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Soil and Land- Use Change Sustainability in the Northern Great Plains of the USA

Deepak Raj Joshi
South Dakota State University, deepak.joshi@sdstate.edu

David E. Clay
South Dakota State University, david.clay@sdstate.edu

Alexander Smart
South Dakota State University, alexander.smart@sdsu.edu

Sharon A. Clay
South Dakota State University, sharon.clay@sdstate.edu

Tulsi P. Kharel
Cornell University

See next page for additional authors

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Authors
Deepak Raj Joshi, David E. Clay, Alexander Smart, Sharon A. Clay, Tulsi P. Kharel, and Umakanta Mishra

Chapter

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Abstract

In the Northern Great Plains (NGP), the combined impacts of land-use and climate variability have the potential to place many soils on the tipping point of sustainability. The objectives of this study were to assess if the conversion of grassland to croplands occurred on fragile landscapes in the North America Northern Great Plains. South Dakota and Nebraska were selected for this study because they are located in a climate transition zone. We visually classified 43,200 and 38,400 points in South Dakota and Nebraska, respectively, from high-resolution imagery in 2006, 2012, and 2014 into five different categories (cropland, grassland, habitat, NonAg, and water). The sustainability risk of the land-use changes was assessed based on the land capability class (LCC) scores at the selected sites. Sites with LCC scores ≤ 4 are considered sustainable for crop production if appropriate management practices are followed. Scores ≥ 6 are not considered suitable for row crop production. From 2006 to 2014, 910,000 and 360,000 ha of land were converted from grassland to cropland in South Dakota and Nebraska, respectively. Approximately 92 and 80% of the grassland conversion to croplands occurred on land suitable for crop production (land capability class, LCC ≤ 4) in South Dakota and Nebraska, respectively.

Keywords: land-use change, sustainability, land capability class, Northern Great Plain, South Dakota, Nebraska

1. Introduction

The conversion of grasslands and forest to croplands is not sustainable if conversion occurs on land not suitable for crop production and if the soil loss rates exceed the rates of soil formation. In semiarid regions, soil erosion is one of the critical factors leading to soil degradation [1]. Erosion is increased when the vegetation cover is destroyed by cultivation [1, 2]. The resulting erosion can reduce the productivity by soil structural degradation as well as by reducing water holding capacity, water and nutrient runoff, and changing other soil properties [3, 4].

The Northern Great Plains (NGP) has undergone extensive management changes since homesteading in the 1880s. These management changes are the result of markets, technologies, and climate variation over time. Climate and market variability results in boom and bust cycles [2]. For example, during World

War I, farmers optimized their profits by plowing and planting grasslands with annual crops. The period of high yields was followed by drought during the 1930s which resulted in the dust bowl and bust. A recent boom occurred between 2006 and 2012 due to increase in maize and soybean price. During this time-period, Reitsma et al. [4] reported that 730,000 ha of grassland was converted to cropland.

During rapid land conversion periods, grasslands are often converted to cropland. This conversion can strengthen the financial resources of individual farms while simultaneously reducing wildlife habitat [5]. Thus, land conversion from grasslands to croplands creates the classical dilemma of balancing economic development with environmental impacts. Between 2008 and 2011, all across the USA, 23.7 million acres of grassland, shrub, and wetland were converted to agricultural land, and 3.2 million acres of wildlife habitat disappeared in North and South Dakotas alone [6]. Grasslands are one of the most threatened and least protected ecosystems.

Worldwide, the NGP ecoregion in North America is considered one of best remaining opportunities for grassland maintenance [7]. Similarly, other adverse side effects of land-use change are increased greenhouse gas emissions [8, 9], reduced water quality [10], and higher soil erosion [11, 12]. In the NGP, the adoption of management practices that improve soil health and minimize soil degradation is critical to insure long-term sustainability [13–19]. We believe that increasing the adoption of sustainable management practices requires a clear understanding of factors driving the land-use change. Reitsma et al. [4] reported that land-use change most likely resulted from many factors including recent technological improvements, land ownership structure changes, climatevariability, various governmental policies, crop prices, and aging workforce [4, 14, 20, 21].

Technology improvements, such as the development of new planting equipment and the wide-scale adoption of transgenic crops, have provided the opportunity to seed annual crops in areas that previously were considered unsuitable for crop production [14]. Moreover, complex interaction of various factors like climatic variability, soil quality, topography, and socioeconomic factors may influence individual decisions [22, 23]. In the NGP, higher rainfall and temperatures linked to climate change were important [7, 24].

From soil erosion perspective, the conversion of grasslands to cropland may be sustainable if conversion occurs on suitable land type [4]. One approach to assess suitability is the land capability classification (LCC) approach. In this approach, soils with LCC values ≤ 4 are generally considered sustainable for annual crops if appropriate management practices are followed. Soils with LCC values ≥ 6 are not considered suitable for annual crops. Soils with a LCC value of 5 may be prone to flooding. The number of restrictions increases as the LCC value increases from 1 to 4 and from 6 to 8. However, Rashford et al. [25] found that between 1978 and 2008, 0.4 million hectare of cropland increased and most conversions occurred on land are considered suitable for crop production (LCC ≤s 1–4). Rashford et al [25] also reported that grassland with LCC ≤ 2 has a 30–50% greater probability of being converted to cropland than grassland with LCC values of 3 and 4.

In light of current pressure on land and various forces driving land-use change, it is essential to examine the dynamics of land changes. The objectives of this study were to calculate the rate of land-use change from 2006 to 2012 and from 2012 to 2014 in South Dakota and Nebraska and assess if land-use changes were sustainable. This region was selected as a model system because it is located in a climate transition zone and it has a humid continental climate on the eastern border and semiarid climate on the western border [26, 27].

2. Materials and methods

South Dakota and Nebraska were selected as model systems because these states contain a wide range of soil, crops, and climate which are representative of other larger areas; both states have a large production capacity for livestock and annual crops; most of the soils were developed in tall and mixed grass prairies; they are located in climate transition zone; and the two states have different access to irrigation water. This region receives most of its precipitation in the spring and fall [14].

The most common annual crops in South Dakota include maize (*Zea mays* L.), soybean [(*Glycine max* (L.) Merr.], and wheat (*Triticum aestivum* L.). In South Dakota, rainfall decreases from east to west, and temperatures decrease from South to North. Additional information on characteristics of South Dakota soils is available in Reitsma et al. [4] and Clay et al. [13]. Farmers in this region use crop rotations that include maize, soybean, wheat, sunflower, canola (*Brassica napus* L.), barley (*Hordeum vulgare* L.), lentil (*Lens culinaris* Medik.), flax (*Linum usitatissimum* L.), and pea (*Pisum sativum* L.).

Eastern Nebraska has a humid continental climate, whereas the western region has a semiarid climate [26, 27]. Eastern part of Nebraska has fertile, moist, and warm soil making it well suited for maize and soybean production. It consists of

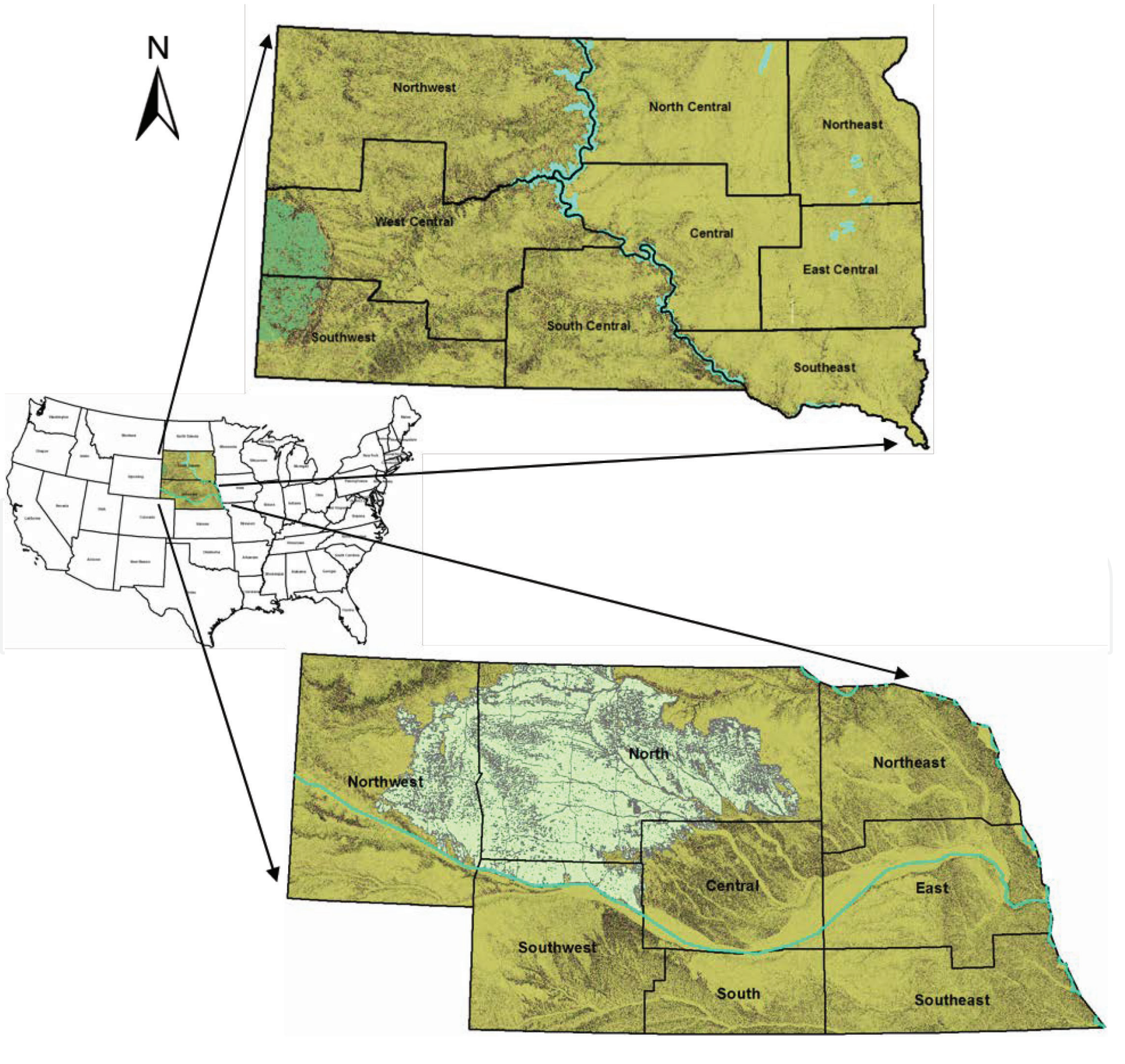

Figure 1.
South Dakota and Nebraska states in the US map along with USDA's National Agricultural Statistics Service (NASS) reporting regions. (Source of Data, USDA-NASS).

loess and glaciated till soils. The Nebraska Sand Hills are contained almost entirely within the Nebraska North NASS region, and it represents one of the most unique and homogenous ecoregions in North America. The Sand Hills are one of the largest areas of semiarid grass-stabilized sand dunes in the world [28].

2.1 Assessing land-use change

The method to assess land use was previously discussed in Reitsma et al. [4] and summarized below. South Dakota has nine National Agricultural Statistics Service (NASS) regions (USDA-NASS, 2015) that include the northeast (NE), south east (SE), north central (NC), east central (EC), central (C), south central (SC), northwest (NW), west central (WC), and south west (SW). Similarly Nebraska has eight NASS regions that include the northwest (NW), north (N), northeast (NE), central (C), east (E), south west (SW), south (S), and south east (SE) (**Figure 1**). Stratified random sampling approach was used for sampling and within each of 17 USDA-NASS reporting districts. In each NASS region, 1600 sampling points were randomly identified using ESRI® ArcMap 10.2.2. These points were laid over high-resolution imagery, obtained from the US Department of Agriculture (USDA), Farm Service Agency (FSA), National Agricultural Imaging Program (NIAP) (USDA-FSA, 2013). The NAIP imagery for 2006 had a 2 m resolution, and the 2012 and 2014 imagery had a 1 m resolution. At each point (8 by 8 m), the dominant land use (cropland, grassland, habitat, non-Ag, and water) was visually identified (for 2006, 2012, and 2014). In South Dakota, 43,200 points in total were visually classified (14,400 points each year), whereas in Nebraska, 38,400 points were classified (12,800 points each year). For validation of our visual assessment and classification system, we randomly selected 100 sampling points from 17 different counties in South Dakota. The predicted management based on the remote sensing data (visual classification) was identical to the known management at these points 100% of the time.

2.2 Assessing changes in soil quality

Land capability class (LCC) and dominant subclass were obtained from the Soil Survey Geographic (SSURGO) data set by superimposing the sampling points over SSURGO [29]. At these points, the LCC value was determined [24]. LCC subclasses are used to help define the limitation. The most common subclass limitations are erosion hazard (e), wetness (w), rooting-zone limitations (s), and climate (c). However this was different than Reitsma et al. [4] where the LCC value was the sum of the component soils within a mapping percent multiplied by its numeric LCC value. This change in classification approach may result in slightly different percentages of soils within a LCC category as reported by Reistma et al. [4].

3. Results and discussion

3.1 Land-use changes in Nebraska from 2006 to 2012

In Nebraska, 43% of the land was in croplands, and the other 45% remained in grasslands in 2006 and 2012. Between 2006 and 2012, 250,000 ha of grassland were converted to cropland at the rate of 41,670 ha $year^{-1}$ (**Table 1**). At the grassland- to cropland-converted sites, 92% had land capability classes that were of 4 or less. These data suggest that based on LCC scores, land-use change occurred primarily on suitable land and therefore based on the soil characteristics should be considered sustainable if appropriate practices are followed.

Change category	Land capability class (LCC) within a category with confidence interval for each proportion in parentheses							
	LCC 1	LCC 2	LCC 3	LCC 4	LCC 5	LCC 6	LCC 7	Estimated land
2006–2012				%				ha × 1000
Nebraska								
Crop-crop	7.42 (0.35)	47.95 (0.67)	24.66 (0.58)	12.02 (0.44)	0.15 (0.05)	7.71 (0.36)	0.04 (0.03)	7130
Crop-grass	9.09 (8.67)	54.55 (15.01)	0	36.36 (14.20)	0	0	0	15
Grass-crop	2.72 (1.20)	21.74 (3.04)	24.46 (3.17)	27.17 (3.28)	1.09 (0.76)	22.83 (3.09)	0	250
Grass-grass	0.37 (0.08)	7.58 (0.35)	10.61 (0.41)	13.59 (0.45)	1.41 (0.16)	60.75 (0.64)	5.02 (0.29)	10750
East								
Crop-crop	11.80 (1.18)	41.11 (1.79)	30.35 (1.68)	13.49 (1.25)	0.10 (0.12)	2.98 (0.62)	0	3580
Crop-grass	14.29 (25.92)	57.14 (36.66)	0	28.57 (33.47)	0	0	0	9
Grass-crop	4.63 (3.96)	25 (8.17)	27.78 (8.45)	32.41 (8.83)	0.93 (1.81)	9.26 (5.47)	0	130
Grass-grass	1.67 (0.76)	18.87 (2.33)	30.71 (2.75)	26.46 (2.63)	1.11 (0.62)	20.26 (2.40)	0.46 (0.40)	1310
West								
Crop-crop	2.59 (0.61)	55.49 (1.90)	18.29 (1.48)	10.40 (1.17)	0.19 (0.17)	12.92 (1.28)	0.08 (0.11)	3550
Crop-grass	0	50 (49)	0	50 (49)	0	0	0	6
Grass-crop	0	17.11 (8.47)	19.74 (8.95)	19.74 (8.95)	1.32 (2.56)	42.11 (11.10)	0	120
Grass-grass	0.06 (0.07)	4.96 (0.62)	5.95 (0.68)	10.60 (0.88)	1.48 (0.35)	70.14 (1.31)	6.07 (0.69)	9440

Table 1.
Land-use change in different land capability classes of Nebraska from 2006 to 2012.

In Nebraska, the state was separated into eastern and western portions. The eastern portion contained three NASS regions (northeast, east, and southeast), whereas the western region contained five regions (northwest, southwest, north, central, and south). In eastern Nebraska, 130,000 ha grassland, at a rate of 21,670 ha year^{-1}, were converted to cropland between 2006 and 2012. At these converted sites, 89.8% had LCC values ≤ 4.

In western Nebraska, 120,000 ha grassland at an annual rate of 20,000 ha year^{-1} were estimated to change from grassland to cropland category. At these converted sites, 56.6% occurred on soils with LCC values ≤ 4.

3.2 Land-use changes in Nebraska from 2012 to 2014

Between 2012 and 2014, 110,000 ha, at a rate of 55,000 ha of grassland year^{-1}, were converted to cropland. At these sites, 83.8% had LCC values ≤ 4 (**Table 2**). This rate of change represents an increase from the 41,670 ha year^{-1} that was observed from 2006 to 2012.

Change category	Land capability class (LCC) within a category with confidence interval for each proportion in parentheses							
	LCC 1	LCC 2	LCC 3	LCC 4	LCC 5	LCC 6	LCC 7	Estimated land
2012–2014				%				ha × 1000
Nebraska								
Crop-crop	7.27 (0.67)	47.09 (47.09)	24.65 (1.12)	12.52 (0.86)	0.18 (0.11)	8.20 (0.17)	0.04 (0.05)	7370
Crop-grass	0	37.5 (33.5)	37.5 (33.5)	12.5 (22.92)	0	12.5 (22.92)	0	12
Grass-crop	1.35 (2.63)	25.68 (9.95)	32.43 (10.67)	24.32 (9.78)	0	16.22 (8.40)	0	110
Grass-grass	0.37 (0.16)	7.40 (0.68)	10.27 (0.79)	13.51 (0.89)	1.44 (0.31)	61.24 (1.27)	5.07 (0.57)	10670
East								
Crop-crop	11.55 (1.14)	40.52 (1.76)	30.34 (1.65)	14.19 (1.25)	0.13 (0.13)	3.20 (0.63)	0	3710
Crop-grass	0	25 (42.44)	50 (49.0)	25 (42.44)	0	0	0	5
Grass-crop	2.04 (3.96)	30.61 (12.90)	30.61 (12.90)	24.49 (12.04)	0	12.24 (9.18)	0	60
Grass-grass	1.73 (0.79)	18.40 (2.36)	30.44 (2.80)	26.59 (2.69)	1.16 (0.65)	20.71 (2.47)	0.48 (0.42)	1260
West								
Crop-crop	2.58 (0.61)	55.80 (1.90)	18.81 (1.49)	10.95 (1.19)	0.23 (0.18)	14.10 (1.33)	0.08 (0.11)	3660
Crop-grass	0	50 (49)	25 (42.44)	0	0	25 (42.44)	0	7
Grass-crop	0	16 (14.37)	36 (18.82)	24 (16.74)	0	24 (16.74)	0	50
Grass-grass	0.06 (0.07)	4.93 (0.62)	5.75 (0.67)	10.58 (0.88)	1.51 (0.35)	70.31 (1.31)	6.10 (0.69)	9410

Table 2.
Land-use change in different soil types of Nebraska from 2012 to 2014.

In eastern Nebraska, 60,000 ha, at a rate of 30,000 ha year^{-1}, of grassland were changed to cropland. At these sites, 87.8% occurred on soils with LCC values ≤ 4. The rate of change between 2012 and 2014 represents an increase, relative to change that occurred between 2006 and 2012. In western Nebraska, 50,000 ha, at an annual rate of 25,000 ha of grassland year^{-1}, was converted to cropland between 2012 and 2014. At these sites, 76% of changes occurred in soils with LCC values that were ≤ 4.

3.3 Land-use changes in South Dakota from 2006 to 2012

Between 2006 and 2012, 5.78% (700,000 ha) of the state grassland (12,120,000 ha) were converted to croplands at an annual rate of 116,700 year^{-1}. Most (92.9%) of the converted grasslands were lands considered suitable for annual crops (LCC ≤ 4) (**Table 3**).

In eastern South Dakota, 480,000 ha of grasslands, at an annual rate of 66,670 ha year^{-1}, were converted to cropland between 2006 and 2012. In this region, 94.5% occurred in soils with LCC values of 4 or less. In western South

Change category	Land capability class (LCC) within a category with confidence interval for each proportion in parentheses							
	LCC 1	LCC 2	LCC 3	LCC 4	LCC 5	LCC 6	LCC 7	Estimated land
2006–2012				%				ha × 1000
South Dakota								
Crop-crop	7.82 (0.41)	63.35 (0.74)	14.89 (0.54)	10.16 (0.46)	0.61 (0.12)	2.88 (0.26)	0.23 (0.07)	5130
Crop-grass	4.76 (1.55)	54.5 (3.62)	17.46 (2.76)	12.17 (2.38)	4.23 (1.46)	5.29 (1.63)	1.59 (0.91)	230
Grass-crop	2.6 (0.69)	50.93 (2.16)	24.72 (1.86)	14.31 (1.51)	0.56 (0.32)	6.13 (1.03)	0.74 (0.37)	700
Grass-grass	0.45 (0.08)	16.79 (0.44)	15.11 (0.42)	16.95 (0.44)	1.02 (0.12)	30.24 (0.53)	17.3 (0.44)	11420
East								
Crop-crop	8.94 (0.92)	67.60 (1.50)	11.30 (1.02)	9.35 (0.93)	0.67 (0.26)	2.04 (0.45)	0.08 (0.09)	4210
Crop-grass	5.96 (3.78)	62.91 (7.70)	9.27 (4.63)	11.26 (5.04)	5.30 (3.57)	3.97 (3.12)	1.32 (1.82)	160
Grass-crop	3.48 (1.79)	59.45 (4.80)	19.40 (3.87)	12.19 (3.20)	0.75 (0.84)	3.98 (1.91)	0.75 (0.84)	480
Grass-grass	1.38 (0.47)	38.48 (1.95)	14.81 (1.42)	17.82 (1.53)	2.47 (0.62)	15.77 (1.46)	8.20 (1.10)	2890
West								
Crop-crop	0	33.77 (4)	39.93 (4.15)	15.86 (3.09)	0.19 (0.37)	8.77 (2.39)	1.31 (0.96)	920
Crop-grass	0	21.05 (12.96)	50 (15.90)	15.79 (11.59)	0	10.53 (9.76)	2.63 (5.09)	70
Grass-crop	0	25.74 (7.35)	40.44 (8.25)	20.59 (6.80)	0	12.50 (5.56)	0.74 (1.44)	220
Grass-grass	0	6.39 (0.68)	15.25 (1)	16.53 (1.03)	0.32 (0.16)	37.17 (1.34)	21.66 (1.14)	8530

Table 3.
Land-use change in different soil types of South Dakota from 2006 to 2012.

Dakota, 220,000 ha at an annual rate of 36,700 ha year^{-1} of grassland were converted to cropland. In western South Dakota, 86.8% of the sites have LCC values of 4 or less.

3.4 Changes in South Dakota from 2012 to 2014

From 2012 to 2014, 1.79% of South Dakota's grasslands were converted to cropland at the rate of 105,000 ha year^{-1} which was slightly lower (116,700 ha/year) than the rate between 2006 and 2012. At these sites, 91.7% occurred in soils with LCC values of 4 or less (**Table 4**). Most of this conversion occurred in eastern South Dakota where 92.5% of the changes occurred on soils characterized as LCC 4 or less, and less than 5% of the change occurred on soils characterized as 6 or 7. In western South Dakota, 85.7% of the grassland-converted sites had LCC values of 4 or less, and <15% of the change occurred in soils with LCC classes that were 6 or greater.

Change category	Land capability class (LCC) within a category with confidence interval for each proportion in parentheses							
	LCC 1	LCC 2	LCC 3	LCC 4	LCC 5	LCC 6	LCC 7	Estimated land
2012–2014				%				ha × 1000
South Dakota								
Crop-crop	7.42 (0.74)	62.37 (1.37)	15.59 (1.02)	10.42 (0.86)	0.66 (0.23)	3.14 (0.49)	0.37 (0.17)	5810
Crop-grass	0.94 (1.84)	47.17 (9.50)	22.64 (7.97)	18.87 (7.45)	1.87 (2.59)	7.55 (5.03)	7.55 (5.03)	150
Grass-crop	2.38 (2.31)	61.90 (7.34)	10.71 (4.68)	16.67 (5.64)	2.38 (2.31)	5.95 (3.58)	0	210
Grass-grass	0.56 (0.17)	17.58 (0.86)	15.10 (0.81)	16.78 (0.84)	1.07 (0.23)	29.82 (1.03)	17.01 (0.85)	11540
East								
Crop-crop	8.56 (0.85)	66.89 (1.42)	11.86 (0.98)	9.47 (0.89)	0.74 (0.26)	2.17 (0.44)	0.24 (0.15)	4720
Crop-grass	1.23 (2.40)	58.02 (10.75)	14.81 (7.74)	17.28 (8.23)	2.47 (3.38)	6.17 (5.24)	0	100
Grass-crop	2.72 (2.63)	67.35 (7.58)	7.48 (4.25)	14.97 (5.77)	2.72 (2.63)	4.76 (3.44)	0	170
Grass-grass	1.66 (0.29)	39.57 (1.90)	14.39 (1.37)	17.26 (1.47)	2.60 (0.62)	15.53 (1.41)	8.08 (1.06)	3000
West								
Crop-crop	0	32.92 (3.62)	39.72 (3.77)	16.54 (2.86)	0.15 (0.30)	9.43 (2.25)	1.24 (0.85)	1090
Crop-grass	0	12 (12.74)	48 (19.58)	24 (16.74)	0	12 (12.74)	0	50
Grass-crop	0	23.81 (18.22)	33.33 (20.16)	28.57 (19.32)	0	14.29 (14.97)	0	40
Grass-grass	0	6.42 (0.68)	15.47 (1)	16.53 (1.03)	0.30 (0.15)	37.07 (1.34)	21.55 (1.14)	8540

Table 4.
Land-use change in different types of soil in South Dakota from 2012 to 2014.

4. Soil and environmental sustainability

One purpose of the LCC system is to provide guidance on sustainability. An implication of LCC system is that land-use changes are not sustainable if soil losses exceed the rate of soil production. However, since the development of the LCC system, during the 1940s, agricultural technologies have improved [30]. These improvements have resulted in (1) the adoption of no-tillage or conservation tillage and cover crops across the NGP, (2) higher yields, (3) increasing soil organic matter contents, and (4) reduced erosion [11, 12, 16].

Given that technologies have changed since the 1940s, it is likely that classification approach based on the technologies of the 1940s may not be appropriate today. For example, Schuller et al. [31] reported that in Chile, adoption of no-tillage reduced erosion by 94% when compared with conventional tillage. Similarly, in South Dakota decreasing tillage intensity and increasing yields contributed to soil organic carbon levels that increased 24% from 1985 t0 2012 [11].

The conversion of grasslands to croplands may reduce methane sink, pest suppression, flood mitigation, pollination, and protection of grassland birds [32]. Land conversion is also likely to increase soil erosion if suitable management practices are not adopted [13, 33] and reduce the amount of carbon stored in the soil [34].

Land-use changes may be driven by a desire to stabilize economic returns in a region with a variable climate. In the NGP, increasing rainfall and temperatures provide an opportunity to grow annual crops [7]. Precipitation variability is projected to increase in Northern Great Plains [7, 14], while increasing atmospheric CO_2 level may help by improving water-use efficiency and crop productivity [35]. Similarly, droughts result in losses in crop yield, grazing capacity, ground water, and plant composition and hydrologic condition of rangeland.

As discussed earlier, one of the primary factors influencing land-use change is economics. Farm economics is influenced by revenues received by farmers and yield and crop production costs [36]. These potential returns and cost vary in time and space. For example, during the period of 2006–2012, maize prices doubled from \$119.68 to \$271.26 Mg^{-1}. However, the maize cost of production was lowest in 2000 (\$395 ha^{-1}) and peaked in 2012 (\$1192.5 ha^{-1}) and then decreased to \$1002.5 ha^{-1} in 2015. Similarly, soybean had similar changes in production cost and selling prices. Marketing year average soybeans price received double from \$236.24 Mg^{-1} in 2006 to \$529.06 Mg^{-1} in 2012. However, during the period between 2012 and 2014, the soybean price decreased to \$371.07 Mg^{-1}, and maize prices decreased to \$135.94 Mg^{-1} [37].

5. Agricultural land market trend and environmental sustainability

From 2011 to 2014, the average value of all agricultural land in South Dakota increased from \$3350 to \$6175 ha^{-1} [36]. The largest gains were observed in highly productive eastern South Dakota. For example, in the southeast and east central NASS regions, non-irrigated cropland had value of \$17,785 and \$15,827.5 ha^{-1}, respectively, in 2014. Slightly lower values were observed in the northeast where land values increased from \$7295 ha^{-1} in 2011 to \$13,227 ha^{-1} in 2014. Similar increases were observed in the north central and central regions. In north western South Dakota, land value increases were much lower, and from 2011 to 2014, it increased from \$1562 ha^{-1} to \$2050 ha^{-1}.

Native rangelands are highly concentrated in the western and central regions of South Dakota, whereas managed pastures are scattered without any particular region of state. Rangeland and pasture land values also tend to cluster in three different groups. East central and southeast regions had the highest rangeland values of \$7152 and \$6745 ha^{-1}, respectively. When compared with 2011, these values represent a 60.82 and 69.79% increase in value. In the second cluster that consists of northeast, north central, and central NASS regions, the per hectare land values are 1859, 1600, and 1828 dollars, respectively. These regions had value increases of 52.75, 68.42, and 80.81% changes from 2011 to 2014. The regions with lowest range value were located in the western part of state and were \$1187 in the south central, \$571 in the southwest, and \$436 in northwest in 2014. The south central (SC), south west (SW), and north east (NE) regions had 87.2, 39.6, and 41.1% increases in rangeland value from 2011 to 2014.

Like South Dakota, Nebraska regional cropland values were clustered into the northeast, central, and western regions. From 2006 to 2014, the value of dry land cropland with irrigation potential in the northeast increased from \$4102 to 16,075 per hectare [38]. Similar increases were observed in the east and southeast areas. In the central region, land value increased from \$3625 ha^{-1} in 2006 to \$12,275 ha^{-1} in 2014. Similar gains were observed in the southern region. Western regions of the state had the lowest price per hectare acre and value increases. For example, in the northwest, land value increased from $1137 to $2337 ha^{-1} from 2006 to 2014.

Thus, the record land market value gain observed in South Dakota and Nebraska varied by region. These gains in land market value could be fueled by various factors such as better agricultural input and equipment supplies, increasing ethanol demand, spiking crop prices, and boosted US agricultural export opportunities [39, 40]. Maize-producing regions, which are the main input source for ethanol plants, had the greatest land value gain. For example, in Nebraska and South Dakota, market value increased within 50 miles of ethanol plants where ethanol production was highly concentrated [41].

However the climbing land values, on the other hand, could raise the farmer debt to buy new farm land. To repay debt from increased land purchase prices, farmers could be forced to intensify crop and livestock production for higher returns, regardless of long-term consequences to land use sustainability. But it is very important to note if such extensive agricultural expansion would be conducive to cropping system and environment. Especially in Northern Great Plains, where periodic patterns of drought persist, such agricultural practices may not be appropriate if expansions are not in more suitable climatic and soil conditions.

6. Summary

Along with economic opportunities to local families, recent technological improvements, land ownership structure changes, climate variability, various governmental policies, and aging workforce are major driving factors for changing grasslands to croplands. Along with these factors, it may also be driven by a desire to increase the value of the land. For example, irrigated cropland had a higher value than grazing lands.

Higher temperature, changing precipitation pattern, increasing CO_2 levels, and extreme climatic events like drought directly affect food production and land use in the NGP. For example, ranchers who faced severe drought during 2012 may have sold their livestock and may have plowed their grassland in order to produce an economic return.

Our study shows that South Dakota had higher grassland conversion rates than Nebraska. During the first 6-year period, 700,000 ha grassland was changed to cropland in South Dakota compared with only 250,000 ha in Nebraska. Similarly, 210,000 ha newly expanded cropland was estimated during the later 2-year period in South Dakota. Contrarily, Nebraska had only 110,000 ha of new cropland. The higher conversion rates in South Dakota than Nebraska are attributed to the type of land available for conversion. In Nebraska, between 2006 and 2012 and between 2012 and 2014, 76.1% and 83.8% of the change occurred on soil are considered suitable for cropland (LCC $\leq$ 4), respectively. However, in South Dakota, over 90% of the land that was converted was considered suitable for croplands. Again, soil types with higher LCC values are not considered suitable and can be less sustainable.

In conclusion, the majority of grasslands converted to the crop land during study period can be managed for sustainable food production with the recommended farming practices. However appropriate soil and crop management research is needed for the portion of converted land that is at higher risk to prevent degradation.

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Author details

Deepak R. Joshi[1], David E. Clay[1*], Alexander Smart[2], Sharon A. Clay[1], Tulsi P. Kharel[3] and Umakanta Mishra[4]

1 Department of Agronomy, Horticulture, and Plant Science, South Dakota State University, USA

2 Department of Natural Resource Management, South Dakota State University, USA

3 Department of Animal Science, Cornell University, USA

4 Ecological Science and Environmental Risk Department, Argonne National Laboratory, USA

*Address all correspondence to: david.clay@sdstate.edu

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