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Forum: Integration of Crop-Livestock Systems: An Opportunity to Protect Grasslands from Conversion to Cropland in the US Great Plains

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ABSTRACT

The Great Plains is a mixture of cropland and grassland mainly used for agricultural purposes, with grasslands under continual threat of conversion to cropland. Agriculturists are advocating for the integration of crop-livestock systems (ICLS) to recouple nutrient cycles, improve biodiversity, and increase resilience of agricultural operations. We address the benefits of ICLS in the Great Plains, contending that focus on improving soil health and financial stability of agricultural operations should reduce the conversion of grasslands to cropland. Using US Department of Agriculture National Agricultural Statistics Service Census of Agriculture survey data from the 1925–2017 category "cropland used only for pasture or grazing," which represents land that had been cropped but converted to annual/perennial pasture and grazed, we showcase that the number of farms and the land area in this category is a reasonable proxy of ICLS. As expected, ICLS dramatically decreased in the entire United States from 1925 to 1945, but from 1945 to 2002 in the Great Plains ICLS remained relatively constant, providing evidence of sustained crop-livestock integration. Consistent high numbers of beef cows during this period and the wide availability of forages and crop residues for ruminants facilitated opportunities for producers to use ICLS on their individual operations (within farm) or among operations where row crop farmers and forage-based producers integrated beef cattle use across the landscape (among farms). This integration, however, was decoupled from 2006 to 2013, a period of high grain prices. As a result, economic value of grasslands was decreased and conversion to cropland was increased. Thus, conservation efforts in the Great Plains for grasslands should focus on keeping grasslands intact for provision of multiple ecosystem goods and services by emphasizing incorporation of ICLS within and among farms to reduce the risk of converting grassland to cropland.

Introduction

Land use in the Great Plains occurs as a continuum among cropping systems and livestock systems across large environmental gradients in precipitation and temperature (Laurenroth et al. 1999). The Great Plains, with mesic environments in the eastern boundary states and semiarid and arid grasslands/rangelands in the western boundary states, comprises 59% and 43% of the total grassland and cropland in the United States, respectively (Bigelow and Borchers 2017; Table 1). Remaining native grasslands, mostly located in the western Great Plains, are largely unsuitable for crop production because of steep slopes, poor soils, or low rainfall. Grasslands described as pastureland or hayland, as well as Conservation Reserve Program (CRP) lands, generally have been cropped in the past but reconverted to grassland for economic, management, or other reasons.

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Table 1
Total area in grassland (pasture and range) and cropland by region and state in the Great Plains and the percentage of each state's area in grassland and cropland (Bigelow and Borchers 2017).

Region and state[1]	Grassland	Cropland	Grassland	Cropland
	———————— Hectares ————————		————————— % —————————	
Northern Plains				
Montana	19 282 996	6 722 672	51.1	17.8
North Dakota	5 399 190	10 980 162	30.2	61.4
South Dakota	10 110 121	7 836 032	51.5	39.9
Wyoming	18 658 300	804 049	74.2	3.2
Central Plains				
Colorado	12 847 773	4 319 028	47.8	16.1
Kansas	7 198 785	11 575 709	34.0	54.7
Nebraska	9 585 830	8 849 393	48.2	44.5
Southern Plains				
New Mexico	22 001 619	788 664	70.0	2.5
Oklahoma	7 998 381	4 570 445	45.0	25.7
Texas	42 349 393	11 827 935	62.6	17.5
Great Plains[1]	155 432 389	68 274 089	58.6	43.0
US Total[2]	265 378 543	158 693 927	29.0	17.3

[1] Grassland or cropland within the Great Plains, as a percent of total grassland and cropland in the United States.
[2] Percent of US land area in grassland and cropland.

The vast majority of Great Plains agricultural lands are managed by private owners. Even though these lands provide numerous ecosystem goods and services to society, the lack of established ecosystem service markets fails to compensate producers for these services. Thus, land use decision making by these private land owners is primarily based on economic considerations. For example, crop prices had the greatest impact on producers' land use decisions during the 2006–2015 period in the northern Great Plains (North Dakota and South Dakota), with wildlife habitat loss the lowest consideration (Wang et al. 2017).

As a result of high crop prices during 2006–2015 (USDA-NASS 2019c), an estimated 2.3 million ha of grassland were converted to cropland, with a majority of this conversion in the Northern Great Plains (Wright and Wimberly 2013; Johnston 2014; Lark et al. 2015; Reitsma et al. 2015; Wright et al. 2017). Improvements in agricultural land drainage via tilling, especially in the eastern portions of the Northern Great Plains, also facilitated this cropland expansion (USDA-NASS 2012; Johnston 2013; Yang et al. 2017). In addition, rapid advancements in agricultural technologies such as larger and more versatile equipment, crop genetics, agrochemicals, and changes in governmental policy to mandate renewable fuel production accelerated grassland conversion to cropland (Wright et al. 2017). A net decrease in CRP lands of 5.3 million ha occurred from 2007 to 2016, with the majority of these lands located in Colorado, Montana, North Dakota, and South Dakota (USDA-FSA 2019).

Conversion of grassland to cropland induces changes to ecosystem function and nutrient cycling such as increasing both wind and water erosion (Turner et al. 2017), reducing soil organic matter (Liebig et al. 2009), and soil carbon (DuPont et al. 2010). Increases in nutrients, due to inputs of nitrogen and phosphorus, often result in eutrophication of waters by point and nonpoint pollution (Schilling et al. 2008; Turner et al. 2018). Thus, many water bodies are thereby defined as "impaired" according to Section 303(d) of the Clean Water Act (SDDENR 2018; ND Department of Health 2019). Negative effects of converting grasslands to croplands are also manifest in fragmented grasslands in the Great Plains endangered numerous wildlife species with obligate birds experiencing steady declines (Brennan and Kuvlesky 2005). Sixty-four migratory and nonmigratory bird species listed as conservation concerns (USFWS 2008) and populations of other grassland obligate and semiobligate vertebrate or invertebrate species are also threatened by grassland losses (USFWS 2019). Remaining native grasslands (see Bauman et al. 2016) exist mostly on marginal lands but provide unique habitat for wildlife that planted grasslands cannot (Bakker and Higgins 2009).

We use US Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) Census of Agriculture survey data (1925–2017) to determine trends of ICLS in the United States and different regions (Northern, Central, and Southern) of the Great Plains. We then review different forms of ICLS. At its core, ICLS involves livestock grazing on cropland for part of the time, mostly after grain harvest in the Northern Great Plains (Kumar et al. 2019), and before wheat harvest in the Central and Southern Great Plains (Epplin et al. 2001). Here livestock graze on grassland before or after using cropland for grazing, which implies both cropland and grassland are required to implement ICLS. We also discuss numerous ICLS expansion opportunities in the Great Plains, as a resurgence in ICLS will create more opportunities to preserve grassland to support livestock when they are not grazing cropland.

Proxy Variable for ICLS Land Practice in the United States

To quantify the change of ICLS over the past century, we used "cropland used only for pasture or grazing" from the USDA-NASS Census of Agriculture surveys (1925–2017) as a proxy variable (USDA-NASS 1945, 1969, 1982, 1992, 1997, 2002, 2007, 2012, 2019a). Cropland used only for pasture or grazing represents land that is suitable for crop production, which could have been used previously as cropland and can be easily converted into cropland, but was used by producers as annual or perennial pasture for grazing purposes. We recognize that ICLS can occur in other common forms including crop residue grazing, cover crop grazing, feeding crop residues, and nonharvested crop grazing (Kumar et al. 2019), so this variable alone underestimates the total number of ha used for ICLS practice. However, since other forms of ICLS ha are either not included in the census data or have a short tracking history (< 5 yr for the interval period of the NASS surveys), the "cropland used only for pasture or grazing" variable is a good proxy variable that demonstrates trends in ICLS ha over the past century.

Our chosen proxy variable for ICLS, "cropland only for pasture or grazing," also provides a good indicator of the overall grassland area change. For example, between 2002 and 2012, this proxy variable showed a sharp decrease of 60% in North Dakota and South Dakota, which was the largest decline since 1945 (data not shown). Meanwhile, decline in grassland ha has also been observed in this region (Wright and Wimberly 2013; Johnston 2014; Lark et al. 2015; Reitsma et al. 2015). This declining trend in ICLS proxy has been curtailed since the 2012 census, a period in which grassland decline has also stabilized in both states (Wang et al. 2018). Such

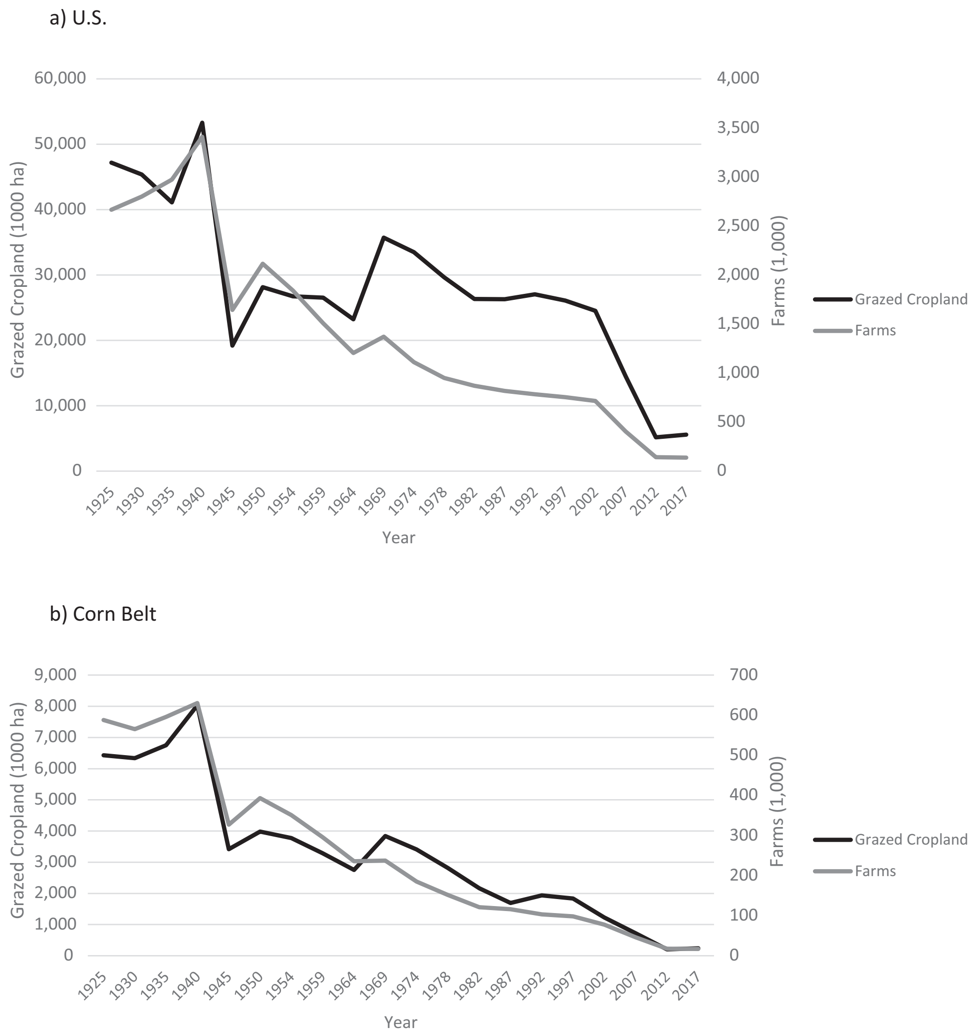

Figure 1. Cropland used only for pasture or grazing in the **a,** United States and **b,** Corn Belt (IA, IL, IN, OH) from 1925 to 2017 (USDA-NASS 1945, 1969, 1982, 1987, 1992, 1997, 2002, 2007, 2012, 2019a).

trends indicate that grassland is a necessary part for ICLS; when ICLS is not practiced, there is little incentive to preserve grassland.

Historic ICLS Snapshot

In 2017, the number of farms and land area using "cropland only for pasture or grazing" in the United States decreased by 95% and 89%, respectively, since 1925 (Fig. 1a). The steep decline from 1925 to 1950 has been attributed to the mechanization of farm equipment and decline in draft animal usage (Vogel 1996). An estimated 32 million ha of pasture were released for other land uses during this time (see Fig. 1a). In the Corn Belt, this decline was greater with only 3% of farms reporting "cropland used only for pasture and grazing" ha since 1925 (see Fig. 1b). A reduction in the number of farms and land area using this practice occurred across the Northern, Central, and Southern Great Plains (Fig. 2). Decoupling of ICLS occurred after World War II with rapidly increased agricultural specialization due to governmental policy, low-cost fossil fuels, and technological advances in machinery, storage, distribution, synthetic fertilizers, pesticides, transgenic crops, global marketing, and confined animal husbandry (Russelle et al. 2007; Sulc and Tracy 2007; Hendrickson et al. 2008; Hilimire 2011; Bonaudo et al. 2014; Lemaire et al. 2014; Sulc and Franzluebbers 2014; Martin et al. 2016). Comparing 2002 with 1925, the reduction in the number of farms was 72–80% in the Northern and Central Plains but only 13% in the Southern Plains, with similar trends in land area using "cropland only for pasture and grazing" as 40–65% reductions in the Northern and Central Plains but only 18% in the Southern Plains (see Fig. 2). These reductions are attributed to agriculture becoming increasingly segmented, with producers specializing in one or few crops (Meehan et al. 2011). Cropland area devoted to small grains, sunflowers, and flaxseed has decreased by over 50% since 1980 to grow row crops (corn, soybeans) over the same period (USDA-NASS 1945, 1969, 1982, 1987, 1992, 1997, 2002, 2007, 2012).

Along the eastern portion of the Great Plains (North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas), a large percentage of the total land area in the western side of each state remains in grassland with lower amounts remaining in grassland in the central and eastern portions of each state. Thus, when crop prices increased from 2006 to 2013 (USDA-NASS 2019c), there were additional decreases in the number of farms and land area in "cropland used only for pasture or grazing" from 2002 to 2017 (see Fig. 2). The national trend followed this similar decline (see Fig. 1a). In the Corn Belt, during this same period, the decline was less steep (compared with total area in cropland; data not shown) because the practice of using cropland only for pasture or grazing was already quite low (see Fig. 1b).

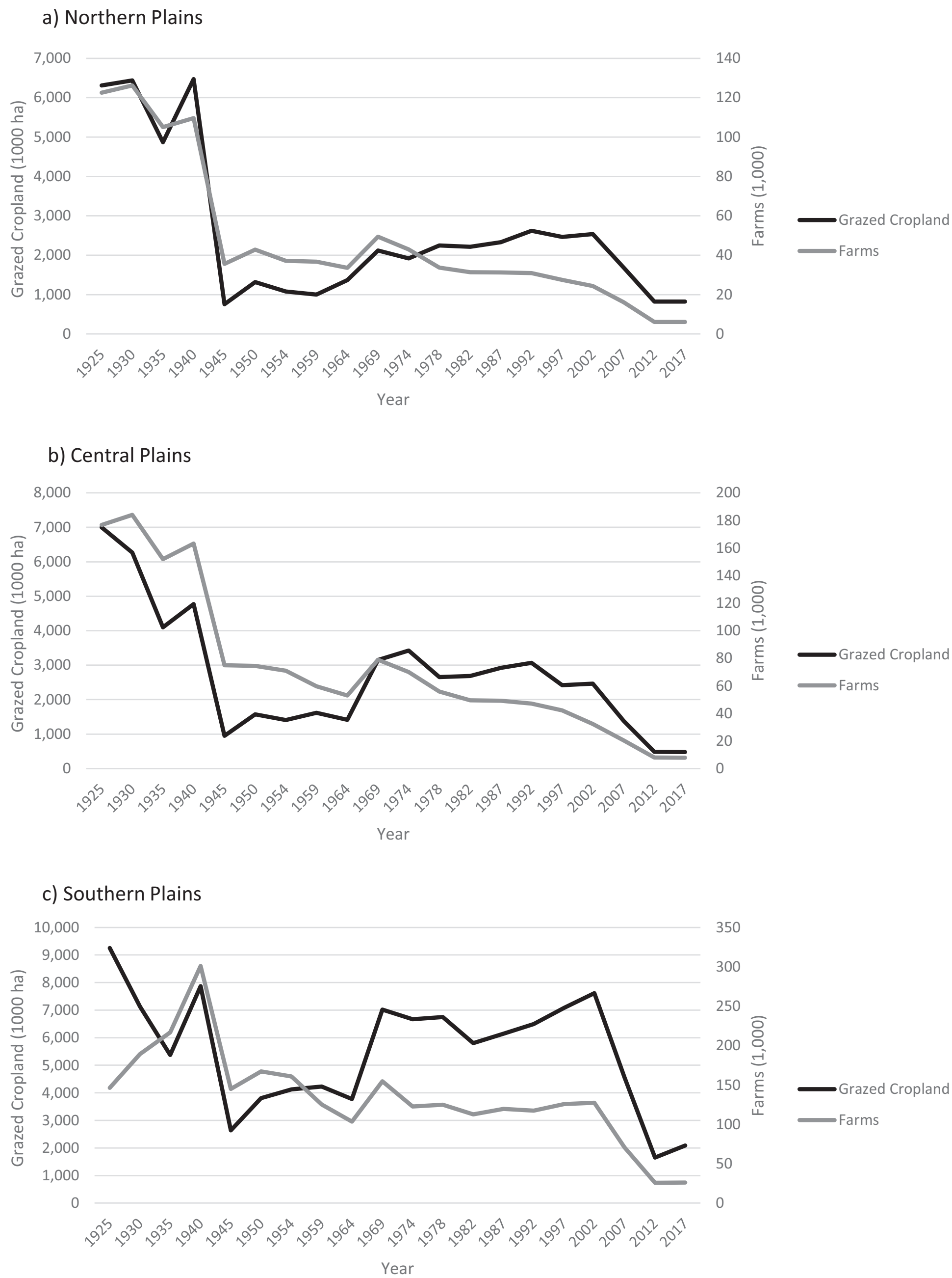

Figure 2. Cropland used only for pasture or grazing in the **a,** northern (MT, ND, SD, WY), **b,** central (CO, KS, NE), and **c,** southern (NM, OK, TX) Great Plains from 1925 to 2012 (USDA-NASS 1945, 1969, 1982, 1987, 1992, 1997, 2002, 2007, 2012, 2019a).

ICLS as a Feasible and Economically Viable Practice in the Great Plains

In the Great Plains, the mixture of cropland and grassland in conjunction with a highly variable climate is well suited for beef production, which is evidenced by high beef cattle numbers (Fig. 3) and the relatively recent high number of farms using the practice of "cropland only for pasture or grazing" (see Fig. 2). This region has traditionally practiced ICLS with the dual use of grazing/grain production or grazing out of wheat in Kansas, Oklahoma, and Texas (Epplin et al. 2001) and cornstalk grazing in the western Corn Belt states of Nebraska, South Dakota, and North Dakota (see Schmer et al. 2017; Redfearn et al. 2019). Therefore, opportunity exists to reverse the previous declines and increase ICLS usage, which may prevent or slow down grassland conversion to cropland.

A recent resurgence in holistic and regenerative approaches to whole-systems agriculture uses the foundation of soil health, with ICLS serving one of the essential principles to increase soil fertility, water infiltration, soil water availability and storage, and nutrient cycling (Lemaire et al. 2014; Derner et al. 2018; Fuhrer 2019). ICLS allows producers a strategy to reduce economic risks associated with producing a single commodity and typically increases enterprise net return compared with either grain-only or forage-only systems (Epplin et al. 2001). Grassland is also a necessity for ICLS practices since cattle need to be relocated to grassland when the cropland-grazing period is over. In the face of market price fluctuations, it is in the best interest of producers to maintain both crop and livestock enterprises, as diversification helps producers maintain a more stable income (Joshi et al. 2019).

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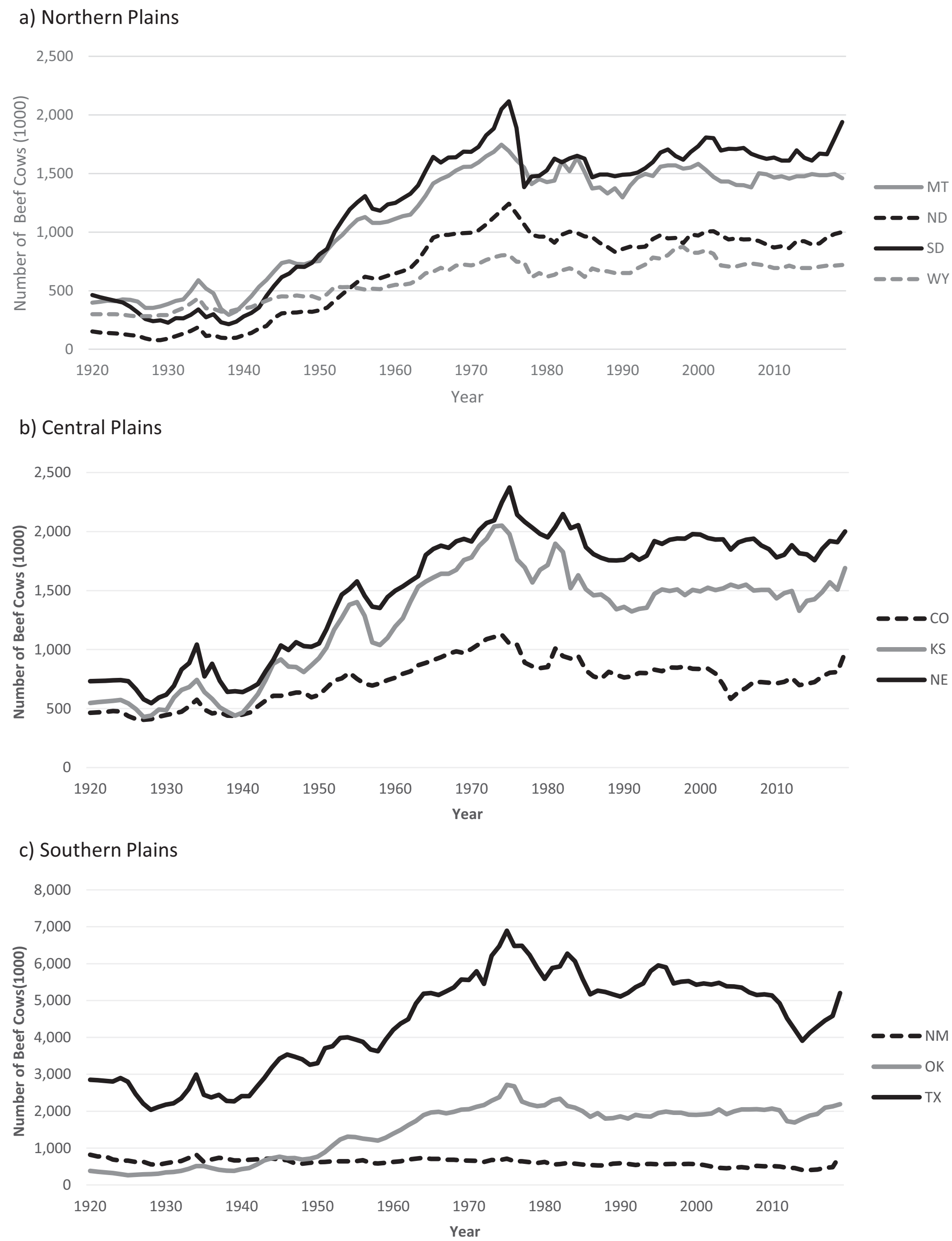

Figure 3. Number of beef cows inventoried on 1 January in the **a,** northern, **b,** central, and **c,** southern Great Plains regions from 1920 to 2018 (USDA-NASS 2019b).

Producers using ICLS practices can also reduce feed costs by extending the grazing season using crop residues and cover crops (Russelle et al. 2007; USDA-SARE 2017; Redfearn et al. 2019; Tobin et al. 2020) and further increase soil carbon, improve nutrient cycling, and reduce purchased fertilizer inputs (Hilimire 2011; Lemaire et al. 2014; Sulc and Franzluebbers 2014). ICLS practices within farms provide opportunities to diversify operations, spread economic risk, and increase cash flow for producers by taking advantage of cyclical markets of livestock and crops (Russelle et al. 2007). Crop farmers who do not own livestock can also take advantage of the across-farm ICLS utilization scenario to achieve soil health benefits and diversify their income stream.

Opportunities for ICLS Expansion in the US Great Plains

Integrated crop-livestock systems have been advocated for the past 2 decades to increase farm profitability and reduce financial risk with changing climate and fluctuating markets (Powell et al. 2004; Hendrickson et al. 2008; Bell and Moore 2012; Bonaudo et al. 2014; Martin et al. 2016). Grassland values increase when more farmers adopt ICLS (Sanderson et al. 2012; Bonaudo et al. 2014; Franzluebbers et al. 2014; Lemaire et al. 2014; Martin et al. 2016), suggesting that private landowners can receive value for protecting remaining grasslands and possibly returning marginal croplands back to grassland.

There are many feasible ICLS expansion opportunities in the US Great Plains. One form of ICLS that has potential for expansion across the Great Plains is the grazing of crop residue by livestock. For example, about 50% of the corn residue hectares are grazed in Nebraska (Redfearn et al. 2019). Extending this ICLS example to Kansas, North Dakota, and South Dakota, where only about 20% of the available corn residue hectares are currently grazed (Redfearn et al. 2019), offers potential to producers in these states to adopt ICLS on more crop hectares. Cover crops, which were planted on only 2% of the northern Great Plains hectares in 2010–2011 (Wade et al. 2015) and increased by nearly 50% for the United States between 2012 and 2017 (LaRose and Myers 2019), offer another opportunity to expand ICLS (USDA-SARE 2017). Another opportunity for incorporating ICLS is to convert marginal croplands to perennial forages (Mitchell et al. 2005) for livestock grazing.

ICLS has been extensively used in the winter wheat-growing region of the Central and Southern Great Plains. Here, wheat pasture is managed as either "grazed out" with livestock remaining on the pasture throughout spring or as "dual purpose" by removing cattle early to enable grain production. Producers employing this ICLS do need to plant wheat earlier compared with wheat for grain production, to provide earlier forage with earlier planting typically reducing expected grain yield (Hossain et al. 2003). Livestock grazing management is needed to prevent overgrazing, which can increase winterkill of wheat and lower grain production (Edwards et al. 2011).

ICLS expansion opportunities are not limited to the within-farm adoption—there are plenty across-farm ICLS implementation opportunities as well. Livestock producers who own pasture but do not have cropland can rent the rights to graze crop residues and/or cover crops. Producers in mixed crop-livestock systems can graze crop biomass and residues to augment forage availability from pastures (Haigh et al. 2019). Web-based systems designed to enhance the cooperation among farmers are available in many states. For example, the South Dakota Soil Health Coalition maintains the South Dakota Grazing Exchange at https://sdgrazingexchange.com. North Dakota State University maintains FeedList (https://www.ag.ndsu.edu/feedlist), a website to connect producers with cover crops, pasture, and crop residues with those who have livestock. Minnesota Department of Agriculture maintains the Cropland Grazing Exchange (http://www2.mda.state.mn.us/webapp/GrazingExchange/MDAHome.html) to match livestock farmers with crop farmers. University of Nebraska–Lincoln maintains the Crop Residue Exchange website https://cropresidueexchange.unl.edu/for crop producers to help make better use of crop residues and develop beneficial grazing agreements with livestock producers. These websites allow the users to create online profiles, much like a social media account, to display their crop-livestock needs. These exchanges have received high use during drought.

Challenges of Implementing ICLS in the Great Plains

Currently, ICLS is mainly restricted to within-farm adoption, which means livestock and cropland being grazed are within the same operation (Wang et al. 2019). Across-farm ICLS integration, such as livestock grazing on another owner's cropland, is lacking. Coordination and promoting efforts to integrate ICLS across farms could be done by university extension personnel to introduce the benefits of across-farm ICLS adoption and create opportunities for farmers who do not own cropland and livestock at the same time.

A primary challenge to incorporating ICLS across farms is the lack of fencing on cropland (Wang et al. 2019). Creative arrangements among local land owners with the use of temporary fence could be used to overcome this challenge. A secondary challenge is soil compaction on cropland being grazed by livestock (Wang et al. 2019). Here, extension personnel can provide recommendations based on soil type and soil moisture conditions to alleviate this challenge.

Implications

Grasslands provide numerous ecosystem goods and services that benefit society, such as provisioning (e.g., forage for livestock production), supporting (e.g., habitat for wildlife, water cycling, carbon sequestration), regulating (e.g., water purification and storage), and cultural (e.g., open space for aesthetic value and outdoor recreation) (Millennium Ecosystem Assessment 2005). Disconnecting livestock grazing from farming systems in the Great Plains puts grasslands at greater risk for conversion to cropland, especially in the transition zones where historical grassland-to-cropland-to-grassland conversion cycles occur. Recoupling livestock and cropping systems into ICLS increases the economic value of grasslands and reduces the risk of conversion to cropland. ICLS adoption within farms is common, but substantial opportunities exist among farms. Despite logistical and infrastructure challenges, university extension personnel can facilitate and coordinate across-farm ICLS adoption. These efforts and interdisciplinary and transdisciplinary focuses on researching sustainable agricultural production, economics, and environmental benefits of ICLS can advance contemporary innovations.

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