



# Does cadastral division of area-based ecosystem services obstruct comprehensive management?



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## ABSTRACT

Management of ecological entities in agricultural landscapes is often challenged by a complex ownership structure governed by a cadastral system dictated by agricultural interests and historical land use practices. The cadastral division is suspected to obstruct the deliverance of ecosystem services (ES) from the landscape. The objective of this analysis is to quantify the cadastral fragmentation of selected landscape-scale ES. Contiguous ecological units and landscape entities as designated in Danish municipal planning were analyzed. The designations comprised the existing ES represented by EU Natura 2000 areas, drinking water protection areas and valuable landscapes, and potential ES in areas designated for potential wetlands, afforestation and recreational trails. In each designated area the cadastral structure in terms of number of units, size, and number of affected properties was analyzed. In all cases a large number of rather small (mean area <10 ha) cadastral units with different owners characterize the designated areas providing particular ES. Accordingly large numbers of properties were affected by the designations. The reasons for the high numbers of cadastral units pertain to the historical background of the cadaster as a tool of optimizing agricultural production. This suggests inherited difficulties in imposing a uniform management regime in cases where regulatory tools are dependent on the attitude of the individual land owner. Difficulties are also arising in situations where potential ES are to be unfolded in spatial explicit contexts; all landowners must be aligned in terms of new regulation if the particular service is to be released simultaneously and uniformly in a spatial defined area. It is concluded that sound ecosystem and landscape management that follows boundaries defined by natural phenomenon is impeded by cadastral divisions.

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## 1. Introduction

The importance of protecting and enhancing ecosystem functioning is broadly accepted if a sustainable development is to be ensured (see, e.g., Daily 1997; De Groot et al., 2010). The ecosystem services (ES) concept has been suggested as a suitable conceptual framework for mapping, quantifying and valuing the worlds' natural resources (De Groot et al., 2002; Boyd and Banzhaf, 2007). Within the ES framework emphasis is put on natural assets' contributions to human well-being. The ES approach to natural capital is considered a suitable framework in which natural systems may be analyzed and problems identified in order to suggest possible solutions for more desirable futures (Costanza et al., 2014). While some ES are confined to small areas,

many ES occur within larger spatial units. Examples of this comprise e.g., groundwater aquifers or habitats for ranging animals. It is usually considered rational to manage ES within ecological entities, defined by ecological reasoned borders, such as watersheds or confined habitat areas (Mills et al., 2010; Shoyama and Yamagata, 2014). This often collides with the fact that environmental governance and management act through legal or administrative bodies that are confined to areas that do not follow natural boundaries, such as nation states or regions (Blomquist and Schlager, 2005). The cross scale dynamics and related problems for governance of entities at different spatial scale levels are well accounted for by, e.g., Cash et al. (2006) or Paavola et al. (2009). The cross-border problems do not vanish when the scale of the management becomes finer. Even in small land areas subject to environmental management, the mismatch between legal units and ecological phenomenon persists (Cumming et al., 2006). In cultural landscapes this management problem is often rooted in the cadastral realities as the division

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of the land surface in individual private properties often implies a challenge for the holistic management approach. In societies with a liberal economy, land is usually privately owned, and environmental regulation works through regulation of the land owner or land users activities and decisions (Falconer, 2000; Winter and May, 2001). The landowner defines the land use practices applied on specified areas, and the landowner becomes the access point of public regulation in the landscape (e.g., OECD, 2001).

Hägerstrand (2001) distinguishes between the so-called territorial competence exerted by the owner of the land and the so-called spatial competences, exerted by the public authorities by regulation of the landowner(s). The territorial competences comprise the land owners decisions regarding farm management and land cover. The spatial competences include e.g., legislation, regulation subsidies, and spatial designations and zonations operating through statutory planning within which certain environmental standards must be met. As the public domain exerts its influence on the environment through the individual land owner, the corresponding practices and subsequent effects on the environment are dictated by the cadastral structure in the landscape.

In practical terms, a land owner has the sovereignty over the land use and land cover, within the limits set by the legislation. But in most OECD countries land owners, e.g., farmers, cannot claim ownership to underground resources, regardless of the character (e.g., groundwater, gas, oil, gravel, peat etc.), but can make use of some of these resources, for example water for irrigation. Otherwise, the owners must subdue to general regulation such as landscape and nature protection measures, and pollution control, since land use practices affect the conditions and quality of the below-ground resources.

Environmental management experiences of the last three decades indicate that regulation of ES in privately owned landscapes is sometimes challenged by the mismatch between the spatial extent of an ecological phenomenon and the spatial extent of the private properties. Examples of Denmark comprise e.g., nature restoration projects which are based on rather simple ecological models and assumptions, but have been extremely complicated to implement because of the cadastral realities on the ground (Hoffmann and Baatrup-Pedersen, 2007). Management of all kinds of ES may imply the need to approach large numbers of land owners, (e.g., Pelosi et al., 2010; Wear et al., 1996). In many situations authorities prefer regulation through general rules that apply equally for all land owners (Primdahl, 1999). But in other situations specific regulation needs to be applied in areas designated for specific purposes or specific zones with special protection requirements. Examples from Denmark comprise the protection of groundwater aquifers (see, e.g., Vejre et al., 2011), or nature areas, but also the effort for enhancing and relieving the potentials of ES such as wetlands restoration projects or establishment of recreational infrastructures (Hoffmann and Baatrup-Pedersen, 2007; Højring, 2002; Madsen, 2003). Though experiences with the problems of cadastral divisions are common, systematic numerical analyses of the cadastral fragmentation of areas providing ES are lacking.

This paper deals with the challenge of regulation of ecological phenomenon that occur across boundaries on rather fine spatial scale levels, i.e., boundaries between privately owned properties in agricultural landscapes. The aim is to analyze two aspects of this; the cadastral obstacles for optimizing the provision of existing ES, and the cadastral obstacles for unfolding potential ES capacities. We hypothesize that the management of many ES other than production-related services is obstructed in agricultural landscapes due to cadastral patterns, and that projects aiming at improving environmental standards and enhancing the provision of services are threatened or delayed by the need to include all land owners in participatory planning processes.

Environmental management executed in spatial units, landscapes and regions, are usually based on ecological models or assumptions (e.g., Bunn et al., 2000). In practice management is exerted as rules or regulations pertaining to certain designated areas that are part of statutory planning. In this context, hence, the use of ecological models refers to the model or assumption that the designations are based on, such as, e.g., protected groundwater aquifers. Rarely the ecological model constitutes the only reasoning in designations, more often political constraints and practical compromise influence the resulting designated area (Apitz et al., 2006).

This analysis comprises mainly officially designated areas appearing in spatial planning documents published by public authorities, mainly Danish municipalities. The designations represent certainly various ES, but it must be kept in mind that they were not mapped as part of a genuine ES mapping procedure, but rather in a spatial planning context, a framework thoroughly discussed by De Groot et al. (2010) and Egoth et al. (2008).

## 2. Material and methods

### 2.1. Study areas

The analysis was performed in three landscapes of western Denmark which has been subject to numerous landscape research projects during the last 18 years (Primdahl 1999; Vesterager and Lindegaard, 2012; Primdahl et al., 2010; Andersen et al., 2013) (Fig. 1). These areas have been subject to on-farm interviews in 1995/6 and in 2008, where data on farm structure, ownership, and agricultural practices were harvested (Kristensen et al., 2004; Andersen, 2013). The areas are denoted as Saltum, Hvorslev and Sønder Omme, respectively (Fig. 2). All areas are lowland areas, however, quite different in terms of geology and terrain. The Saltum area consists of an elevated area of eroded morainic land forms surrounded by extensive areas of marine origin. The Hvorslev area consists of a moraine plateau dissected by meltwater valleys from the termination of the last ice age. The Sønder Omme area consists of isolated, deeply eroded moraine landforms surrounded by extensive glacio-fluvial plains.

### 2.2. Cadastral data

Cadastral data from 2013 was used in our analysis. The Danish cadaster provides information of the exact location on each piece of land, which in all cases has a legal owner, typically a physical person, but also public authorities, trusts, and companies. Usually a farm in Denmark consists of several cadastral units, some located near the farm, while others are dispersed in the landscape for historical land use reasons. The latter comprises typically peat groves, forests or meadows that previously represented valuable resources contributing to the farming practices by delivering fuels, hay or grazing opportunities. During the process of structural development in the past decades many farms have been amalgamated. In our analysis, cadastral units belonging to the same estate have been merged, i.e., cadasters belonging to the same juridical unit are treated as one unit of land (even though they are not always contiguous). In this way, we work on the level of the legal property unit rather than the cadastral unit. This reflects the fact that the farm property is an economic or management entity, and that the owners' actions on one specific piece of land may have consequences for the remaining part of the property too. One farmer may however possess several farm properties, and as such, the farmer's possessions may consist of several territorial farms properties and many more legal property units. All this play a vital role in management of ES other than the production-related ones. However, the ownership of several

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