Land Use Policy 63 (2017) 160–173

Contents lists available at ScienceDirect

Land Use Policy

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

Cropland expansion and grassland loss in the eastern Dakotas: New insights from a farm-level survey

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ARTICLE INFO

Article history:
Received 25 October 2016
Received in revised form 4 January 2017
Accepted 22 January 2017
Available online 3 February 2017

Keywords:
Native grasslands
Agriculture
Conservation reserve program
Land conversion
Farm operations

ABSTRACT

The western Corn Belt region of the United States has become a hotspot for agricultural extensification and consequent land use and land cover changes. The goals of this research were to characterize geographic patterns of grassland loss resulting from cropland expansion in the eastern Dakotas, and to understand how these changes were associated with characteristics of individual farms and farm operators. We collected data on grassland conversion and other land use decisions through a mail survey of farm operators in North and South Dakota. Overall, 40% of respondents converted at least some grassland to cropland between 2004 and 2014, and the total acreage of converted grassland was equivalent to 5.1% of the surveyed farm acreage. Although most converted grassland acres (3.2% of farm acreage) were from land enrolled in the conservation reserve program (CRP), there were also substantial amounts of native grassland conversion (1.0%) and tame grassland conversion (0.9%). The total acreage of grassland conversion was more than four times larger than the acreage enrolled in CRP and other conservation programs. Different types of grassland conversion (e.g., native grassland versus CRP) were concentrated in different parts of the study region, and were spatially disjunct from the areas of highest conservation program enrollment. Larger farms were more likely than smaller farms to expand their cropland acreage and accounted for a disproportionate share of grassland conversion. Younger farm operators, higher levels of farm income, higher proportions of rented croplands, and marginal yields were also associated with cropland expansion and grassland conversion. Although CRP and other land retirement programs will remain important policy mechanisms for conservation in this region, they are not sufficient to maintain current levels of grassland cover and do not provide protection for native grasslands. Alternative conservation strategies and new agricultural policies are thus critically needed to maintain the ecosystem services provided by grasslands.

1. Introduction

Agriculture has the most significant environmental footprint of all human land use practices, with 38% of the earth's terrestrial surface used as cropland and pasture for the production of food and energy (Foley et al., 2011). Much of this expansion has occurred during the two centuries from 1800 CE to the present (Klein Goldewijk et al., 2011), and the resulting conversion of billions of acres of natural ecosystems has led to loss and fragmentation of native habitats; substantial emissions of CO_2 and other greenhouse gasses; increased soil erosion; decreased water supplies and degraded water quality; and impairment of critical ecosystem services such as pollination (Foley et al., 2005). As a result, one of the most important global challenges is the need to meet increasing human demands for greater quantities and better quality of food while conserving biodiversity and sustaining critical ecosystem services (Foley et al., 2011). To inform future agricultural land use policies, it is necessary to first quantify the geographic patterns and temporal trends of historical land use. Technologies such as geographic information systems (GIS) and satellite remote sensing have provided remarkable capabilities for measuring and mapping land cover and land use at regional to global scales. However, there is also a need to understand the drivers of these changes, particularly

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http://dx.doi.org/10.1016/j.landusepol.2017.01.026

the characteristics and behavior of the individual agents who make the underlying land use decisions. This paper contributes to the body of knowledge about the patterns and determinants of agricultural land use change through the analysis of new survey data from farm operators in the western Corn Belt, an area that has been highlighted as a hot spot of row crop expansion at the expense of perennial grasslands (Wright and Wimberly, 2013).

1.1. Recent land use trends in the western corn belt

Although most of the recent global expansion of agriculture has occurred in the tropics (Foley et al., 2011; Gibbs et al., 2010), there has also been substantial growth of cropland area in temperate regions. Based on an analysis of the USDA Cropland Data Layer (CDL), Lark et al. (2015) found that 7.3 million acres of land in the conterminous United States that had been uncultivated since at least 2001 was converted to croplands over the four-year period from 2008 to 2012, resulting in a net cropland increase of nearly 3 million acres. These changes were spatially aggregated such that net cropland expansion rates of 5% or greater were concentrated in a few key areas, including the margins of the Corn Belt in the Midwestern United States. Using a similar CDL dataset, Wright and Wimberly (2013) found a net loss of 1.3 million acres of grassland that resulted from conversion to corn or soybeans in five states comprising the western Corn Belt over the five years from 2006 to 2011. Johnston (2014) also used the CDL to analyze land cover trends across the eastern Dakotas and found that corn and soy agriculture expanded by 27% (3.8 million ha) during the two years from 2010 to 2012. In another recent study based on manually-interpreted digital aerial photography, Reitsma et al. (2015) reported a net grassland loss of 4.6 million acres resulting from cropland expansion in the state of South Dakota over the six years from 2006 to 2012.

The results from these remote-sensing based studies are congruent with annual Crop and CRP Survey data from the USDA. There were dramatic increases in harvested corn and soybean acres during the 10 years between 2004 and 2014 (Fig. 1). The combined corn and soybean acres increased from 4.7 to 8.4 million acres in North Dakota (ND) and from 8.3 to 10.4 million acres in South Dakota (SD). During the same period, the combined acreage of wheat and CRP decreased from 11.1 to 9.1 million acres in ND and from 2.7 million to 2.0 million acres in SD. Even though there were significant declines in wheat and CRP acres, their combined reduction (2.8 million acres) was much less than the total increase in corn and soybean acres (5.6 million acres) in the same 10-year period. Thus, a large proportion of the increase in corn and soybean acres likely came from non-CRP grass covers. There is considerable variability in estimates of land use change based on different datasets because of disparities in the time periods covered, study area boundaries, minimum mapping units, measurement techniques, and definitions of land use and land cover classes. Despite these differences, there is consistent evidence that a substantial expansion of croplands has resulted in widespread loss of grassland habitat in the western Corn Belt over the past decade, particularly in the eastern portions of ND and SD.

1.2. Regional drivers of land use change

These land use and land cover transitions have arisen through the confluence of technical innovations, agricultural policies, and changing markets for agricultural products that have made it profitable to expand row crops onto land that was previously considered marginal for crop production. For example, the availability of more efficient planting equipment and improved seeds that are tolerant of cold and wet conditions has allowed earlier corn planting and facilitated the expansion of corn into new areas that would

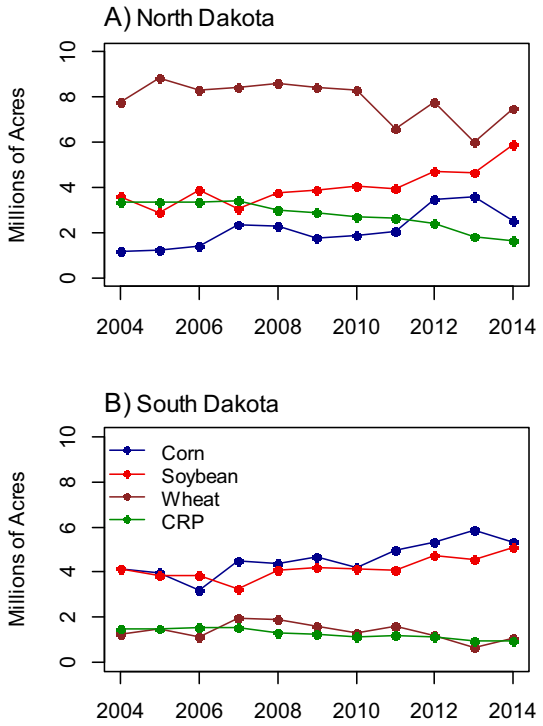

Fig. 1. Trends of the harvested acres of major crops and enrolled CRP acres in A) North Dakota and B) South Dakota from 2004 to 2014. Sources: Corn, soybean, and wheat data, USDA National Agricultural Statistics Service (NASS); CRP data, USDA Farm Service Agency (FSA).

otherwise be climatically unsuitable (Herdt, 2006; Kucharik, 2006). Advances in reduced-till and no-till agriculture (Perry et al., 2016; Triplett and Dick, 2008) have also led to earlier crop planting and facilitated the expansion of moisture-demanding crops like corn into drier areas. Furthermore, the development of more efficient technologies for moving soil and rocks has reduced the costs associated with land conversion, and the improvement of materials and techniques for tile drainage has facilitated the planting of crops in areas where excessive soil moisture previously limited plant growth.

Changes in federal crop insurance programs, particularly their dramatic expansion since 1990, have also contributed to the shifts in land cover and land use within the region. Availability of government-subsidized insurance for the major agricultural crops is much more extensive than insurance for grass-based agriculture, and has favored the planting of crops over grass-based production (Miao et al., 2014). The amount of subsidies provided to a particular land unit increases with the unit's yield variability and with expected revenue for a given crop on that land unit. Corn is a high-input, high-revenue crop and has historically been a marginal crop in the Dakotas where climatic fluctuations have led to crop failures in the western and northern regions (Claassen et al., 2011). As a result, corn generally receives a larger subsidy than would another crop on a given land unit. Thus, the expansion of the crop insurance program, while not specifically directed at corn, has favored corn with higher subsidies when compared with those provided to other crops.

Until recently, the region's crops were used overwhelmingly to feed humans or animals that provide proteins for human consumption. Beginning in the late 1990s and propelled by federal legislation that either promoted or required the use of biofuels in energy for transportation purposes, a wave of corn-based ethanol refineries was constructed throughout the Greater Corn Belt during the first decade of the 21st Century. Most of the increased corn production