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## BUILDING RESILIENT MEDITERRANEAN SILVOPASTORAL SYSTEMS: LESSONS FROM IBERIAN DEHESAS AND MONTADOS

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**Summary:** Silvopastoral systems are more biodiverse and resilient than open pastures but their complexity limits their competitiveness. Innovative market strategies, governance systems and policy measures are needed to ensure their long-term resilience.

**Keywords:** Oak woodlands; agroforestry; tree regeneration; ecological intensification; governance

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### 1. Introduction

Agroforestry has gained increasing attention across the world in recent decades due to its recognized environmental, social and economic benefits (Herder et al., 2017). Among the various categories of agroforestry, Silvopasture (SP) is presumably the most widespread and diverse (Moreno and Rolo, 2019). SP intentionally integrates livestock with trees and/or shrubs—either native or planted—alongside forages within the same land unit, fostering mutual benefits among all components (Jose et al., 2017). Trees serve multiple functions, providing fodder, shade, shelter, timber, fuelwood, cork and tanning, while also contributing to biodiversity and ecosystem services.

SP include scattered trees in grasslands, live fences, windbreaks, fodder tree banks, cut-and-carry systems, tree plantations with livestock grazing, pastures between tree alleys and intensive SP systems (Mosquera-Losada et al., 2009). These range from densely wooded pastoral forests to open wooded grasslands, such as savanna-like landscapes with scattered trees. In arid regions, trees and shrubs often become the primary forage resource (Papanastasis et al., 2008). Many livestock farms combine SP with forage crops to supplement feed during less favourable seasons (Moreno and Pulido, 2009). SP is predominantly found in marginal areas where challenging topography, low soil fertility, and/or climatic constraints limit intensive agriculture. However, traditional SP systems are increasingly threatened by environmental and economic pressures, largely due to the decline of traditional management practices. The replacement of fuelwood by fossil fuels, forage browsing by concentrated feeds, and seasonal grazing by continuous grazing has led to two diverging trends: land-use intensification in some areas and land abandonment or degradation in others (Pinto-Correia, 2000).

One of the most well-documented SP systems is the Iberian Montado and Dehesa, a complex agroforestry landscape that has been extensively studied (Plieninger et al., 2021). Using it as a model, we identify the key challenges currently threatening traditional SP systems and explore solutions to enhance their resilience in the future.

### 2. The Agroforestry system Montado and Dehesa

The Montados and the Dehesas occur in the SW part of the Iberian Peninsula. They are ancient, human-shaped ecosystems, deeply embedded in the region's cultural identity. These systems are characterized by an open canopy of evergreen oaks—mainly *Quercus suber* and *Quercus ilex* spp. *rotundifolia*—often mingled with other Mediterranean tree species and shrubs. The understory consists of natural or cultivated grasslands. Singular landscape elements, such as woodlots, shrub patches, rock outcrops,

riparian galleries, and Mediterranean temporary and permanent ponds, add further complexity to the Montado and Dehesa matrix. These features enhance biodiversity and provide essential ecosystem services. Beyond cork harvesting, the economic viability of these systems has traditionally relied on low-intensity, large-scale grazing (Sales-Baptista et al., 2016).

In the European Union, agroforestry covers approximately 15.4 million hectares, representing 3.6% of the total territorial area. Nearly half of this (45%) consists of Mediterranean oak-based agroforestry systems, including Dehesa in Spain (3.6 million hectares), Montado in Portugal (1.1 million hectares), and similar systems in Greece, Italy, Spain, and Portugal (Herder et al., 2017).

Despite their valuable public goods and ecosystem services, Montados and Dehesas have been in decline over recent decades (Acácio et al., 2021). In Portugal, both total area and tree cover density have steadily decreased since 1990, highlighting the increasing vulnerability of these landscapes. Various factors have been cited in the literature, but key drivers include management decisions leading to unsustainable grazing and soil practices (Almeida et al., 2016), which have contributed to long-term soil degradation and tree regeneration failure.

### **3. The importance of trees**

#### *3.1. Its productive function*

The primary product of cork oaks' Montados is cork, which is harvested from the tree bark. In the Dehesa, as well as in Montados dominated by holm oaks, additional resources such as acorns consumed by domestic animals and branches managed as a fodder bank provide essential feed during periods of herbaceous grassland shortage. Moreover, trees contribute to the development and maintenance of the herbaceous stratum (López-Díaz et al., 2014). Trees influence pasture productivity, quality, and phenology (Moreno and Rolo, 2021). Grasses growing under tree cover tend to have higher nutrient content, exhibit increased growth during winter, and wither later in late spring. In summary, trees not only provide additional forage resources but also extend the availability of high-nutritional-value green forage for livestock. Novel intensive SP systems which integrate protein-rich trees and shrubs with highly productive grass understory, are gaining momentum in the context of climate change and the push for greater fodder autonomy on farms (Mahecha et al., 2022). Additionally, trees offer livestock protection from excessive solar radiation, extreme temperatures, and strong winds. This sheltering effect can improve animal well-being, reduce their nutritional requirements, conserve fodder resources, and enhance farm profitability (Mantino et al., in prep.).

#### *3.2. Its protective function*

Trees also provide multiple environmental services in SP systems, including atmospheric carbon fixation, soil fertilization, erosion control, improved microclimate, biodiversity conservation, and enhanced landscape quality. Spatial heterogeneity in SP ranges from fine-scale gradients caused by scattered tree canopies to broader land-use and land-cover variations that define extensive SP farms and landscapes. Additionally, trees serve as a refuge and fodder source for many species. Together, these factors create ecological niches that support a wide range of organisms, making SP systems frequently more biodiverse than comparable forests, open pastures, and farmlands (Díaz et al., 2013). Studies in the Dehesa indicate that the amount of carbon sequestered in soil beneath tree canopies is twice that of open areas (Howlett et al., 2011). Furthermore, the carbon sequestration potential of SP could significantly offset greenhouse gas emissions associated with livestock production (Reyes-Palomo et al., 2022). Trees also help reduce nutrient leaching and odors in more intensive or fertilized silvopastures.

### **4. Main challenges and possible pathways to promote resilience**

#### *4.1. Management practices*

SP have historically provided multiple products and supported various trades, many of which are now falling into disuse. Examples include the progressive abandonment of transhumance, shepherding,

silvicultural practices, and the harvesting of wild products. However, new opportunities are emerging, particularly in biomass utilization. Biomass chips production for domestic and industrial heating, as well as biochar production, is creating renewed interest in tree pruning and the use of trees as a fodder bank. As part of a pilot project aimed at enhancing circularity, forage autonomy, and carbon neutrality in Dehesa farms, biomass waste from pruning and shrub clearing is being pyrolyzed. The resulting biochar is then used in stables as bedding, which helps reduce gas emissions and improves livestock welfare. Finally, the biochar-enriched manure is applied as fertilizer to legume-forage crops, enhancing soil fertility. In another pilot project, close monitoring of soil health—along with the adoption of minimum tillage and targeted pH and toxicity corrections—is yielding promising results regarding pasture diversity and forage mass production (Guimarães et al., 2023). Additionally, legume enrichment of native pastures and adaptive rotational grazing are showing significant potential for improving forage autonomy in Dehesa farms. Recent advances in virtual fencing are gradually facilitating the implementation of more adaptive rotational grazing schemes. These innovations are leading to improvements in livestock carrying capacity, soil conservation, and tree regeneration. Finally, the rising interest in natural foods presents new market opportunities for traditionally harvested SP products, such as aromatic plants, asparagus, mushrooms, and even acorns, which are increasingly being used in baking.

#### 4.2. *Natural tree regeneration*

In many cases woody vegetation has been hardly managed and/or management has not adapted to ongoing ecological and economical changes. Indeed, the progressive degradation and deforestation of SP has been denounced for Mediterranean wood pastures (Moreno and Pulido, 2009) and other semiarid (Yadav et al., 1997) and tropical (Angelsen and Kaimowitz, 2004) regions. At the other extreme, especially in mountain areas, abandonment is the harsh reality, resulting in woody encroachment of SP, with important changes on their functioning and productivity (Asner et al., 2004). The true challenge is to integrate the dual objectives, intensification (e.g., pasture improvement) that could play against tree regeneration, and periodical woody encroachment that guarantees soil and tree regeneration and thus, sustainability of the system. With the decline of transhumance, farm management strategies should incorporate both seasonal and multi-annual rotation cycles to ensure adequate sapling recruitment. Once established, the most vigorous saplings should be protected to maintain a diverse, multi-aged tree cover that supports long-term system resilience.

#### 4.3. *Gaining economic resilience through Ecosystem Services*

Many studies have clearly demonstrated the productive potential and ability of various agroforestry systems—both traditional (such as Dehesa-Montado) and more innovative ones—to efficiently provide environmental services (Burgess and Rosati, 2018). The provision of environmental services by SP includes climate change mitigation and adaptation, soil erosion control, water protection, biodiversity conservation and promotion, and fire prevention. Although, there are still multiple technical, political-administrative and financial challenges to overcome for the successful implementation of schemes of payment for ecosystem services (PES), the menu of PES options for livestock farmers is growing in countries such as Australia and EE:UU (Salzman et al., 2018). In the absence of an assured demand for carbon and conservation credits (and/or certified products), promoters of PES initiatives will have to provide the initial investment (usually public funds) until a consistent portfolio of buyers of such credits or products is established. In this regard, Guimarães et al. (2023), through a transdisciplinary dialogue involving researchers, practitioners (i.e farmers), public authorities and policy makers, identified 12 potential strategic management practices (and their cost) along with the technical support that farmers would need. They conclude that a Result-Based Payment scheme could be an affordable solution for public policies in the Montado system.

#### 4.4. *Gaining social resilience through new governance schemes*

In their recent book 'Governance for Mediterranean Silvo-Pastoral Systems', Pinto-Correia et al. (2022) highlight the need of new governance solutions to address the multiple challenges faced by Mediterranean SP. They identify some key stones to move forward:

- Defining owners', stakeholders' and societal expectations for the future of SP territories
- Understanding the social and institutional drivers of change
- Acknowledging different patterns of ownership and different motivations
- Opening up for new actor roles
- Identifying and resolving conflicts
- Building new ecological, social and institutional equilibriums

## 5. Policies to support the system and respond to the challenges

1. SP systems, insofar as their diversity and complexity are key elements of their sustainability, should be fully recognised in any agricultural policy and payment scheme.
2. High tree cover should not be a sole criterion for classifying an area as forested in order to exclude it from agricultural payments. As far as grazing activity is dominant, regardless of herbaceous cover, no reduction coefficient should be applied to determine the eligible area of SP for public grants.
3. Many shrub species also play outstanding roles in the productivity, as forage source, and sustainability, by facilitating tree regeneration (nursery effect), of the Mediterranean SP systems. Consequently, policies should not only allow for a certain degree of scrubland in SP, but should also encourage it in order to ensure their long term persistence.
4. To reduce the risk of wildfire, agricultural policy should articulate mechanisms to encourage grazing in strategic areas at risk of abandonment due to their orography and inaccessibility, instead of penalising them for excessive tree and/or shrub cover.
5. SP frequently locate in more nature value territories, encompassed with greater environmental requirements in terms of permitted management practices, what should be compensated by public payments for biodiversity conservation and the provision of ecosystem services. This requires the development of an appropriate Environmental Accounting System that quantifies the value of environmental services such as carbon sequestration, biodiversity, water quality, landscape aesthetics, etc. that each farm/system generates.
6. In order to maintain the profitability, SP farms needs productive innovations, improving the production of its components, management and production techniques, diversification and differentiation of its products in terms of quality and marketing channels. All these aspects can and should be supported with different measures under Rural Development Plans.
7. Finally, it should be pointed out that SP frequently are landscape of Cultural Heritage, a sufficient reasons for them to form a priority part of the Rural Development policies in their regions/countries.

## 6. Conclusions

SP systems work in a delicate equilibrium among deforestation and encroachment. The reconciliation of grazing with natural regeneration is an essential, and not always well-managed, element for the ecological sustainability of extensive SP systems. The simplification of multiple uses, the loss of traditional practices, and out-dated governance schemes compromises their competitiveness and thus their socio-economic sustainability. The search of carbon neutrality and valuing their high-quality products and ecosystems services could bring a new opportunity for these traditional systems.

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