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Research Paper

Land use change and habitat fragmentation of wildland ecosystems of the North Central United States

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ABSTRACT

Wildlands and their ability to conserve biodiversity and provide ecosystem services are threatened by unprecedented land use intensification. Effective conservation of these wildlands depends on identifying their ecological boundaries and assessing land use change trajectories and habitat fragmentation within those boundaries. We evaluated the extent of land use intensification and fragmentation of six land cover classes and six ecosystem types within nine greater wildland ecosystems (GWEs) of three ecoregions in the north-central United States. Land use intensification across the ecoregions was characterized by assessing changes in NLCD land cover classes and housing density from 2000 to 2011. We used LANDFIRE BpS data to assess fragmentation effects on ecosystem types. We found relatively similar trends in land use intensification across the region with overall net changes by 1.2%, 1.1%, and 1% for the Central Plains, Western Mountains, and Western Plains, respectively. The study region has retained 58% of the area of original ecosystem types with a decrease of mean core area by −30% during the post-European period. The analysis revealed that some ecosystems either already lost over 70–80% area or are quickly approaching this threshold leading to an additional extinction of species due to land use intensification. This analysis can help managers in identifying sustainable conservation priorities to minimize surrounding land use patterns impacts on protected systems. We conclude that managers are likely to face multiple challenges to maintaining ecosystem conditions in their present or near present states while establishing connectivity with regional networks of protected lands.

1. Introduction

Wildlands are the areas dominated by natural process with relatively free from human impacts and chiefly occupied by native species that keep ecosystem services intact and biodiversity functioning (Balmford et al., 2002; Efroymson, Jager, & Hargrove, 2010; Kalisz & Wood, 1995). Wildlands are not necessarily free from human influences, but rather the degree of human influence is relatively low and consistent with the objectives of sustaining ecological services. Within the U.S., these areas of relatively intact natural vegetation are centered on federal lands and sometimes include surrounding state, county, and private lands that have not currently been subjected to intense land use. Besides recreational and aesthetic values, wildlands are vital in providing ecosystem services such as provisioning food and water, regulating pollination, nutrient cycles and floods, and providing habitat required for maintaining the viability of species' gene pools (Schulte, Pidgeon, & Mladenoff, 2005).

Within the US and in many countries, human populations and land use pressures are increasing around protected areas faster than in other rural lands and climate is changing in protected areas as in other locations (Radeloff et al., 2010; Wade & Theobald, 2010; Wittemyer et al., 2008). The aerial extent of wildlands has been declining in most of the Earth's biomes during recent centuries as industrial societies have expanded (Ellis, 2011). The wildlands that exist today are undergoing increased land use intensification in and around them (Gaston, Duffy, & Bennie, 2015; Radeloff et al., 2010; Wade & Theobald, 2010). These increases in human pressure caused a 10% decline in the area of large wildlands globally between 1993 and 2009 (Watson et al., 2016). In addition to increased human pressure on the periphery of protected areas, downgrading in legal protection, downsizing of area, and degazettement of protected areas is widespread globally (Mascia & Pailler, 2011). A recent analysis in the western US found that wildlands are being lost at a rate of "one football field every 2.5 min" Theobald et al. (2016). These changes have the potential to degrade biodiversity, ecosystem function, and the ecosystem services that we value in protected areas.

A challenge in wildland ecosystems conservation is delineating the surrounding area within which land use change can influence the

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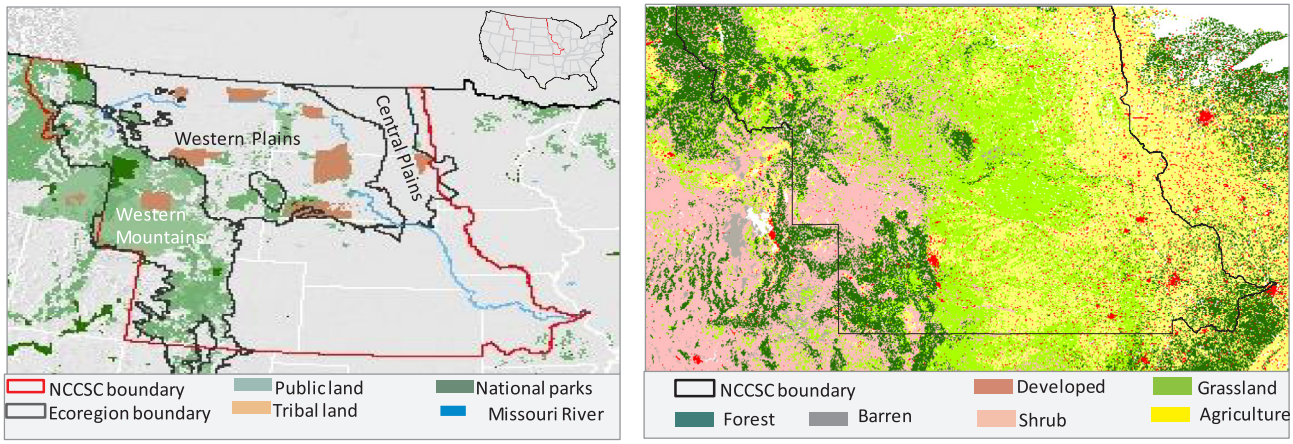

Fig. 1. Map of the study area showing land allocation types, state boundaries and ecoregion boundaries over shaded relief (left) and land cover map of study area from National Land Cover Data 2011 (right).

functioning of the wildlands. Accordingly, Protected Area Centered Ecosystems (PACEs), were defined as the ecological zone surrounding protected areas in which land use intensification can have undesirable influences on biodiversity and ecological processes of the protected areas (Hansen et al., 2011). An analysis of 60 PACEs in the contiguous U.S (Hansen et al., 2014) found that most PACEs experienced substantial change over the 20th century (> 740% average increase in housing density since 1940, 13% of vascular plants are presently non-native, temperature increase of 1 °C/100 yr since 1895 in 80% of PACEs), and projections suggest that many of these trends will continue at similar or increasingly greater rates (255% increase in housing density by 2100, temperature increase of 2.5°–4.5 °C/100 yr, 30% of PACE areas may lose their current biomes by 2030). Given these past and projected rates of change, maintaining ecological integrity within and connectivity among remaining wildlands is a high priority for conservation (Belote, Dietz, Jenkin, & et al., 2017).

Within the U.S, the north central region (Fig. 1) may present unique challenges and opportunities for sustaining and restoring wildlands. The region includes gradients in topography, climate, demography, and land allocations relevant to wildland conservation strategies. The topographically complex Rocky Mountains include large wildlands centered on iconic parks such as Yellowstone and Rocky Mountain. The natural amenities of the region have attracted high rates of population growth and land use development (Baron, 2002) and have motivated substantial efforts to maintaining ecological integrity within these wildlands and connectivity among them (Hansen, Monahan, Theobal, & Oliff, 2016). Precipitation and humidity are low in the rain shadow east of the Rockies and increase substantially eastward to the Mississippi Valley which receives moist humid air masses from the Gulf of Mexico. The extensive shortgrass prairie in the Western Plains support primarily livestock grazing while cultivated agriculture is widespread in the moister the Central Plains. Most of the Western and Central Plains are allocated as private lands, with public lands representing 28% of the region and tribal lands covering 14% of the region. Thus, wildlands in the plains region are relatively small and isolated by private lands. Mean annual temperature is projected to increase 4.9–5.3 °C by 2100 across the High and Central Plains (Adhikari et al., in review). The relatively flat topography here is a major driver of direction and rate of climate shifts, known as climate velocity, organisms will be required to move long distances to remain in climates similar to those of today (Belote, Dietz, McKinley, & et al., 2017; Ordonez, Martinuzzi, Radeloff, & William, 2014). Unlike the Rockies and most of the US, the Western Plains underwent a substantial loss of human population and abandonment of agricultural lands during 1950–2000 (Brown, Johnson, Loveland, & Theobald, 2005; Parton, Gutmann, & Travis, 2003; Sleeter et al., 2013). This depopulation event has been suggested to be an opportunity to "rewild" the plains, reintroducing keystone species and expanding the area allocated to conservation (Freese, 2015; Popper & Popper, 2006)

In this paper, we quantify changes in land cover and use, and fragmentation of natural habitats in and around wildlands of the north central US to provide a context for conservation planning across the region. We expand the concept of PACE from being centered on our most protected lands, national parks, to the areas in and around the national forests, national grasslands and tribal lands that represent the cores of wildlands in the region (Fig. 2). These 'Greater Wildland Ecosystems' (GWEs) represent the regions within which land use change may alter ecological processes and biodiversity within the core public and tribal wildlands. Our objectives are:

(1) Quantify trajectories and rates of change in land cover and land use for 2000–2010, the most recent period available, for GWEs across the climate, land allocation, and demographic ecotones of the north central US; and (2) Evaluate fragmentation of biophysical habitat types from pre-European settlement times to present within the GWEs. The results are relevant to the strategies for maintaining or restoring ecological integrity and connectivity that are likely to be most effective within each GWE.

2. Methods

2.1. Study area

We combine six EPA Level III ecoregions into three coarser ecoregions to represent the major biogeoclimatic units of the study area: Western Mountains, Western Plains, and Central Plains ecoregions (Fig. 1). Topography grades from folded mountains in the west to plains of decreasing elevation to the east. The climate across the study area includes: cold continental with pronounced elevational influences on precipitation in the mountains; cold, semi-arid continental climate in the Western Plains with north-south temperature gradients; and subhumid in the Central Plains. Soil fertility generally increases from west to east. Vegetation transitions from sagebrush/grassland valley bottoms and coniferous forests in uplands in the mountains to shortgrass and mixed grass prairie to the tall-grass prairie in the east. Major rivers dissect the Western and Central Plains and support deciduous riparian vegetation communities.

We delineated nine GWEs in the study area confined to six EPA Level III ecoregions (ERs) (Fig. 2). We grouped them into three ecoregions that represented aggregations of these five ecoregions. These three ER includes: 1) Western Mountains representing Middle Rockies, Wyoming Basin, and Southern Rockies ERs, 2) Western Plains representing North Western Great Plains ER and Northwestern Glaciated