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Patterns and causes of land change: Empirical results and conceptual considerations derived from a case study in the Swabian Alb, Germany

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ABSTRACT

Land-use and land-cover change profoundly affect human well-being and, therefore, have become a major topic for society. A thorough understanding of past and present processes transforming landscapes is essential for guiding future developments toward the sustained provision of the ecosystem services humans critically depend upon. Drawing on the driving forces and resilience frameworks, we identify possible variables and patterns of land change, connecting them to empirical findings in three case study areas in the Swabian Alb region, southwestern Germany. GIS-based analysis of historical and contemporary maps from four time layers between the 1820s and 2009 reveals complex and spatially differentiated trajectories. Woodland expansion, marginal grass- and heathland conversion and expansion of urban areas were the main change processes affecting all case study areas. A literature review regarding causes of these changes points to socioeconomic drivers at the supraregional scale, playing themselves out in diverse ways on areas with contrasting natural site characteristics. Human agency also fosters the alteration of large-scale drivers of change at the local level. We conclude that policy and management strategies need to be particularly sensitive to natural site characteristics and take both driving forces and human agency into account. Landscape-scale studies of patterns and causes of land change, making cross-site and cross-issue comparisons, are necessary to test how far our insights may apply to other geographical contexts and land change processes.

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Introduction

In the past few decades, land-use and land-cover change, abbreviated as "land change", has become a major topic for society in various contexts, but particularly as connected to the issue of sustainability (Turner et al., 2007). Land change implies alteration in the provision of ecosystem services which, in turn, has consequences for human well-being. As the Millennium Ecosystem Assessment (2005) points out, the current global trajectory is degradation of ecosystems and their related services. However, land-cover change may also improve ecosystem services, e.g. expanding forests contribute to carbon fixation. Moving beyond a focus on degradation, some approaches provide an optimistic view on the possible development of human-shaped environments. Particularly the cultural landscape approach highlights how a rich biodiversity can be intimately interrelated with economic and cultural values (Farina, 2000) and promotes land-use practices that foster these links, for instance High Nature Value farming (Oppermann et al., 2012). Land change is currently a pressing topic for land management and related policies. The crucial questions to be addressed are how ongoing degradation can be stopped and positive interactions between nature and people be enhanced, in order to sustain a broad array of ecosystem services (Schaich et al., 2010). To be able to guide future developments toward such desirable outcomes, a thorough understanding of past and present landscape-transforming processes is essential. This particularly calls for monitoring of land changes and investigation of their underlying causes (Antrop, 2005).

There is a multitude of empirical studies on land change, but many are not connected to overarching frameworks, which facilitate the provision of generalizable results. In consequence, it is often not possible to transfer insights across space and time, identify patterns of change and inform land-related decision making beyond the cases studied. Hence, systematic cross-site comparisons of case studies revealing general insights still remain a major challenge (Parker et al., 2008). On the other hand, several publications cover conceptual considerations on land change, but are

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only loosely connected with empirical data. However, a firm empirical basis is needed to prevent simplifications and to move beyond existing myths on drivers of land change and suitable strategies to address them (Lambin et al., 2001).

Facing these challenges, the aim of this paper is to connect conceptual and empirical approaches to the study of land change in a Central European context. We intend to identify general patterns of land change, understood as linkages between causes and effects that may be transferred to other geographical regions and/or land change processes (e.g. specific constellations between driving forces that foster certain trajectories). For this, we firstly introduce two frameworks for conceptualizing patterns and causes of land change: driving forces and resilience. Secondly, using the example of three communities in the Swabian Alb region in southwestern Germany, we analyze land change that took place between the 1820s and 2009 as well as the causes of the main trends observed. This is done on the basis of a GIS analysis of historical and recent maps and an extensive literature survey. We discuss these empirical results in relation to the driving forces and the resilience frameworks, seeking to elaborate on the causal chain between controlling variables, including different types of drivers and the role of human agency, and land change. This leads to conclusions on possible implications of our work for the analysis and the management of land change.

Concepts for the study of land change

There are two influential frameworks dealing with the topic of land change and its causes. The driving forces concept is rooted in geography and explicitly focuses on land change. By contrast, the resilience approach is based on system dynamics in general and has been translated to environmental contexts, where it is receiving increasing attention.

The driving forces framework

The study of driving forces of land change has a long history in geography, especially in research dealing with human-shaped, so called cultural landscapes (Brandt et al., 1999; Bürgi et al., 2004). This approach is closely connected to the evolving field of land change science, rooted in different theoretical backgrounds broadly conceptualizing human–nature relationships (Turner et al., 2007). Although attempts at developing general conceptual models for the causes of land change have been undertaken from the very beginning (see Baker, 1989 for an early review), more typical are rich, often GIS-based, case study analyses referring to a specific investigation area or topic (e.g. Bicik et al., 2001; Wittig et al., 2010).

Summing up established methods and considering new research directions, Bürgi et al. (2004) propose a standard procedure for the investigation of the drivers of land change. Referring to Brandt et al. (1999), they specify five types of driving forces:

- socioeconomic, e.g. effects of WTO agreements;
- political, as expressed in political programs, laws and policy;
- technological, e.g. effects of infrastructural development;
- natural, constituted by site factors (e.g. soil characteristics) and natural disturbances (from avalanches to climate change); and
- cultural driving forces, as the most complex and vague dimension of aspects shaping landscapes.

A key question of recent research in this field is how to conceptualize human agency in relation to driving forces and land change. In this regard, Hersperger et al. (2010) describe two possible roles of actors: On the one hand, actors may affect driving forces, e.g. when policy makers shape socioeconomic or political conditions. On the other hand, human agency may directly change land, for instance through farming and other land-use practices. Hersperger et al. (2010) describe four basic models for linking land change with driving forces and actors, who are here understood as proximate causes of land change. These models vary in their appropriateness for specific study aims and contexts. In our case study, we seek to understand the causal relationship between controlling variables and land change. For this, we will investigate land change by GIS analyses and a literature survey providing information on diverse driving forces and actors. As suggested by Hersperger et al. (2010) for this research question and type of data available, we will follow the DF-A-C model as a framework that conceptualizes driving forces as influencing actors who, in turn, shape land change.

The resilience framework

Resilience has been defined as "the capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity" (Walker et al., 2006). This framework focuses on the dynamics of change and how to adapt to and shape it (Walker and Salt, 2006). Seen as a tool for achieving sustainability, it has been taken up by a wider research community evolving around the ecosystem approach.

At the heart of the framework is the notion of social–ecological systems (SES), according to which people are closely coupled with the ecosystems in their environment (Folke, 2006). This implies social and ecological sub-systems at multiple scales, whose interactions determine a system's inner structure and functional organization (Liu et al., 2007). Key variables driving SES are described as slow, for example nitrogen content in soil, but resilience researchers also acknowledge fast variables, such as fire events or social revolutions. Many researchers agree that change is essentially driven by a small set of three to five variables (the "rule of hand"; see Kinzig et al., 2006). Hereby, the resilience community focuses attention toward slow and mostly natural controlling variables (see Walker and Salt, 2006). However, the idea of the outstanding significance of slow variables is increasingly contested, at least when applied to systems with a strong social component (e.g. Kinzig, 2012).

It is assumed that SES are not affected in a linear way by their variables. On the contrary, systems are able to cope with change without altering themselves until they cross certain thresholds. Then the system shifts to another state with a different identity and different internal feedbacks. Typically, it is difficult or even impossible to reverse such regime shifts (Scheffer and Carpenter, 2003).

System identity and change is constituted by processes which can be organized hierarchically, at different scales across time and space, resulting in nested structures referred to as panarchy (Gunderson and Holling, 2002). As Chapin et al. (2009, p. 16) point out, "change can occur at multiple levels of organizations, such as individuals, communities, watersheds, and regions. [...] For example, dynamics at larger scales (e.g., migration dynamics or wealth) provide legacies, context and constraints that shape patterns of renewal (system memory). Dynamics at finer scales (e.g., insect population dynamics, household structure) may trigger release (revolt; e.g., insect outbreak)." Change can thus be caused by two different types of cross-scale effects. On the one hand, "revolt" describes situations where fast and small events overwhelm slow and large ones. On the other hand, change may be shaped by variables at the larger and slower scales that determine the system's configuration at the smaller and faster scales ("remember").

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