checked with regional experts. Questionnaires could ask key actors in urban regions to identify the main actors in the planning process, to describe their role and the power relations in order to model plan implementation. Furthermore, questionnaires could request key actors to assess the overall governance performance within the region, to describe its effect on certain urban transformations (e.g. success of nature conservation), and to evaluate the impact of external conditions on the region's plan making and implementation.

If spatial planning can be implemented in inputs and rules for land-change models, exciting analyses will be possible. Eventually, the effectiveness of spatial planning can be assessed by comparing the outputs of land-change models with and without spatial planning drivers or by comparing the results of land-change modelling including spatial planning drivers with the actual land-use. The first case highlights the impact of spatial planning related to other drivers of land change, whereas the second case emphasizes the impact of spatial planning, including projects, continuous developments, territorial governance and external conditions, on land change.

5.3. Research agenda

In Sections 4.1 – 4.3 we showed research challenges and prospects for 1) the intentions expressed in the plans; 2) the means of implementation of the plans through governance processes and 3) the role of external conditions influencing implementation. These three components are crucial for understanding the role of spatial planning for land change and for better linking the planning and land change domains. Grounded in this work and structured according to Fig. 2 we here propose an agenda for future research. This research agenda specifically identifies research topics for *Plan, Plan implementation* and *Land change (*see three dark blue boxes in Fig. 2). All three main topics should be pursued with highest priority in their respective fields. The fourth dark blue box in Fig. 2, *Plan making*, is essential to comprehend strategic spatial planning processes but somewhat of lower priority for understanding the role of planning in urban land use change. The research agenda lists for each research topic several sub-topics, ordered according to their priority.

Research topic A: *Plan* with expressions of land change intentions.

Priority 1: Research to develop methods for selecting and transforming information on intended land change into data suitable for land change modelling

Priority 2: Generation of data sets on intended land change for urban regions as well as large geographical areas

Priority 3: Research to standardize methods for analyzing land change intentions in plans

Priority 4: Development of guidelines for modelers to choose the plan most suited for their purpose (e.g. strategic spatial plan, comprehensive plan, land-use-plan)

Priority 5: Development of a systematic body of knowledge on information representation and meaning

Research topic B. *Plan implementation* sustained by territorial governance and external conditions, to understand realistic implementation processes and outcomes.

Priority 1: Research to quantify the diverse influences of territorial governance and external conditions on plan implementation for 1) continuous development and 2) projects

Priority 2: Research to develop methods to efficiently collect data to describe plan implementation processes and outcomes

Priority 3: Land change model development to account for implementation processes

Priority 4: Continuation of research on the importance of key factors and actors of territorial governance and external conditions, as well as their interaction, for plan implementation

Research topic C. *Land change* data and modeling.

Priority 1: Generation of high resolution data on land functions, multifunctionality, density of use and other aspects crucial for planning

Priority 1: Development of a widely applicable system of urban land-use categories that bridges planning and land change

A strong cooperation of the domains of planning and land-change modelling will be paramount for pursuing this research agenda successfully. This cooperation could be supported with regular meta-analysis and with targeted sessions at conferences and working groups to ensure interdisciplinary exchange and to develop the scientific community.

5.4. Conclusions

Land-change studies could clearly benefit from a better understanding of how planning influences land use patterns (e.g. Stokes and Seto, 2016; Turner ll et al., 2013). Research as outlined is essential to establish a truly theory-based approach to describe and model the role of spatial planning in urban land-use change. More broadly, such research could help to close the gap between spatial planning and land change science. Further advancements in this matter are essential since land-change science is moving towards designing sustainable land transformations and novel land systems while promoting the concept of land governance in order to co-design solutions for global sustainability.

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