Ecological Indicators 85 (2018) 956–965

Contents lists available at ScienceDirect

Ecological Indicators

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

Impact of an agri-environmental scheme on landscape patterns

Evan P. Tanner*, Samuel D. Fuhlendorf

Oklahoma State University, Department of Natural Resource Ecology and Management, 008C Ag Hall, Stillwater, OK 74078, USA

ARTICLE INFO

Keywords:
Agriculture
Conservation Reserve Program
FRAGSTATS
Grasslands
Policy
Spatial scale

ABSTRACT

Human culture and policy play an important role in structuring landscape patterns. Agriculture is an example of a land use practice that has altered landscape patterns worldwide and agricultural intensification coupled with broad patterns in land use change have resulted in decreased cover of native plant communities and a loss in biodiversity. The Conservation Reserve Program (CRP) was initially developed to address large agricultural surpluses by transitioning highly erodible cropland into conservation-related perennial cover types. Research has demonstrated that this program can help restore ecological processes across landscapes. However, this program can also impact landscape patterns across multiple spatial scales, though its direct influence to these patterns is poorly understood. To understand the contribution of currently enrolled CRP lands to broadscale landscape patterns, we used FRAGSTATS and non-metric multidimensional scaling (NMDS) to assess how patch- and class-scale landscape patterns change in relation to grasslands across the state of Oklahoma with the presence and theoretical absence of CRP. Furthermore, we determined how these patterns vary across three spatial extents: the statewide, the Environmental Protection Agency (EPA) defined ecoregions, and the county extents within Oklahoma. Though impacts at the statewide extent were minimal, NMDS results indicated shifts in landscape patterns across ecoregions and counties that were primarily associated with increases in effective mesh size and largest patch index. Our results indicate that CRP can help maintain complexity of the grassland matrix through improving connectivity. However, the direct impacts of CRP on landscape patterns is dynamic across spatial scales and these effects influence the overall perceived impact of CRP to grassland patterns.

1. Introduction

Human culture and policy can play an important role in structuring landscape patterns (Meyer, 1995; Nassauer, 1995; Donald and Evans, 2006). The resulting changes in landscape patterns from human influences can impact ecological processes within these landscapes (Turner, 1989) which will have implications on the structuring of biological communities at multiple scales (Turner, 1987; Forman, 1995; Wallace and Gray, 2002). Within North America, habitat loss and human-induced rapid environmental change (HIREC; Sih et al., 2011) are key catalysts in the widespread decline of biodiversity (Pimm and Raven, 2000). This loss in biodiversity can lead to the degradation of an ecosystem's multifunctionality (Maestre, 2012) and a decrease in its ecological resilience (Lavorel, 1999). Thus, understanding the direct and indirect effects of the cultural and policy-driven changes on landscape patterns should be of concern to both conservationists and policy-makers.

Agriculture is an example of a human land use practice that has altered landscape patterns worldwide (Meyer, 1995; Foley et al., 2005), and agricultural intensification and management practices coupled with broad patterns in land use change have resulted in decreased cover of native plant communities and a loss in biodiversity (Fuhlendorf and Engle, 2001; Brennan and Kuvklesky, 2005; Donald and Evans, 2006). In North America, native prairies have been the most negatively impacted ecosystem resulting from agricultural land use practices (Samson and Knopf, 1994) associated with intensive row-crop and center pivot agriculture (Johnson et al., 2012) that has benefited from technological advances and shifts from historic grazing patterns to practices that favor increased production of domestic livestock (Fuhlendorf and Engle, 2001; Smith, 2003). Development of agri-environmental schemes (AES) by policy makers have sought to assist private landowners in offsetting negative impacts of agricultural practices through economic incentives from the government. Establishing AESs can influence landscape patterns in ecologically beneficial ways by improving landscape connectivity or improving matrix quality, such as facilitating increased matrix permeability (and thus reduced patch isolation [Donald and Evans, 2006]). However, the spatial organization and land management objectives of these schemes is highly dynamic (Donald and Evans, 2006). Furthermore, the scale at which AESs are implemented may not coincide with the scale at which ecological

* Corresponding author.
E-mail addresses: evan.tanner@okstate.edu (E.P. Tanner), sam.fuhlendorf@okstate.edu (S.D. Fuhlendorf).

https://doi.org/10.1016/j.ecolind.2017.11.043
Received 14 April 2017; Received in revised form 6 November 2017; Accepted 20 November 2017

processes and patterns occur (i.e., spatial mismatch), which can mislead assessments of these programs' ecological benefits and lead to difficulties in understanding how to implement AES coverage in an effective way (Pelosi et al., 2010). Thus, assessing the impacts of these schemes on landscape patterns will vary based on the scale at which they are investigated (Park and Egbert, 2008).

One such AES which has been established to help retain vegetation cover and promote soil conservation in an agricultural matrix is the Conservation Reserve Program (CRP). Established in 1985, the CRP supports voluntary retirement of agricultural lands through cost share assistance and incentives to landowners enrolling lands in 10 or 15 year contracts (Stubbs, 2014; FSA, 2015). As of November 2016, approximately 9.57 million ha were enrolled in the CRP, however enrollment has declined since peaking in 2007 (FSA, 2015). Yet, the CRP has been shown to provide a number of benefits such as maintaining landscape scale ecological processes (i.e., carbon storage [Gelfand et al., 2011], enhancing groundwater recharge [Rao and Yang, 2010]), while also providing habitat or a mechanism to maintain habitat connectivity for many species of conservation concern (Johnson and Schwartz, 1993; Delisle and Savidge, 1997; Hagen et al., 2016). Yet, even with these demonstrated benefits, the CRP faces challenges in maintaining enrollment as policy changes (i.e., a federally mandated national decrease in the maximum enrolled acreage [Stubbs, 2014]) and increases in crop prices, in part associated with an increased ethanol use in gasoline mandated through the auspices of the 2007 Energy Independence and Security Act, have resulted in widespread exiting of CRP enrollment by private landowners nationwide (Chen and Khanna, 2014; Morefield et al., 2016). Furthermore, the criteria for success of CRP was initially related to the restoration of landscape level ecological process. Yet, establishment of the program can influence landscape patterns (Park and Egbert, 2008). Thus, empirically demonstrating the ecological benefits of CRP enrollment on landscape patterns continues to be important in maintaining support for this policy-driven system in a dynamic economy.

Throughout much of the Great Plains, CRP enrollments are typically focused on converting croplands into grasslands (Park and Egbert, 2008). This results in a novel and policy driven landscape, in which CRP lands impact the patterns within both grassland and agricultural matrices. Though the trade-off between cropland loss to grassland gain is not always one-to-one when implementing CRP (i.e., the occurrence of slippage, in which existing grasslands are converted to croplands to offset CRP enrollment [Erickson and Collins, 1985]), the direct benefits of CRP mentioned earlier suggest that this program is important in maintaining ecological processes and functions indicative of grasslands throughout the Great Plains (Egbert et al., 2002).

Yet, at a broad scale, it is important to understand how the introduction of CRP lands changes grassland patterns, as size and configuration of grassland patches can influence the overall ecological benefits provided (Fuhlendorf et al., 2002; Soons et al., 2005; Thogmartin et al., 2006). For instance, faunal abundance patterns (Thogmartin et al., 2006), population persistence (Fuhlendorf et al., 2002), species' distributions (Laliberte and Ripple, 2004), movement patterns (Diffendorfer et al., 1995), and species richness patterns (Herkert, 1994; Laliberte and Ripple, 2004) can all be influenced by grassland patch size and fragmentation. Such patterns have important implications for area-sensitive species (Herkert, 1994; Johnson, 2001) and are attributing to widespread population declines throughout many grassland faunal species (Laliberte and Ripple, 2004; Brennan and Kuvlesky, 2005). Likewise, native floral colonization can decrease as grassland connectivity decreases (Soons et al., 2005) and non-native invasion dynamics can be influenced by patch size (Minor and Gardner, 2011) and patch shape indices (i.e., how much edge effect is present in each patch [Koper et al., 2010]). Furthermore, patch isolation of grasslands can influence community composition by acting as a filter on faunal species traits (Helsen et al., 2013).

Beyond understanding how grassland patch configuration changes when introducing these AES to a landscape, consideration of the landscape matrix in which these AES patches are introduced may be critical to their success (Kleijn and Sutherland, 2003; Tscharntke et al., 2005; Batáry et al., 2011), though this has not been evaluated for CRP. These schemes have been shown to be more effective in increasing species richness when established in croplands within a matrix dominated by land cover lacking natural vegetation (i.e., simple matrix [$\leq$20% natural vegetation cover; Andrén, 1994]; Batáry et al., 2011). This effect of matrix complexity surrounding an AES also has taxon-specific implications, in which certain taxonomic groups respond positively (increased species richness) to an AES regardless of the surrounding matrix (i.e. arthropods and plants), while the response of other groups may be dependent on the complexity of the matrix surrounding an AES (herbivores; Batáry et al., 2011). Thus, understanding how matrix complexity may influence the effectiveness of an AES in changing landscape patterns can be critical when determining whether or not these schemes will succeed in restoring biotic and abiotic processes to grasslands within North America.

In this study, we sought to understand how landscape patterns were influenced by the establishment of CRP land across Oklahoma. Novel land run/land lotteries settlement systems (Bohanon and Coelho, 1998), policy driven changes resulting from the Dust Bowl (i.e., Land Utilization Program [Wooten, 1965], first establishments of shelterbelts [Anonymous, 1986]), and more modern environmental policies (i.e., CRP) have resulted in a landscape whose modern history has been constantly shaped by human culture and policy. Though many of these policies have sought to offset the impact of production and restore areas to grasslands (Laycock, 1988), significant reductions and fragmentation of the state's native grassland communities continues through woody encroachment (Engle et al., 2008), conversion of grasslands to agricultural production (Samson and Knopf, 1994) and biofuels (Lark et al., 2015), and more recently through increases in infrastructure associated with energy production (i.e., wells/pads, pipelines, and associated roads; Allred et al., 2015). An AES such as the CRP may offer a promising way to maintain coverage and connectivity of grasslands within Oklahoma, yet identifying direct impacts of this program through spatially explicit modeling across scales is necessary to fully understand how this program is affecting the landscape. Though previous research has demonstrated that CRP can positively influence grassland connectivity (Egbert et al., 2002; Park and Egbert, 2008; Spencer et al., 2017), these studies have focused on smaller extents (i.e, county level) in areas with relatively high coverage of CRP lands. By focusing on a much larger extent, we are able to determine the circumstances in which CRP begins to really impact landscape patterns. Specifically, our objectives were to (1) assess patch- and class- scale landscape patterns in relation to grasslands across the state of Oklahoma with the presence and theoretical absence of CRP and (2) scale down to the Environmental Protection Agency (EPA) defined ecoregions and county extents within Oklahoma to determine how variation in scale influenced the overall impact of CRP establishment on grassland landscape patterns.

2. Methods

2.1. Study area

Analysis was conducted within the state of Oklahoma, which is approximately 181,295 km^2 in area and is a landscape structured primarily by a west-to-east gradient in average annual precipitation and a north-to-south cline in average annual temperatures (Rice and Penfound, 1959). Average annual precipitation (1981–2010) ranges from ~43 cm in the semi-arid west to ~142 cm in the southeastern portion of the state. Likewise, average annual temperatures (1981–2010) range from ~14 °C along the northern border to ~17 °C along the southern border. However, average annual temperatures decrease along a western elevational gradient, in which the average annual temperature for the western panhandle region is ~13 °C. All