Agriculture, Ecosystems and Environment 184 (2014) 135–144

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Arid old-field restoration: Native perennial grasses suppress weeds and erosion, but also suppress native shrubs

Lauren M. Porensky[a,*], Elizabeth A. Leger[a], Jay Davison[b], W. Wally Miller[a], Erin M. Goergen[a,1], Erin K. Espeland[a,2], Erin M. Carroll-Moore[a]

[a] Department of Natural Resources and Environmental Science, University of Nevada, Reno, NV 89557, USA
[b] University of Nevada Cooperative Extension, Fallon, NV 89406, USA

ARTICLE INFO

Article history:
Received 11 July 2013
Received in revised form
12 November 2013
Accepted 21 November 2013
Available online 20 December 2013

Keywords:
Cropland abandonment
Irrigation
Native shrub facilitation
US arid Great Basin
Walker Basin
Weed control

ABSTRACT

Rates of cropland abandonment in arid regions are increasing, and abandoned fields in such regions can have low levels of ecosystem function and biodiversity. Long-lived, drought-tolerant shrubs are dominant components of many arid ecosystems, providing multiple ecosystem services such as soil stabilization, herbaceous plant facilitation, carbon storage and wildlife habitat. On abandoned agricultural fields, shrub restoration is hindered by multiple challenges, including erosion, water stress and invasive species. We hypothesized that applying short-term irrigation and seeding native perennial grasses would facilitate native shrub establishment by reducing erosion and weed abundance. Using a blocked split-plot design, we evaluated the separate and combined impacts of short-term irrigation and perennial grass seeding on five-year restoration outcomes (including direct measurements of wind erosion) at two former agricultural fields in North America's arid Great Basin. After two years, irrigation had increased the density and biomass of seeded grasses by more than ten-fold. The combination of irrigation and seeded grasses was associated with significantly lower wind erosion, weed density and weed biomass. Three years after irrigation ended, seeded grasses remained significantly more abundant in formerly irrigated than non-irrigated plots. Formerly irrigated plots also had significantly less bare ground, annual plant cover and weed biomass than non-irrigated plots. Large plant-canopy gaps were fewer in irrigated and seeded plots. Although seeded grasses reduced erosion and invasion, they failed to facilitate native shrub establishment. Shrub cover and density were highest in plots that had been drill-seeded and irrigated, but lacked perennial grasses. Our results indicate that short-term irrigation has persistent restoration benefits, and that a tradeoff exists between the benefits and costs of seeding perennial grasses into degraded arid shrubland sites.

Published by Elsevier B.V.

1. Introduction

Shrub establishment is often a central goal of restoration in arid regions. Long-lived, drought-tolerant shrubs dominate the plant communities of many arid ecosystems (e.g., Ackerly, 2004; Miller et al., 2011; Wang et al., 2012), and these shrubs provide important functional benefits. For example, shrubs can stabilize soils, facilitate the establishment of other plants, store carbon, and provide critical wildlife habitat (Garcia-Estringana et al., 2013; Fonseca et al., 2012; Miller et al., 2011; Stavi et al., 2011; van Zonneveld et al., 2012). Shrubs can also increase ecosystem-level biodiversity, both by increasing the abundance and diversity of understory plants (van Zonneveld et al., 2012) and by providing resident and transient wildlife with habitat and forage (Miller et al., 2011).

On denuded sites, native shrub restoration is hindered by both abiotic and biotic challenges. Abiotic challenges include wind erosion and water stress, which can reduce seedling survival and growth (Maestre et al., 2001; Okin et al., 2006). Climate change will likely exacerbate abiotic challenges by increasing drought frequency and intensity (IPCC, 2012). Shrubs can also be difficult to restore due to the presence of mature grasses, which can limit or reduce shrub establishment (Boyd and Svejcar, 2011; reviewed by Meyer, 1992; but see Williams et al., 2002). To improve shrub restoration in degraded drylands, it may be necessary to actively mitigate these restoration barriers.

* Corresponding author at: USDA ARS, Rangeland Resources Research Unit, Fort Collins, CO 80526, USA. Tel.: +1 408 621 0804.
E-mail addresses: lauren.porensky@ars.usda.gov (L.M. Porensky), eleger@cabnr.unr.edu (E.A. Leger), davisonj@UNCE.unr.edu (J. Davison), wilymalr@cabnr.unr.edu (W.W. Miller), erin.goergen@gmail.com (E.M. Goergen), erin.espeland@ars.usda.gov (E.K. Espeland), ecarrollmoore@gmail.com (E.M. Carroll-Moore).
[1] Present address: St. Petersburg College, Clearwater, Fl 33733, USA.
[2] Present address: USDA ARS, Pest Management Research Unit, Sidney, MT 59270, USA.

0167-8809/$ – see front matter. Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.agee.2013.11.026

Table 1
Seeded species and management methods for different subplots.

Common Name	Scientific name and authority	Season; variety	kg/km^2 Sown	Planting date	Seed preparation and planting	Code
–	–	–	0	–	Only cultipacker	Control
Inland saltgrass	*Distichilis spicata* (L.) Greene	Warm; Wildland collection	1.57	Jul 2008	Scarified for 2 mo. before seeding (40 °C & 20 °C, each 12 h); only drill	Disp
Indian ricegrass	*Achnatherum hymenoides* (Roem. & Schult.) Barkworth	Cool; Nezpar, Rimrock	0.896	Dec 2007	Drill + cultipacker	Achy
Basin wildrye	*Leymus cinereus* (Scribn. & Merr.) Á. Löve	Cool; Trailhead	1.12	Dec 2007	Drill + cultipacker	Leci
Western wheatgrass	*Pascopyrum smithii* (Rydb.) Á. Löve	Cool; Arriba, Rosana	1.34	Dec 2007	Drill + cultipacker	Pasm
Beardless wheatgrass	*Pseudoroegneria spicata* (Pursh) Á. Löve	Cool; Whitmar	0.896	Dec 2007	Drill + cultipacker	Pssp

We studied shrub restoration on abandoned agricultural fields in a cold desert ecosystem. Globally, cropland abandonment has increased exponentially since the mid-1800s (Cramer et al., 2008), and abandoned agricultural fields represent an emerging focus of restoration ecology in arid regions. In Nevada, at the heart of North America's arid Great Basin ecoregion, the amount of actively farmed land declined by 34% between 1992 and 2011 (USDA National Agricultural Statistics Service, 2012). Although passive restoration of arid agricultural fields may be possible in some circumstances (e.g., Scott and Morgan, 2012), a passive approach usually leads to slow or incomplete recovery (Otto et al., 2006; Munson et al., 2012), or further degradation (Jackson and Comus, 1999).

The long-term ecological legacies of agricultural abandonment in arid regions can include altered soil properties (e.g., less organic matter, less soil carbon, nitrogen and phosphorous, higher bulk density), altered plant communities (e.g., lower plant diversity, lower native plant abundance, lower total plant cover, lower cover of dominant shrubs, less forb cover) and reduced ecological stability (e.g., larger temporal fluctuations in plant cover, density and diversity, higher probability of conversion to a degraded state) (Burke et al., 1995; Elmore et al., 2006; Kawada et al., 2011; Morris et al., 2011; Munson et al., 2012; Xu et al., 2010). Agricultural abandonment without active restoration often leads to substantial wind erosion (Kawada et al., 2011; Okin et al., 2006), and the combination of soil disturbance, loss of vegetation, reduced native propagule pressure, increased nutrient availability, and dense weed seedbanks makes abandoned fields highly susceptible to exotic plant invasion (Cramer et al., 2008; Elmore et al., 2006; Milton and Dean, 2010; Török et al., 2012). Thus, on arid old-fields, active restoration (e.g., soil remediation, herbicide application, or planting) is often necessary to improve ecosystem stability and function (Jackson and Comus, 1999; Otto et al., 2006; Munson et al., 2012).

Planting native perennial grasses in abandoned fields can prevent or reduce weed invasion (Bugg et al., 1997; Blumenthal et al., 2005; Török et al., 2012) and reduce wind erosion (Okin et al., 2006), mitigating some of the barriers hindering shrub establishment (Maestre et al., 2001). At the same time, co-occurring grasses and shrubs will likely compete for limited resources (Maestre and Cortina, 2004). Impacts of grasses on shrub success may vary depending on grass or shrub species identity (Maestre et al., 2001; Meyer, 1992) or resource availability (Maestre and Cortina, 2004). According to the stress-gradient hypothesis, positive interspecific interactions should be more common when stress is high (Bertness and Callaway, 1994), and several studies in dryland ecosystems have found evidence for greater plant–plant facilitation at more stressful sites (e.g., Arredondo-Núñez et al., 2009; Forey et al., 2009) or at more stressful times (e.g., Veblen, 2008). In contrast, other studies suggest that stress can lead to increased competition for scarce resources (e.g., Bowker et al., 2010; Holmgren and Scheffer, 2010; Odadi et al., 2011).

Irrigation infrastructure is still present on many abandoned agricultural fields in arid regions, and this allows restoration practitioners to modify stress by irrigating seedlings during the establishment phase. However, it remains unclear whether short-term irrigation translates into longer-term restoration success (Josa et al., 2012; Roundy et al., 2001). It is also unclear whether short-term irrigation will increase or decrease the likelihood of grass-shrub facilitation (Forey et al., 2009; Jankju, 2013; Maestre and Cortina, 2004; Maestre et al., 2001).

We used a broad-scale manipulative experiment to determine the separate and combined impacts of seeded perennial grasses and short-term irrigation on 5-year restoration outcomes at abandoned agricultural sites in the Great Basin, where little previous work exists. Our study addressed three specific research questions:

(1) Does short-term irrigation increase the establishment and long-term survival of shrubs or grasses, and do the impacts of irrigation depend on grass species identity?
(2) Do grasses mitigate potential shrub restoration barriers by suppressing weeds or reducing erosion, and do grass impacts depend on irrigation status or grass species identity?
(3) Do grasses facilitate shrubs, and does facilitation depend on irrigation status or grass species identity?

Our results provide information about the likely outcomes of passive vs. active restoration on former agricultural fields in arid shrublands, as well as what specific restoration methods succeed best in arid ecosystems.

2. Materials and methods

2.1. Study sites and species descriptions

Two study sites were located along the lower reaches of the Walker River, 11.5 km south of Mason, Nevada USA. The Valley Vista Ranch (VV) site (38°50′58″N, 119°11′04″W) was used for alfalfa production until the start of the experiment, while the 5 C's Cottonwood Ranch (5C) site (38°50′45″N, 119°11′02″W) was a denuded pasture formerly used for burro and llama grazing. Both sites are located on Malapais (loamy-skeletal, mixed, superactive, mesic Typic Haplocambids) complex soils (dominated by Malapais gravelly sandy loam and Malapais stony sandy loam) (USDA Soil Conservation Service, 1984). Soil testing indicated that the sites have a moderately alkaline pH and low salinity (saturated soil paste, Bower and Wilcox, 1965), relatively high concentrations of water extractable nitrate (saturation extract, Bower and Wilcox, 1965),