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Research Article-Editor's Choice

Assessment of Range Planting as a Conservation Practice☆

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ABSTRACT

Natural Resource Conservation Service Range Planting — Conservation Practice Standards provide guidelines for making decisions about seedbed preparation, planting methods, plant materials selection, seeding rate, seeding depth, timing of seeding, postplanting management, and weed control. Adoption of these standards is expected to contribute to successful improvement of vegetation composition and productivity of grazed plant communities. Also expected are some specific conservation effects, such as improved forage for livestock; improved forage, browse, or cover for wildlife; improved water quality and quantity; reduced wind or water erosion; and increased carbon sequestration. The success of specific conservation practices and the magnitude of conservation effects are highly dependent on ecological-site characteristics, the initial degree of deviation from desired site characteristics, and weather, all of which are highly variable in both time and space. Previous research has produced few studies directly linking range planting conservation practices to conservation effects. Assessment of conservation effects attributed to rangeland planting practices must, therefore, be separated into two components: 1) evidence of the degree to which specific management practices have been shown to result in desirable vegetation change and 2) evidence supporting positive conservation effects of alternative vegetation states. The aggregate literature generally supports both 1) the existing conservation practice recommendations for rangeland seeding and 2) the inherent assumption that if these practices are successful, they will result in beneficial conservation effects. High spatial and temporal variability in these systems, however, may limit the success of generic or prescriptive management practices. Current conservation practice recommendations could be improved by incorporating more direct linkages to the ecologically based technical literature, more up-to-date information on adaptive management strategies in highly variable rangeland systems, and integration of monitoring strategies designed to directly test the efficacy of specific conservation practices.

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Introduction

The Natural Resources Conservation Service (NRCS) Range Planting Conservation Practice Standard (CPS 550) is used to develop NRCS management recommendations for improving vegetation composition and productivity of grazed plant communities when the existing ecological state is insufficient to meet management goals and natural recovery toward a more desirable state is not expected. Successful implementation of range planting treatments is assumed to confer some or all of the following conservation effects: improved forage availability for grazing animals; improved wildlife habitat; reduced erosion by wind and/or water; improved water quality and quantity; and increased carbon sequestration.

The relevant spatial domain for CPS 550 includes rangelands in 17 western states that exhibit diverse vegetation types, management priorities, and climatic syndromes and that also vary internally along latitudinal and elevational gradients (Barbour and Billings 2000; Natural Resources Conservation Service 2006). Resource management issues common to all areas, however, are a generally arid or semiarid climatology, high annual and seasonal variability in weather, and intense competition from introduced annual weeds or expanding populations of native woody plants (Hardegree et al. 2012a, 2012b).

The success of specific conservation practice recommendations and the potential ecological outcomes realized are highly dependent on ecological site characteristics, the initial degree of deviation from desired site characteristics, and weather, all of which are highly variable in

☆ Superscript numbering throughout the text indicates that an expanded list of reference citations may be found.

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both time and space. This variability has perhaps contributed to the relatively short-term and site-specific nature of most rangeland seeding studies, as well as the general lack of longer-term studies directly linking range planting conservation practices and conservation effects per se. This linkage is primarily derived indirectly through 1) evidence of the degree to which specific planting techniques have been shown to produce successful plant establishment and 2) evidence supporting the positive conservation effects of alternative vegetation states. We have, therefore, separated our assessment into two components: 1) an evaluation of the direct benefits of recommended practices from the Range Planting CPS and 2) a brief review of specific conservation effects attributed to alternative vegetation states.

Assessment of the Direct Benefits of Range Planting Practices

The Range Planting CPS includes general recommendations for identification and utilization of site-appropriate plant materials, along with the use of soil preparation and planting techniques for optimization of seedbed microclimate.

Plant Materials Development and Selection

The Range Planting CPS recommends selection of plant materials that are adapted to both climate and microclimate as affected by soil type, landscape position, and range-site characteristics. Gross climatic variability generally determines the historical complement of native species at a site and the suitability of introduced plant materials (Shown et al. 1969; Shiflet, 1994; Barbour and Billings 2000; Vogel et al. 2005; Natural Resources Conservation Service 2006[1]). The general importance of climate is acknowledged in seeding guides in the form of tables that list species and cultivar suitability as a function of mean annual precipitation (Jordan 1981; Jensen et al. 2001; Lambert 2005; Ogle et al. 2008a, 2008b; Bower et al. 2014). Seeding guides may also cite climatic thresholds below which active seeding practices are not recommended (Anderson et al. 1957; Jordan 1981).

Plant material recommendations for both native and introduced species are based primarily on plant materials discovery, screening, and breeding programs by NRCS Plant Materials Centers and other government research and agricultural experiment station programs (Roundy and Call 1988; Asay et al. 2003[2]). Native plant populations that have been identified as possessing superior productivity, vigor, establishment, disease resistance and/or seed-production characteristics, or alternatively have been bred for such traits, are then evaluated and released for commercial use (Schwendiman 1958; Johnson and Asay 1995; Jensen et al. 2001; Asay et al. 2003; Jones et al. 2004a, 2004b; Jones 2010; Robins et al. 2013[3]). More recent efforts in plant material development and evaluation focus on selection for, or comparison of, specific ecological and physiological traits (Aguirre and Johnson, 1991a, 1991b; Johnson and Asay 1995; Arredondo et al. 1998; Jensen et al. 2005; Parsons et al. 2011; Leger and Baughman 2015[4]). These efforts incorporate and report detailed experimental design information but are often based on relatively controlled experimental conditions in the laboratory and greenhouse or an agricultural field environment (Arredondo et al. 1998; Jones et al. 2010[5]). The majority of current plant material recommendations, however, are based on evaluations of field performance that are not accessible through refereed journal publications (Jensen et al. 2001; Lambert 2005; Ogle et al. 2008a, 2008b[6]). In order to be more effective, future plant materials need to be ecologically appropriate for the site (Jones 2013), especially if the site has converted to a novel ecosystem (Jones et al. 2015). Seeding prescriptive genetic diversity to the site to assist natural evolutionary processes has been termed “assisted evolution” (Jones and Monaco 2009). In some cases, it may be advantageous to intentionally develop such material by practicing artificial selection (Chivers et al. 2016) for functional traits that contribute to ecological fitness (Jones et al. 2010).

Seedbed Preparation and Planting Methods

Seedbed preparation and planting methods are designed to optimize microclimatic conditions for planted species, to increase the number of favorable microsites for germination and establishment, and to mitigate or control competition from undesirable species (Call and Roundy 1991; Sheley et al., 1996, 2006; Roundy and Call 1988; Krueger-Mangold et al. 2006).

Surface Modification

Soil-surface modification is often justified by expectations of increased water availability to the seed, either by improving seed–soil contact, reducing the amount of surface area subject to evaporation, increasing infiltration and water-holding capacity, or creating specific microsites that either receive or retain water more effectively (McGinnies 1959; Roundy et al., 1992; Madsen et al. 2015[7]). In some situations, cultivation without surface firming can increase the surface area subject to evaporation, reduce effective seed–soil contact, reduce seeding depth control, decrease hydraulic conductivity from deeper soil layers, and stimulate weed establishment if seeds are not effectively buried (McGinnies 1962; Kyle et al. 2007; Boyd and Obradovich 2014). Subsequent soil firming from press wheels or cultipackers improves hydraulic conductivity to the seed by reducing soil surface area and soil macroporosity (Hyder and Sneva 1956; McGinnies 1962). The bulk of the range planting literature does not separate treatment effects of soil firming from effects of specific cultivation and planting procedures, which are usually performed together (Bement et al. 1965; McGinnies 1972; Slayback and Renney 1972). Studies that compare multiple seed-bed preparation methodologies often find differences in relative seeding success with different equipment and techniques, but specific inferences can only be made at the treatment level for a given site and year (Hubbard and Smoliak 1953; Hyder et al. 1955[8]). Few studies of this type have been replicated adequately in multiple years or on multiple sites (Bement et al. 1965; Eckert and Evans 1967; Klomp and Hull 1972; Wood et al. 1982; Young et al. 1990; Bakker et al. 2003).

Animal trampling, land imprinting, pitting, furrowing, and rolling treatments have all been used in conjunction with broadcasting to capture or preserve moisture and to press surface-applied seed into the soil (Ethridge et al. 1997; Roundy et al. 1992[9]). Animal ingestion and subsequent deposition of seeds in dung has also been used as a mechanism to disperse seeds into favorable microsites (Akbar et al. 1995; Andrews 1995; Auman et al. 1998; Gokbulak and Call 2004; Kronberg 2015; Ocumpaugh et al. 1996; Traba et al. 2003). Differential establishment success relative to position of soil surface features has been reported and is generally attributed to differences in fine-scale microclimatic conditions (Anderson and Swanson 1949; Hyder and Sneva 1956; McGinnies 1959; Hull 1970; Bragg and Stephens 1979; Hauser 1982; Eckert et al. 1986; Roundy et al. 1992). Surface-modification treatments, however, have also been reported to push small seeds too far into the soil or to cause surface features to fill with soil from wind and water erosion, resulting in seed burial exceeding optimal establishment depth (Hyder and Sneva 1956; Kincaid and Williams 1966; McGinnies 1972; Slayback and Renney 1972; Winkel et al. 1991a).

Positive effects of soil-surface modification may be less relevant in very wet years when water is generally available, regardless of surface treatment, or in very dry years when plantings are unsuccessful regardless of seedbed preparation technique (McGinnies 1968; Stuth and Dahl 1974; Wood et al. 1982; Eckert et al. 1986; Roundy et al. 1990, 1992; Winkel and Roundy 1991; Romo and Grilz 2002).

Mulch Application

Application of mulch is frequently advocated as a mechanism to reduce water loss and moderate soil-surface temperatures, although with the caveat that it is probably not cost-effective for most rangeland applications (Lavin et al. 1981; McGinnies 1987; Ethridge et al. 1997; Young et al. 2013). Relatively expensive soil surface amendments are generally applied only after high-impact disturbance such as mine reclamation or