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Research Paper

A comparison of microclimate and environmental modification produced by hedgerows and dehesa in the Mediterranean region: A study in the Guadarrama region, Spain

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HIGHLIGHTS

- Temperature profiles were similar in hedgerows and dehesa.
- Hedgerows had higher soil water content, lower wind speeds, and higher total soil organic carbon.
- Conditions under woody vegetation in both systems extended out to the adjacent open fields.
- Hedged fields have advantages over dehesa for shelter, production and natural capital.

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ABSTRACT

Two common forms of traditional land use systems in Mediterranean landscapes are dehesa and hedged fields. Both are agroforestry systems in which domestic stock are pastured: amongst parklike trees in dehesa, and in enclosures surrounded by stone walls and woody vegetation in hedged fields. The latter are now tending to be replaced by dehesa due to labour costs. Here, we investigate the boundary layer microclimate and environmental characteristics of these two land uses in order to evaluate the respective differences in relation to climate modification, soil organic carbon, and soil water content. *Fraxinus angustifolia*-dominated sites were investigated in the Guadarrama mountains, Spain, in high summer with simultaneous sampling under trees in both dehesa and hedgerows and in adjacent open fields. Whilst temperature profiles were similar in both systems, hedgerows had higher soil water content, lower wind speeds, and higher total soil organic carbon compared to dehesa, and moreover these trends also applied to open fields of the respective systems. We conclude that not only do hedged fields have advantages over dehesa for shelter and production, but that the climatic modifications of hedged field systems potentially modify boundary layer climates on a broader scale than both individual fields and dehesa. Thus, the conservation of hedged field systems provides natural capital and broad environmental gains.

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1. Introduction

Agriculture is the dominant landuse of western Europe comprising half the land surface area (measured as arable land, permanent crops, pastures and mixed mosaics) (Meiner, Georgi, Petersen, & Uhel, 2010). In the Mediterranean Basin a long history of human presence have fashioned cultural landscapes that intermingle natural vegetation with fields for crops or grass in the form of savanna-like 'dehesas' (Antrop, 1997; Bunce et al., 2001; Schmitz, De Aranzabal, Aguilera, Rescia, & Pineda, 2003). These comprise multi-purpose agroforestry systems with a mosaic of widely spaced trees combined with crops, pasture or shrubs (Grove & Rackham, 2001). Many such traditional European agroforestry systems have declined sharply over the last century and in the Iberian peninsular the pace of change has accelerated greatly since the 1950s with significant depopulation of many rural areas (Comins, Sendra, & Sanz, 1993; Díaz, Campos, & Pulido, 1997; Eichhorn et al., 2006; Pinto-Correia, 1993).

Notwithstanding these declines, agricultural-dominated landscapes still often contain natural capital in the form of woody vegetation that provide ecosystem services such as provisioning

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(e.g., wood for fuel, timber), regulating (carbon sequestration, purification of air and water), and cultural services (e.g., cultural and aesthetic) (Hassan, Scholes, & Ash, 2005; Höchtl, Born, & Plieninger, 2010). Woody vegetation in dehesas have been reported to improve soil fertility, microclimate, soil water-holding capacity and have beneficial effects both in terms of moderating the environmental conditions of adjacent crop fields and on overall species diversity (Bergmeier, Petermann, & Schroder, 2010; Gea-Izquierdo, Allen-Díaz, San Miguel, & Cañellas, 2010; Joffre & Rambal, 1988; Jose, Gillespie, & Pallardy, 2004; Moreno, Obrador, & Garcia, 2007; Moreno Marcos et al., 2007; Sánchez, Lassaletta, McCollin, & Bunce, 2010).

Another multi-purpose agroforestry system of the Mediterranean region is the mosaic of fields bounded by stone walls, often naturally colonized by woody vegetation (Sánchez et al., 2010). (We refer to the latter as 'hedgerows' – see Section 2.) Like dehesas, hedgerows in the Mediterranean are capable of reducing soil erosion (Donjadee, Clemente, Tingsanchali, & Chinnarasri, 2010), modifying the microclimate (Casa, Valentini, Scarascia, & Mugnozza, 1994; Sánchez et al., 2010), maintaining soil water content, protecting orchards (Gomez-del-Campo, 2010), as well as providing habitat for woodland (Sitzia, 2007) and other plant species (Bassa, Chamorro, José-María, Blanco-Moreno, & Sans, 2012) whilst at the same time serving their primary function of enclosing pastures. The microclimate of such hedgerows have been shown to be a factor governing the occurrence of certain insects on farmland (Gardiner & Dover, 2008; Ricci, Franck, Bouvier, Casado, & Lavigne, 2011; Scalercio, Iannotta, & Brandmayr, 2007) and in the Mediterranean region hedgerows have also been shown to aid the survival of forest carnivores in agricultural landscapes (Pereira & Rodriguez, 2010).

Rural landuse in Europe is currently undergoing polarization – with intensification on the one hand and extensification/marginalization and abandonment on the other – with implications for changing socioeconomic, cultural and biodiversity values of landscapes (Plieninger & Schaar, 2008; Schmitz et al., 2003). Such processes result in structural changes to these traditional landscapes that may have as yet unknown consequences for the landscape values and resources (Plieninger, Höchtl, & Spek, 2006) as well as the natural services they provide. In our study area traditional pasture systems with hedgerow dominated by *F. angustifolia* are being transformed into dehesa systems, thus maintaining land as pasture but potentially with a lower demand for labour. When neglected, fields suffer encroachment by woody vegetation with deterioration of pastures (Mairota, Leronni, Xi, Mladenoff, & Nagendra, 2014). Thus, we are particularly interested in comparing and evaluating the modifying effects on the environment of the pastures brought about by the transformation of hedgerow into dehesa systems.

The change and decline of *Quercus* dehesa has been well documented (e.g., Eichhorn et al., 2006) but little comparable information exists for dehesas dominated by other species such as *F. angustifolia* as in our study area (Madera & Uradnicek, 2001; Sánchez et al., 2010). These *F. angustifolia*-dominated hedgerow and dehesa landscapes differ substantially from those of *Quercus*-dominated dehesas in (amongst other environmental factors) the higher water table requirements of the soil (Jaeger, Gessler, Biller, Rennenberg, & Kreuzwieser, 2009) that, with the characteristic structure of the vegetation, contribute to form multipurpose cultural landscapes. We hypothesize that the vertical structures of both systems bring about modifications in microclimate and soil conditions but the extent to which the systems differ is unknown. The findings will have possible implications for ecology, production, and management. Our study focuses on high summer since this dry period produces a strong climatic constraint (Joffre & Rambal, 1993) when a soil water deficit is a key factor affecting productivity (Ibañez, Lledó, Sánchez, & Rodá, 1999).

2. Methods

2.1. The study area

The study was carried out in three sites situated on the gently sloping (10°–20°) south-facing pediment of the Central Mountain Range (Guadarrama) in the Madrid region (40°40′ to 40°46′ N and 4°02′ to 3°34′ W). The substrate of the study fields is formed by granite and gneiss rocks and arkoses. The flora of hedgerow and dehesa systems comprise natural vegetation although the species composition may have been influenced by deliberate selection and by browsing. *F. angustifolia* is the most frequent tree species forming the dehesas and hedgerows in this region in contrast to other dehesas in Spain which are dominated by oaks *Quercus* spp. Other common woody species in this study area include *Quercus rotundifolia*, *Quercus pyrenaica*, *Salix* spp., *Euonymus europaeus*, *Prunus spinosa*, *Acer monspessulanum*, *P. spinosa*, *Rosa micrantha*, *R. corymbifera*, *R. canina*, *R. squamosa*, *Frangula alnus*, *Crataegus monogyna*, *Osiris alba*, *Rubus ulmifolius*, *Lonicera etrusca*, *L. periclymenum* and *Rhamnus cathartica*. Common species in the herbaceous layer under the woody vegetation include *Aristolochia paucinervis*, *Centaurea nigra*, *Primula veris*, *Viola riviniana*, *Agrimonia eupatoria* and *Alliaria petiolata*. In the fields the most common herbaceous plants are *Arrhenatherum elatius*, *Dactylis glomerata*, *Festuca ampla*, *Holcus lanatus*, *Agrostis castellana*, *Anthyllis vulneraria*, *Briza media*, *Trifolium* spp., *Rumex acetosa*, *Plantago lanceolata*, *P. media*, *Lotus corniculatus* and *Hypochoeris radicata*.

The hedgerows in this study comprise field margins which originated as stone walls built as a defence by farmers and landowners against the rights of Mesta transhumance sheep (Grove & Rackham, 2001; Klein, 1920). These *c.* 1 m high stone walls are an integral part of the field margins that surround dehesas and are still useful to keep cattle in fields. We refer to these structures as 'hedges' or 'hedgerows' although they comprise a mix of stone wall and woody vegetation. Maintenance includes repair of stone walls and pollarding of *F. angustifolia* to provide browse for cattle during the summer period (although cattle also eat other hedgerow plants) (Sánchez, 2001). During the winter months hedgerows and the woody vegetation in the dehesa serve as a refuge for stock against cold winds.

2.2. Site selection

Three sites were selected on the southern side of the Central Mountain Range (Guadarrama). All sites had a common land use – cattle ranging – the most widespread use of such land throughout the study area. Grazing in each field is controlled by shepherds who move cattle between fields to control for over-grazing. Initial site selection was made using aerial photographs and cartography to control for vegetation structure and relief. Hedgerow networks were chosen to be close to dehesa fields with both systems having similar characteristics in terms of size, vegetation cover, species composition, horizontal structure and aspect. The selection process involved fieldwork to measure hedgerow and dehesa vegetation so that they could have similar characteristics in terms of mean woody vegetation cover for each field. Hedgerow homogeneity was measured using a standardized procedure (Bickmore, 2002). Though uncommon, hedgerows having barbed-wire to protect the hedgerows from browsing were excluded in the selection process to enable a more uniform sample.

The three most similar study sites were selected, namely: Collado Mediano (hereafter referred to as Coll-Med), El Vellón-Lozoya

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