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OPINION ARTICLE

The Chilean Espinal: Restoration for a Sustainable Silvopastoral System

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Abstract

The mediterranean habitats of central Chile are rich in endemic species, but threatened by land-use changes. In this context, we suggest that restoration of the traditional espinal silvopastoral system could improve its sustainability and conservation value. Past research on the espinal embraced negative stereotypes of peasants, the tree *Acacia caven*, and the semiarid landscape to recommend abandoning the silvopastoral system. We think that recommendation is premature and ignores the value of the espinal as a classical Chilean cultural landscape. Drawing on lessons from silvopastoral systems in Latin America and the Mediterranean, here we suggest several management interventions and incentives that could be developed to restore the espinal. Particular challenges in espinal include low biomass production due to the semiarid climate and the lack of a traditional sustainable timber or non-timber product of *A. caven*. Our recommendations include sustainable production and use of biochar and bark extracts from *A. caven* to improve espinal soils, the promotion of shrubs and the use of small mammal disturbances, and their artificial analogs to improve *A. caven* reproduction, and rotational livestock herding to form mosaic landscapes. These techniques could lead to higher forage biomass and increased livestock weights. Incentive structures to implement these management activities could include tax benefits for private protected area (IUCN category VI) creation, REDD+ and PES programs, along with promotion of the cultural value of the espinal. Further research is urgently called for on ecosystem services, ecological baselines, biochar, and other management and incentive structures that could be applied in the espinal.

Key words: ***Acacia caven*, biochar, Chile, espinal, PES, REDD+, silvopastoral system.**

Introduction

Restoration of landscapes with known histories of human activity is a challenge for ecology, and raises questions about its roles in society. Conflict between goals and values can be particularly acute in drylands where desertification is a threat, in areas of high endemism, and in cultural landscapes under changing socioeconomic conditions. Mediterranean-climate habitats often fall in all three categories. An interdisciplinary, critical, and creative approach is essential to address the complex problems presented by their restoration (Khater et al. 2012). Here, we consider the espinal (Fig. 1), a silvopastoral habitat of the mediterranean climate region of central Chile, a semiarid area rich in endemic species but threatened by expansion of agriculture (Armesto et al. 2009). Developing a sustainable silvopastoral system of conservation value in the espinal has largely been overlooked.

Espinal is a savanna of *Acacia caven*, abutting remnants of matorral and sclerophyllous forest (Donoso 1982). Since the colonial period, espinal has been used as pasture for livestock (Ovalle et al. 1990). Overexploitation leads to an "educated" view of the espinal as lacking cultural or biodiversity values, forming a landscape associated with rural poverty (Aronson et al. 1998; Root-Bernstein 2012). It is "used and then used up" for short-term gain (Galaz Montero 2004; Root-Bernstein 2012). Past studies suggested that the espinal is degraded and irretrievably mismanaged, and that *A. caven* is a "parasite" (e.g. Ovalle et al. 1990; Aronson et al. 1993*a*, 1998; Ovalle et al. 1999). After initial optimism about improving production with non-native trees (Aronson et al. 1993*b*), the authors later recommended that most espinals be "reallocated" to other economic uses (Ovalle et al. 1999). Nevertheless, these authors' claim that espinal has passed a critical ecological threshold remains unsubstantiated. We are not aware of published research quantitatively assessing critical thresholds in espinal, either according to the authors' criteria or modern criteria (Guttal & Jayaprakash 2009). Meanwhile, agronomy studies suggest non-catastrophic reversibility of some parameters of espinal condition (Navarro Gutiérrez 1995).

Complicating the picture, *A. caven* may be considered an invasive species. Assessing the invasive status of species involves value-laden interpretation of scientific findings (Larson 2007*a*). *Acacia caven* is thought to have been introduced

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Figure 1. Views of espinal. Top left, espinal in summer (dry season) in an agricultural landscape. Top right, espinal grazed by sheep (spring). Bottom left, espinal in early spring. Bottom right, espinal in winter (wet season) with mounds made by the fossorial rodent *Spalacopus cyanus*. Photographs © M.R.-B.

by indigenous people and their camelids from across the Andes before European colonization (Ovalle et al. 1990). Although cattle are responsible for recent *A. caven* seed dispersal within Chile (Gutiérrez & Armesto 1981), wild camelids are now extirpated from central Chile and their historical role as trans-Andean seed dispersers for Argentinian chaco trees is uncertain (Fuentes et al., 1989). If guanacos (*Lama guanicoe*), a native camelid species, are responsible for *A. caven* range expansion, then arguably this is a case of dispersal, not invasion (Schlaepfer et al. 2011). By contrast, treating *A. caven* as an invasive species could be justified in terms of its dominance and its apparent replacement of endemic sclerophyllous forests (Larson 2007*b*; Davis et al. 2011; Van de Wouw et al. 2011). However, this justification should also consider the contribution of current anthropogenic influences (Larson 2007*a*). Paleoecological data could also put the arrival of *A. caven* in perspective (Froyd & Willis 2008). Finally, Chileans view the tree *A. caven* as classically Chilean (Root-Bernstein 2012; Root-Bernstein & Armesto in press). Thus, eradication or failure to restore espinals might be viewed negatively, or might contribute to destroying rural people's current relationships to the landscape (Bardsley & Edwards-Jones 2006; Larson 2007*a*). We think there is an argument to be made that *A. caven* is a keystone species in the cultural landscape, that its range expansion was a "natural" process, and that its current distribution does not have a net harmful impact (see below).

We propose that the espinal has been understudied and potentially misunderstood, and deserves renewed attention. Here, we provide a novel viewpoint on espinal restoration and sustainable management as a silvopastoral system of conservation value.

What Makes a Good Silvopastoral System?

Silvopastoral systems are anthropogenic open woodlands used for livestock pasture. Extensive management of livestock is made profitable partly by managing the landscape for tree products, non-timber forest products, and other use values (Surová & Pinto-Correia 2008; Bugalho et al. 2011). The resulting heterogeneity provides enhanced ecosystem services and greater biodiversity than alternative land uses (Berrahmouni et al. 2009; Sirami et al. 2010). Large continuous landholdings are critical (Pinto-Correia 2000).

Espinal management largely focuses on improving the quality and biomass of plants that serve as forage for livestock (Ovalle et al. 1990; del Pozo et al. 2006). In addition, espinals can be managed for the production of herbs, medicinal plants, honey, and charcoal (Pacheco Marín 2005). A small-scale study found that charcoal production accounted for 12% of espinal landholders' income, agriculture 50%, animal husbandry 32.8%, and other forestry products 3.9% (Galaz Montero 2004). Overstocking of livestock and periodic felling of *Acacia caven* for charcoal production reduce *A. caven* density, herb biomass, and soil quality.

Relatively little is known about the biodiversity and ecosystem services of espinals. Increasing *A. caven* cover is

associated with increasing soil organic content and microbial biomass (Muñoz et al. 2007), N and P in the soil and herbaceous cover (Ovalle et al. 2006). Espinals with and without shrubs provide habitat for many native small mammals and birds (Iriarte et al. 1989; Lazo & Anabalon 1992). Our research group is currently initiating a study of espinal ecosystem services.

Espinal currently covers around 45% of the landscape in central Chile (Van de Wouw 2012), but data on the sizes and connectivity of espinal landholdings are lacking. Landscape-scale connectivity is threatened by incentives to convert to monocultural agriculture or other alternative land uses (Armesto et al. 2009). Private protected areas (PPAs), a development intended to offset the lack of PAs in central Chile, are philanthropic (Pauchard & Villaroel 2002). A law formalizing PPAs is currently under consideration.

Espinal restoration goals could include: (1) improving the yield of key products; (2) reinforcing the ecosystem services provided; and (3) developing legal, economic, and cultural incentives for sustainable management. Here, we discuss several approaches that may deserve greater attention.

Management for Sustainable Wood Products

A possible replacement for charcoal that would draw on the same traditional practices is biochar (Xu et al. 2012). Application of biochar (lignocellulose matter, burnt in low or no oxygen) to soil, along with compost or manure, can alleviate loss of soil fertility, replace chemical fertilizers, and contribute to carbon offset mechanisms for small landholders (Glaser 2007). Adding biochar to soil increases available nutrients and organic material, contributes to carbon storage, increases soil pH in acid soils, and increases drought resistance, among other benefits leading to increased plant biomass (Xu et al. 2012).

Industrial production of biochar is already being trialed in Chile. We propose that small-scale biochar production could use sustainably harvested wood from *Acacia caven*, which would be directly reinvested in espinals. Wood could be harvested through coppicing, maintaining a continuous open canopy. *Acacia caven* timber productivity increases with tree density, between 1,524 and 2,347 $kg\,ha^{-1}\,yr^{-1}$ for adults (Navarro Gutiérrez 1995). Traditional ovens used for charcoal production yield 23–30% of charcoal by weight (Galaz Montero 2004; Pacheco Marín 2005). A potential range for sustainable small-scale biochar production is thus between 0.35 and 0.704 $t\,ha^{-1}\,yr^{-1}$. Positive effects of biochar have been found for rates of application starting at 0.5 t/ha (Sohi et al. 2010). We, thus, believe that biochar could potentially improve espinal productivity.

Soil quality in espinals could also be improved with secondary metabolites from *A. caven*. Extracts in ethanol of *A. caven* bark, high in tannins and phenols, reduce soil nitrification and increase microbial biomass (Suescun et al. 2012). Bark extract in ethanol could thus improve soil nutrient availability and decomposition rates in espinals.

Management for Espinal Reproduction

Acacia caven reproduction could be facilitated in two steps, first by promoting seedling establishment and second by protecting seedlings from herbivory. Natural and artificial pits and mounds, such as those dug by small mammals, facilitate seedling establishment (Dean & Milton 1991; Dhillion 1999). Pits and mounds in espinals can be increased by protecting small mammal populations (Eldridge & James 2009) or using farm equipment (Limb et al. 2010). After seedling establishment, protection from herbivory is essential. Rotating livestock grazing pressure over a landscape promotes the growth of nurse plants (e.g. shrubs), which protect seedlings from herbivory (Provenza & Papachristou 2009).

Promoting nurse plants has other advantages as well. Silvopastoral landscapes with a mosaic of shrub densities are not only preferred by human users but also have a more robust set of ecosystem services, more biodiversity, and more secondary non-timber forest products (de la Fuente de Val et al. 2004; Surová & Pinto-Correia 2008). Along with facilitating shrub establishment, rotating flocks through small areas of rangeland forces livestock to eat not only the palatable but also the less palatable herbs and shrubs. Livestock that learn to mix herbs with various secondary metabolites in their diet gain more weight, bringing more profit, than those that do not (Provenza & Papachristou 2009).

Incentivizing Sustainable Espinal Management

Barriers to adoption of sustainably managed silvopastoral systems in Latin America and the Mediterranean include lack of funding or perverse private economic incentives, and scarce technical knowledge (Campos et al. 2007; Pagiola et al. 2007). Subsidies favoring large-scale landscape connectivity and the creation of silvopastoral PPAs (i.e. IUCN category VI) would help make the espinal an economically and ecologically viable system (Pinto-Correia 2000; Moon & Cocklin 2011). In addition, direct payments for voluntary sustainable management and restoration activities could secure desired ecosystem service and conservation outcomes. REDD+ (Reducing Emissions from Deforestation and forest Degradation) and payment for ecosystem services (PES) programs are two such options.

REDD+ is a funding mechanism agreed by the United Nations Framework Convention on Climate Change in 2010 that pays stakeholders to reduce forest-related carbon emissions. Chile has a Phase 1 plan for implementing REDD+ (CONAF 2012), and espinal is included in its focus on mediterranean habitats (A. Sartori 2012, personal communication). A key issue to resolve in REDD+ implementation in espinals is likely to be coordination with agricultural policy (Petkova et al. 2010). We encourage CONAF to include espinals in its Phase 2 pilots of REDD+ activities.

PES programs pay landowners to adopt management and restoration measures. No such program currently exists for espinals in Chile. The first step in designing a PES program would be to quantify ecosystem services provided by

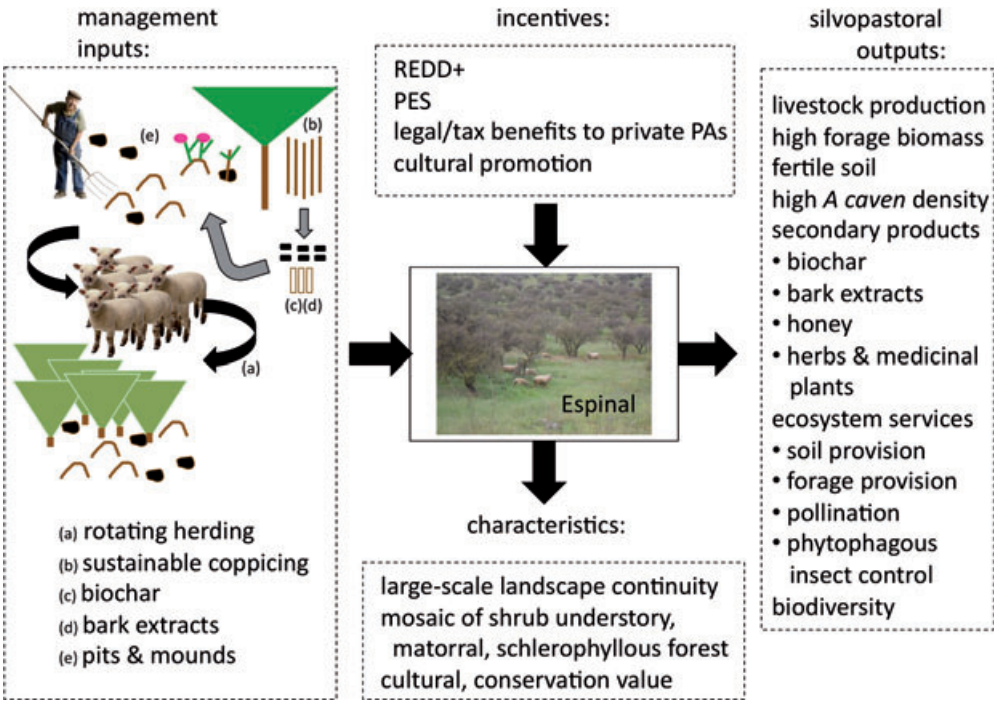

Figure 2. Visual summary of suggested management and incentive options for the espinal silvopastoral system (in-pointing arrows), along with their expected restoration and sustainability outcomes (out-pointing arrows). Photograph © M.R.-B.

espinals (see above). Bundling or layering payments for multiple ecosystem services can reduce perverse incentives and increase payment equity between participants (Montagnini & Finney 2011). Silvopastoral systems provide many examples of successful PES programs (e.g. Pagiola 2007; Murgeitio et al. 2011). One advantage is that revenue from livestock can compensate for initial investments in new management practices (Montagnini & Finney 2011).

Policy implementation could stall because of cultural biases. We observe a tendency to represent smallholders' unsustainable espinal management as due to their fundamental ignorance and laziness, rather than as a rational response to economic incentives (e.g. Aronson et al. 1998). This perception may work against development of and investment in the research, training, and funding mechanisms necessary to restore espinals. To work against this potential bias, stakeholders could develop and publicize a more positive image of the espinal as a cultural landscape with biodiversity value (Root-Bernstein 2012).

Conclusions

Earlier research suggested that the espinal was a degraded and inherently unsustainable silvopastoral system that should be abandoned (Ovalle et al. 1999). We believe that this advice ignored the cultural value and biodiversity of the espinal, and discounted the capacity of new economic incentives to alter management practices. Here, we have suggested several established and experimental methods for improving espinal restoration and management (Fig. 2). We think it could be productive for researchers, conservationists, and policy makers to share lessons from other semiarid cultural landscapes and silvopastoral systems, to work toward a sustainable espinal.

Implications for Practice

- Creative thinking may reveal other possible *Acacia caven* sustainable timber and non-timber products, making silvopastoralism more attractive.
- Livestock herding practices can impact overall biodiversity and ecosystem services and deserve further study in silvopastoral systems.
- PES programs show that ecological outcomes, management practices, and poverty can be altered. This message conflicts with fatalistic local narratives about espinal. Restoration ecologists should realize that both visions implicate them in a multifaceted socio-historico-policito-economic issue.
- For ambiguous nonendemic species like *A. caven*, public and scientific debate for and against their restoration, and discussion of what restoration would mean, may help to clarify the species' socioecological roles.

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