



# Losing a heritage hedgerow landscape. Biocultural diversity conservation in a changing social-ecological Mediterranean system

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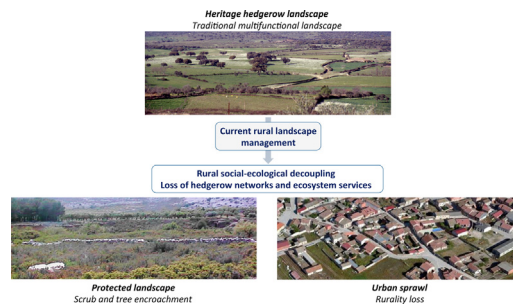
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## HIGHLIGHTS

- We studied an ancient hedgerow network of medieval origin in Central Spain.
- There is a process of rural social-ecological decoupling of the hedgerow landscape.
- The hedgerow network has been degraded both inside and outside protected areas.
- Multiple use hedge species decline affecting the provision of ecosystem services.
- New regulations for the protection of hedgerow landscapes are needed.

## GRAPHICAL ABSTRACT



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## ABSTRACT

Traditional rural landscapes host a biocultural heritage acquired by rural societies, developed in a secular adaptation with nature. Hedgerows play a key role in preserving biocultural diversity and associated ecosystem services. Despite their benefits, in some European regions inappropriate hedge management has led to a drastic degradation of hedgerows, with significant effects on natural and biocultural diversity, landscape connectivity and sustainable flow of ecosystem services. In Central Spain, an ancient hedgerow landscape constitutes a valuable natural and cultural heritage recognized by the establishment of different protection categories. We quantify the main tendency of change of this landscape over time, detecting a process of rural social-ecological decoupling both inside and outside protected areas. The hedgerow network has progressively been degraded and destructured together with the decline and local extinction of woody species, all of them of traditional use and some recorded in red lists for species conservation. This reveals weaknesses in the design and management plans of protected areas that should be effective in conserving the heritage of cultural landscapes and their valuable biocultural diversity and provision of ecosystem services. There is a need to elaborate regulations for the protection of hedgerow landscapes in the Spanish legislation, based on social-ecological relationships.

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## 1. Introduction

Hedgerows are key features in many traditional agrosilvopastoral systems. Usually they are man-made and have been planted by rural

societies from the Neolithic period with the main aim of closing fields (Morgan Evans, 1994). Traditionally, hedgerows have as their prime agricultural roles to serve as field boundaries, windbreaks and fences for livestock, providing them with food and shelter (Baudry et al., 2000; Bird et al., 2002; Harvey et al., 2005). It is undeniable that hedges exist in the landscape because they have real agricultural functions and that the development of the hedgerow landscape is linked to the evolution of agricultural and livestock activities (Marshall and Moonen, 2002).

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These networks of woody vegetation across landscape also perform important ecological functions, promoting biodiversity and providing provisioning, regulating and cultural ecosystem services (Millennium Ecosystem Assessment, 2005; Dainese et al., 2016). They improve crop productivity, reduce pest incidence (Marshall and Moonen, 2002; Morandin et al., 2014), maintain landscape connectivity (Baguette et al., 2000; Hanski et al., 2000; Busck, 2003; Davies and Pullin, 2007; Wehling and Diekmann, 2009; Staley et al., 2012), protect soils and reduce erosion (Keesstra et al., 2016) and processes associated with this regulation ecosystem service, such as the movement of sediments, fertilizers and pesticide from agricultural lands (Logsdon and Chaubey, 2013; Novara et al., 2013). Likewise, it is increasingly documented that hedgerow networks provide valuable breeding habitat, refuge and food for wildlife and can help to sustain beneficial species (Dover and Sparks, 2000; Olson and Wäckers, 2007; Boughey et al., 2011; Buse, 2012; Miñarro and Prida, 2013; Morandin and Kremen, 2013; Cross et al., 2015, among others). Specifically, hedgerows can serve to develop a network of ecological corridors that can facilitate the movement of beneficial organisms, such as pollinators, in the landscape matrix (Schmucki and De Blois, 2009; Morandin and Kremen, 2013; Dainese et al., 2016). In addition, hedgerows have significant historical and cultural values, hosting many useful species with symbolic, ritual and ceremonial uses (Burel and Baudry, 1995; Baudry et al., 2000; Macdonald and Johnson, 2000; Busck, 2003; Schmitz et al., 2007; Alignier and Baudry, 2015).

Given the ecological multifunctionality of hedgerows and their importance for sustainable agriculture and conservation of rural biodiversity (Deckers et al., 2005; Schmitz et al., 2017), the EU Biodiversity Strategy has designated hedgerows as a priority habitat for conservation (JNCC-DEFRA, 2012) and some European countries have developed programs for the conservation and restoration of hedgerow networks in institutionalized frameworks, encouraging farmers to plant hedges through subsidy schemes with public funding (Busck, 2003; Kleijn and Sutherland, 2003; Croxton et al., 2004; Boughey et al., 2011; Fuentes-Montemayor et al., 2011). Thus, hedgerow management, conservation and restoration activities can be considered as dependent on social-ecological systems with multiple interactions and feedbacks between landscape characteristics, local actors, socioeconomic conditions, land planning and public support (Busck, 2003; De Aranzabal et al., 2008; Rescia et al., 2010; Palomo et al., 2011; Schmitz et al., 2018). Since hedgerows play a key role in the maintenance of biodiversity and functionality of landscapes, they can be used as indicators of the state of conservation of rural landscapes providing an ecological, social and historical valuable basis for conservation and land-use planning (Burel and Baudry, 1995; Schmitz et al., 2007). However, despite their social-ecological benefits and conservation efforts, in some European regions inappropriate hedge management has led to a drastic loss of hedgerow networks. Over the last decades, both rural abandonment and agricultural intensification processes, the main land use change trajectories (Schmitz et al., 2003; Antrop, 2006; Antrop and Van Eetvelde, 2008; De Aranzabal et al., 2008; Nainggolan et al., 2012), have resulted in the widespread loss, removal or alteration of long-standing hedgerows in many regions with significant effects on natural and biocultural diversity (Le Cœur et al., 2002; Deckers et al., 2005; Schmitz et al., 2007, 2018; Sánchez et al., 2010; Boughey et al., 2011). The hedgerow degradation process has serious implications for species conservation, maintenance, connectivity and resilience of cultural landscape and the preservation of a sustainable flow of ecosystem goods and services to society (Dover and Sparks, 2000; Bengtsson et al., 2003; Lindborg and Eriksson, 2004; Davies and Pullin, 2007; Olson and Wäckers, 2007; Essl et al., 2015).

Faced with the increase in habitat degradation, loss of biodiversity and alteration of ecological processes, protected areas (PAs) represent the cornerstone of conservation efforts (DeFries et al., 2005; Nelson and Chomitz, 2011). PAs, designed to safeguard remaining habitats and species, are central to conservation strategies and their

effectiveness can range from areas with inclusive and adaptive programs for sustainable management to areas with no active management, known as “paper parks” (Timko and Innes, 2009; Nagendra et al., 2013). Hedgerow network landscapes need to be actively managed in order to be maintained, and current socioeconomic changes, as well as a misunderstood idea of preservation of nature, do not favour their conservation. In recent years the effectiveness of some measures to conserve nature and biodiversity is being questioned, since land conservation policies have frequently been defensive and management plans often neglect or even restrict traditional rural activities and forget the local population, which have contributed to the high conservation values recognized in cultural landscapes (Le Cœur et al., 2002; Schmitz et al., 2012). In the Mediterranean region, traditional grazing activity has favoured the diversity of habitats and species (Montalvo et al., 1993), but nature protection policies focused on naturalness and wilderness have led to the restriction and elimination of grazing in many PAs (Verdú et al., 2000). These nature conservation efforts have resulted in the decline of functional species composition and plant diversity of pasture systems (Peco et al., 2006), loss of natural and biocultural diversity and, ultimately, in the abandonment of the rural landscape and the reduction or disappearance of traditional knowledge (Verdú et al., 2000; Millennium Ecosystem Assessment, 2005; Plieninger, 2006; Petanidou et al., 2008; Schmitz et al., 2012). Additionally, too often management plans of PAs are dependent on administrative boundaries and political legislation, and not on social-ecological relationships, biophysical processes and ecosystem services fluxes. This reduces their effectiveness in protecting landscapes based on social-ecological interactions, such as hedgerow landscapes (DeFries et al., 2007).

This study was undertaken in order to analyse the temporal evolution and conservation status of a relict hedgerow landscape of medieval origin in Central Spain, partially included within the boundaries of different categories of PAs. The aims were: i) to evaluate the social-ecological changes of the region, explicitly considering hedgerows as integral components of the local social-ecological systems; ii) to assess the gap between the management targets of PAs and the effective hedgerow network conservation. To this end we empirically examine the typology and dynamics of the social-ecological interactions and the main indicators of change of the hedgerow landscape studied, inside and outside the boundaries of PAs.

## 2. Methods

### 2.1. Study area

The study area is located in the piedmont of the southern slope of the Guadarrama Mountain Range, in the Madrid Region (Central Spain; Fig. 1a). The climate is continental Mediterranean and the substrate consists of granitoid and gneiss rocks with lithic and dystrophic leptosols. The natural vegetation is Mediterranean forest comprising different species of trees and scrubs (*Quercus ilex*, *Q. pyrenaica*, *Q. faginea*, *Fraxinus angustifolia*, *Cistus ladanifer*, *Lavandula stoechas*, *Cytisus scoparius* and *Genista cinerea*, among others). Throughout centuries, the area has become a human-shaped landscape where original forests have been transformed into *dehesas* (open savannah-like woodlands used as pastures) of *Quercus* spp. or *Fraxinus angustifolia* interconnected by hedgerow networks. This results in a multifunctional silvopastoral system that has constituted the main traditional economic activity in this territory (Schmitz et al., 2012). In this area, the hedgerow network landscape is very old (13th century) and constitutes a valuable natural and cultural heritage (Fig. 1b). In its origin, dry stone walls enclosing pastures were built by farmers as a defence against the transhumant herding of the Mesta, mainly sheep. Hedges comprise a mix of stone walls and woody vegetation growing alongside the wall and their original structure and spatial configuration of the fields and drove roads were

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