

University of Nebraska - Lincoln

DigitalCommons@University of Nebraska - Lincoln

Agronomy & Horticulture -- Faculty Publications

Agronomy and Horticulture Department

2019

Assessing the Value of Grazed Corn Residue for Crop and Cattle Producers

Daren Redfearn

University of Nebraska-Lincoln, dredfearn2@unl.edu

Jay Parsons

University of Nebraska-Lincoln, jparsons4@unl.edu

Mary Drewnoski

University of Nebraska, Lincoln, mary.drewnoski@unl.edu

Marty Schmer

USDA, Agricultural Research Service, marty.schmer@ars.usda.gov

Rob Mitchell

USDA, Agricultural Research Service

See next page for additional authors

Follow this and additional works at: <https://digitalcommons.unl.edu/agronomyfacpub>



Part of the [Agricultural Science Commons](#), [Agriculture Commons](#), [Agronomy and Crop Sciences Commons](#), [Botany Commons](#), [Horticulture Commons](#), [Other Plant Sciences Commons](#), and the [Plant Biology Commons](#)

Redfearn, Daren; Parsons, Jay; Drewnoski, Mary; Schmer, Marty; Mitchell, Rob; MacDonald, James; Farney, Jaymelynn; and Smart, Alexander, "Assessing the Value of Grazed Corn Residue for Crop and Cattle Producers" (2019). *Agronomy & Horticulture -- Faculty Publications*. 1213.

<https://digitalcommons.unl.edu/agronomyfacpub/1213>

This Article is brought to you for free and open access by the Agronomy and Horticulture Department at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Agronomy & Horticulture -- Faculty Publications by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

Authors

Daren Redfearn, Jay Parsons, Mary Drewnoski, Marty Schmer, Rob Mitchell, James MacDonald, Jaymelynn Farney, and Alexander Smart

Assessing the Value of Grazed Corn Residue for Crop and Cattle Producers

Daren Redfearn,* Jay Parsons, Mary Drewnoski, Marty Schmer, Rob Mitchell, James MacDonald, Jaymelynn Farney, and Alexander Smart

Core Ideas

- Grazed corn residue is a cost-efficient forage resource.
- Current value of grazed corn residue is \$95 M returned to the crop sector in NE, SD, KS, and ND.
- Gross value for grazed corn residue is \$191 M for the beef cattle sector in NE, SD, KS, and ND.
- Opportunities exist to increase use of corn residue grazing.
- Transportation costs and animal care arrangements are complicating factors.

Abstract: Integrated crop–livestock systems have included grazing perennial grasses during the spring and summer and corn (*Zea mays* L.) residues during the winter. Our objectives were to identify opportunities for expanded corn residue use through grazing and provide an economic assessment for value-added grazing. We estimated the economic value to the crop sector through grazing leased corn residue at over \$95 million for Nebraska, South Dakota, Kansas, and North Dakota under current management. Additionally, gross economic value to the livestock sector in these states was estimated at greater than \$191 million. Advantages for increased grazing use of corn residue include managing residue quantity in high-yielding environments, providing a source of supplemental revenue, and expanding integrated crop–livestock systems using a simple, but cost-efficient practice.

D. Redfearn, Dep. of Agronomy and Horticulture, Univ. Nebraska-Lincoln, Lincoln, NE 68583; J. Parsons, Dep. of Agricultural Economics, Univ. Nebraska-Lincoln, Lincoln, NE 68583; M. Drewnoski and J. MacDonald, Dep. of Animal Science Univ. Nebraska-Lincoln, Lincoln, NE 68583; M. Schmer, USDA-ARS, Agroecosystem Management Research Unit, Lincoln, NE 68583; R. Mitchell, USDA-ARS, Wheat, Sorghum, and Forage Research Unit, Lincoln, NE 68583; J. Farney, Southeast Agricultural Research and Extension Center, Kansas State Univ., Parsons, KS 67357; A. Smart, Dep. of Natural Resources Management, South Dakota State Univ., Brookings, SD 57007.

Copyright © American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. 5585 Guilford Rd., Madison, WI 53711 USA. This is an open access article distributed under the terms of the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)
Agric. Environ. Lett. 4:180066 (2019)
doi:10.2134/ael2018.12.0066

Received 18 Dec. 2018.

Accepted 19 Jan. 2019.

*Corresponding author (dredfearn2@unl.edu).

THE WESTERN Corn Belt, has historically been corn (*Zea mays* L.) and wheat (*Triticum aestivum* L.) cropping systems with cattle integrated on nearby grasslands. A large quantity of grasslands in this region were converted into annual crops during the mid-2000s (Wright and Wimberly, 2013), resulting in lower available forage resources. To maintain efficiencies of beef cattle (*Bos taurus*) production systems, improved use of forage resources in a sustainable manner is essential. Recent agricultural production data ranked Nebraska, South Dakota, Kansas, and North Dakota in the top 10 states for both corn and beef cattle production in the United States. In 2017, Nebraska, South Dakota, Kansas, and North Dakota had 6.2 million beef cows (USDA National Agricultural Statistics Service, 2018). Forage-based livestock production is a fundamental component of agricultural economies.

Across the United States, corn grain yield, along with crop residue, has increased by 50% over the past three decades (Gallagher and Baumes, 2012), providing an affordable winter forage. For grazed corn residue, recommended stocking rates are calculated to consume less than 20% of the total residue produced (Rasby et al., 2014). Ulmer et al. (2019) reported data from six on-farm research sites across Nebraska, with total residue removal rates between 10 and 45% (mean = 24%). Numerous corn residue grazing studies reported minimal to no negative effects on subsequent crop production (Clark et al., 2004; Drewnoski et al., 2016; Stalker et al., 2015; Tracy and Zhang, 2008; Ulmer et al., 2019). Studies in Nebraska showed minor to no negative effect on soil properties (e.g., soil bulk density, aggregate stability, hydraulic properties) with corn residue grazing (Rakkar et al., 2017, 2019), whereas moderate grazing had positive impacts on soil nutrients compared with no grazing (Rakkar and Blanco-Canqui, 2018). Increased near-surface soil compaction from grazing crop residues is considered the biggest negative impact on soil properties (Clark et al., 2004; Rakkar and Blanco-Canqui, 2018), but increased soil compaction

Abbreviations: ARMS, Agricultural Resource Management Survey; AUM, animal unit month.

tends to be short-term, a result of natural freeze–thaw cycles in this region.

The goals of this paper are to identify opportunities for expanded corn residue use through grazing and provide an economic assessment of current corn residue grazing in Nebraska, South Dakota, Kansas, and North Dakota. Schmer et al. (2017) pointed out that methods were needed to identify how corn residues can be profitably incorporated into regional integrated crop–livestock systems. This is important for states like Nebraska, South Dakota, Kansas, and North Dakota, which have about 20% of the beef cow inventory in the United States (USDA National Agricultural Statistics Service, 2018).

Methodology

We used published research and other readily available data from the USDA to substantiate the current value of corn residue grazing and the potential value if corn residue grazing capacity was increased in Nebraska, South Dakota, Kansas, and North Dakota. For our purposes, we used corn production and beef cattle inventory data (USDA National Agricultural Statistics Service, 2018) and assumed a constant percentage of grazed corn residue based on calculated estimates from the 2010 Agricultural Resource Management Survey (ARMS) Corn Phase II Version 23 (USDA Economic Research Service, 2010) from data reported by Schmer et al. (2017).

To determine current corn residue value to crop producers, we used corn residue grazing rental rates per hectare, with the livestock owner responsible for care and fencing. To calculate the gross value of current corn residue to cattle producers, we compared the grazing fee rates for cattle in 2017 (USDA National Agricultural Statistics Service, 2018) to corn residue grazing rental rates on a per head per day basis, assuming fencing and full care are provided by the crop producer. The comparison of grazing corn residues to stockpiled native grasses for winter grazing is viable in many parts of Nebraska and the other states in the western Corn Belt. Other options would include hay feeding, with costs higher than grazing either corn residue or stockpiled winter range.

A break-even distance was calculated for cattle producers to estimate the maximum distance they would be willing to ship cattle to and from corn residue fields. We assumed shipments were full loads of nonlactating beef cows and the grazing period was 53 d for Nebraska, 34 d for South Dakota, 52 d for Kansas, and 35 d for North Dakota (M. Schmer, unpublished data; 2010 ARMS Corn Phase II Version 23).

Value to the Crop Sector

Using \$37.05 ha⁻¹ as the most commonly reported corn residue grazing rental rate for Nebraska (Cox-O'Neill et al., 2017), we estimated the current value of grazed corn residue in Nebraska at greater than \$74 million (Table 1) in returns to the crop sector. Rental rates for corn residue grazing in South Dakota, Kansas, and North Dakota were much lower than for Nebraska. In Kansas, regional estimates of average cash rent per hectare for crop residue in 2017 ranged from \$14.83 to \$22.24 (Brockus et al., 2018; Wick and Simon, 2018). Using an average of \$18.53 ha⁻¹, we estimate the current value of grazed corn residue in Kansas at greater than \$7 million. Rental rates for grazed corn residue in South Dakota and North Dakota were obtained from University Extension specialists (J. Davis, personal communication, 2018; T. Petry, personal communication, 2018) and resulted in an estimated current value of grazed corn residue in those states of \$12.9 million and \$3.9 million, respectively.

Total corn residue harvested was greater than 50% in Nebraska, while South Dakota, Kansas, and North Dakota had near 20% utilization of the corn residue (Schmer et al., 2017). A survey of Nebraska farmers indicated that 40% of corn producers currently not grazing corn residue would not consider doing so regardless of potential revenue from the activity (Cox-O'Neill et al., 2017). As such, we estimated that a conservative increase in grazing utilization of 10% of the 6 million ha of corn residue available might add \$15 million additional value to the bottom line of crop producers in these four states (Table 1).

Value to the Livestock Enterprise

Nebraska, South Dakota, Kansas, and North Dakota all have large beef cow herds (Table 2). Using a corn residue

Table 1. Corn grain and residue production data and current and potential value of grazed corn residue in the Nebraska, South Dakota, Kansas, and North Dakota for the crop sector.

State	Grain harvested†	Corn residue				Residue value		
		Grazed‡	Baled‡	Total harvested	Available to graze§	Rental rate¶	Current#	10% increase††
	ha	% of ha			ha	\$ ha ⁻¹	\$ million	
Nebraska	3,764,000	53.5	0.5	54.0	1,731,440	37.05	74.6	6.4
South Dakota	2,056,000	21.1	0.6	21.7	1,609,848	29.65	12.9	4.8
Kansas	2,104,000	18.3	3.9	22.2	1,636,912	18.53	7.1	3.0
North Dakota	1,313,000	18.1	1.4	19.5	1,056,965	12.36	2.9	1.3

† Data for grain harvested taken from USDA National Agricultural Statistics Service (2018) production data.

‡ Percentage grazed and baled corn residue from Schmer et al. (2017); percentage total harvested hectares is sum of grazed and baled corn residue.

§ Corn residue available to graze calculated as grain harvested (ha) – [grain harvested (ha) × total corn residue harvested (% of ha)].

¶ Corn residue rental rates assume water is available, but livestock owner is responsible for care and fencing: Nebraska, Cox-O'Neill et al. (2017); South Dakota, J. Davis (personal communication, 2018); Kansas, average of Brockus et al. (2018) and Wick and Simon (2018); North Dakota, T. Petry (personal communication, 2018).

Current residue value calculated as grain harvested (ha) × corn residue grazed (% of ha) × rental rate (\$ ha⁻¹).

†† Potential 10% increase value calculated as corn residue available to graze (ha) × 10% × rental rate (\$ ha⁻¹).

stocking rate of 1.2 ha animal⁻¹ reported by Asem-Hiablíe et al. (2016) from a regional survey for the northern Great Plains, we estimated that up to 88% of Nebraska beef cows graze corn residue. This is fourfold greater than our estimates for the other three states. This implies the current excess of corn residue available in Nebraska is largely due to a lack of cows. Another option would be grazing stocker calves or yearlings and providing supplemental protein and energy (Watson et al., 2015).

Using a corn residue stocking rate of 1.2 ha animal⁻¹ and 1.3 animal units animal⁻¹ (Asem-Hiablíe et al., 2016) along with grazing days per animal (M. Schmer, unpublished data; 2010 ARMS Corn Phase II Version 23), we estimated a gross value for grazed residue based on grass rental rates per animal unit month (AUM) of over \$150 million for Nebraska (\$16.72 AUM⁻¹ or \$38.41 head⁻¹) and \$191 million for the four-state region (Table 2). This value would need to cover all costs for the cattle producer associated with grazing the residue, including residue rental, fence, water, transportation, and any additional care expenses.

Nebraska, South Dakota, Kansas, and North Dakota have numerous crop and livestock management similarities. Greater residue use as a percentage of all cattle operations is reported for the eastern Northern Plains compared with the western Northern Plains (Asem-Hiablíe et al., 2016). Conversely, mean herd size increases from the eastern region to the western region of the northern Great Plains. Intuitively, this suggests that a greater percentage of smaller operations in the eastern region with reduced herd sizes are more capable of fully utilizing corn residue for their needs than the larger ranches located in the western region. We used residue rental rates on a per head per day basis assuming full care obtained from various University State Extension sources to account for all costs associated with grazing corn residue except transportation of the cattle to and from the residue field. Any difference between gross value and full care rental

rates (fence, water, and additional care expenses) in Table 2 accrue to the cattle producer to cover transportation costs and return on investment for using a cheaper feed resource.

Under the assumption that cattle are transported in full loads of 36 head and a shipping rate of \$2.50 per loaded kilometer, we calculated a maximum break-even distance for Nebraska of 277 km. This is almost twofold more than for any of the other three states and helps explain the much higher corn residue utilization for grazing in Nebraska compared to the other three states. Cattle in the western region of Nebraska are much more likely to be transported to corn residue fields in the eastern region on a regular basis compared with the other three states.

Constraints to Implementation

Grazing Consequences

Grazing corn residues is not a new practice. However, crop producers have expressed continued concerns regarding soil compaction and potential for negative effects on farming practices, such as interference with fall fertilizer application (Cox-O'Neill et al., 2017). A Kansas survey identified water availability, lack of fencing, and additional labor as the three primary limitations for not grazing corn residue (Johnson and Blasi, 2018). In the Dakotas, the short time-frame from harvest to snow cover has been suggested as an impediment to grazing corn residue farther north.

Supply and Demand

Sizable differences in perennial grass pasture grazing rental rates among states with both concentrated corn grain and cattle production resulted in differences concerning willingness to compensate for utilizing corn residue for grazing. This was manifested in differences for corn residue rental rates and willingness to transport cattle greater distances to graze corn residue. Intuitively, the integration of livestock into cropping systems would be more straightforward when accomplished within a single operation. However, given the

Table 2. Beef cow inventory, corn residue and perennial grass rental rates, and gross value of grazed corn residue returned to the beef cattle sector.

State	Beef cows		Corn residue				Perennial pasture		Break-even distance¶¶
	Inventory†	Percent grazing residue‡	Grazed§	Grazing duration¶	Grazed#	Rental rates††	Grazing fee rates‡‡	Residue gross value§§	
	no.	%	ha	d	AUMs	\$ head d ⁻¹	\$ AUMs ⁻¹	\$ million	km
Nebraska	1,910,000	88	2,013,740	53	3,854,075	1.00	39.80	153.4	277
South Dakota	1,801,000	20	433,816	34	532,630	1.00	31.50	16.8	89
Kansas	1,507,000	21	385,932	52	723,005	0.50	21.00	15.1	154
North Dakota	981,000	20	237,653	35	300,367	0.50	19.00	5.7	81

† Data from USDA National Agricultural Statistics Service (2018).

‡ Corn residue grazed (animal unit months [AUMs])/1.2/beef cow inventory. Assumes 1.2 ha animal⁻¹ (Asem-Hiablíe et al., 2016).

§ Grain harvested × percentage corn residue grazed (Table 1).

¶ M. Schmer, unpublished data; USDA Economic Research Service (2010).

Corn residue grazed (ha)/1.2 × 1.3 × grazing duration (d)/30 d. Assumes 1.2 ha animal⁻¹ and 1.3 AUMs animal⁻¹ (Asem-Hiablíe et al., 2016).

†† Corn residue rental rates assume full care with water and fence included on a per head per day basis estimated from personal correspondence (J. Davis, personal communication, 2018, South Dakota; T. Petry, personal communication, 2018, North Dakota), published Extension bulletins (Brockus et al. 2018, Kansas), or online residue rental listings (cropresidueexchange.unl.edu).

‡‡ Data from USDA National Agricultural Statistics Service (2018).

§§ Corn residue grazed (AUMs) × grazing fee rates.

¶¶ (Grazing fee rates – corn residue rental rates) × [grazing duration (d)/30 d] × AUMs animal⁻¹/transportation costs. Assumes 1.3 AUMs per animal. Transportation cost assumptions are 36 animals per load and \$2.50 per loaded kilometer.

recent focus on intensive management of single enterprises, implementation can become complicated. It is realistic to expect much of the future integration of livestock into cropping systems to occur across multiple operations.

Economic Awareness

Poffenbarger et al. (2017) conducted an extensive economic analysis of integrated crop–livestock systems in Iowa. They showed that diversified farming systems had greater profitability even without the integration of cattle, but including cattle into the system resulted in greater returns still. However, grazed corn residue was not considered as a system component. Liebig et al. (2017) outlined a conceptual framework for broadening the application and inclusion of “Integrated Agricultural Systems.” The framework emphasized a grazing component on cropland. The results from both studies are important because they validate including a grazing component in cropping systems, however brief the window.

Sulc and Tracy (2007) identified several constraints to adopting integrated crop–livestock systems in the US Corn Belt, including movement of traditional diversified systems to focused enterprise systems based on simplified production management with reduced managerial and labor requirements, coupled with government support systems and limited incentives for increasing operational diversity. They recommended additional methods to increase diversity that would facilitate integrating livestock into existing systems. Among these was increased utilization of crop residues, which has historically been an important component of integrated production systems in Nebraska, South Dakota, Kansas, and North Dakota.

Implications

Our synthesis illustrates the value of grazed corn residue as a method to markedly augment net return to both crop and livestock enterprises through integration. Nonetheless, it also pointed out obvious, yet influencing circumstances. For example, farms are becoming more specialized; grain producers are growing more grain; beef producers are producing more beef; and regions are becoming more specialized in production enterprise activities.

We rediscovered that challenges for increasing grazed corn residue exist. Continued development of innovative efforts aimed at diversifying winter feeding to meet these challenges remain. On the other hand, numerous opportunities remain to increase net return for some crop and livestock producers in Nebraska, South Dakota, Kansas, and North Dakota by increasing grazing utilization of corn residue as a cost-efficient winter forage for beef cows.

Acknowledgments

This research is supported by Multi-State Hatch Project NC1181 “Enhancing Resiliency of Beef Production under Shifting Forage Resources”; the United States Department of Agriculture National Institute of Food and Agriculture, Coordinated Agriculture Projects, Award No. 2016-68004-24768; Hatch Project 1007541 “Economic Systems for Integrated Crop and Livestock Production.” The University of Nebraska, Nebraska Extension, and USDA are equal

opportunity employers and providers. These groups prohibit discrimination in their programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status. Also, family status, parental status, religious preference, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual’s income is derived from any public assistance program has no effect on program delivery. Mention of trade names or specific commercial products in this publication is solely for the purpose of providing specific information and neither endorses nor implies recommendation or endorsement by the University of Nebraska, Nebraska Extension, or USDA.

References

- Asem-Hiablie, S., C.A. Rotz, R. Stout, and K. Stackhouse-Lawson. 2016. Management characteristics of beef cattle production in the northern plains and Midwest regions of the United States. *Prof. Anim. Sci.* 32:736–749. doi:10.15232/pas.2016-01539
- Brockus, K., T. Husa, M. Taylor, and J. Forshee. 2018. 2017 River Valley Extension district lease survey summary. K-State Research and Extension, Clay Center, KS.
- Clark, J., J. Russell, D. Karlen, P. Singleton, D. Busby, and B. Peterson. 2004. Soil surface property and soybean yield response to corn stover grazing. *Agron. J.* 96:1364–1371. doi:10.2134/agronj2004.1364
- Cox-O’Neill, J.L., K.M. Ulmer, M. Rakkar, L. Franzen-Castle, H. Blanco-Canqui, M.E. Drewnoski, J.C. MacDonald, and R.J. Rasby. 2017. Perceptions of crop consultants and crop producers on grazing corn residue in Nebraska. *J. Ext.* 55(8):5R1B2.
- Drewnoski, M.E., J.C. MacDonald, G.E. Erickson, K.J. Hanford, and T.J. Klopfenstein. 2016. Long-term corn residue grazing improves subsequent soybean yields in a corn–soybean rotation. *Crop Forage Turfgrass Manage.* 2. doi:10.2134/cftm2015.019
- Gallagher, P.W., and H. Baumes. 2012. Biomass supply from corn residues: Estimates and critical review of procedures. USDA Agricultural Economics Rep. 847. USDA, Washington, DC.
- Johnson, S.J., and D.E. Blasi. 2018. KSRE Winter 2017–2018 crop residue survey. K-State Research and Extension. <http://enewsletters.k-state.edu/beeftips/2018/11/01/ksre-winter-2017-2018-crop-residue-survey/>.
- Liebig, M.A., J.E. Herrick, D.W. Archer, J. Dobrowolski, S.W. Duiker, A.J. Franzluebbers, J.R. Hendrickson, R. Mitchell, A. Mohamed, J. Russell, and T.C. Strickland. 2017. Aligning land use with land potential: The role of integrated agriculture. *Agric. Environ. Lett.* 2:160043. doi:10.2134/ael2017.03.0007
- Poffenbarger, H., G. Artz, G. Dahlke, W. Edwards, M. Hanna, J. Russell, H. Sellers, and M. Liebman. 2017. An economic analysis of integrated crop–livestock systems in Iowa, USA. *Agric. Syst.* 157:51–69. doi:10.1016/j.agsy.2017.07.001
- Rakkar, M., and H. Blanco-Canqui. 2018. Grazing of crop residues: Impacts on soils and crop production. *Agric. Ecosyst. Environ.* 258:71–90. doi:10.1016/j.agee.2017.11.018
- Rakkar, M.K., H. Blanco-Canqui, R.J. Rasby, K. Ulmer, J. Cox-O’Neill, M.E. Drewnoski, R.A. Drijber, K. Jenkins, and J.C. MacDonald. 2019. Grazing crop residues has less impact in the short-term on soil properties than baling in the central Great Plains. *Agron. J.* 111:109–121. doi:10.2134/agronj2018.03.0224
- Rakkar, M., M.E. Drewnoski, J.C. MacDonald, T.K. Klopfenstein, R. Drijber, and H. Blanco. 2017. Impacts of cattle grazing of corn residues on soil properties after 16 years. *Soil Sci. Soc. Am. J.* 81:414–424. doi:10.2136/sssaj2016.07.0227
- Rasby, R.J., M.E. Drewnoski, and A. Stalker. 2014. Grazing crop residues with beef cattle. EC278. University of Nebraska Extension, Lincoln, NE.
- Schmer, M.R., R.M. Brown, V.L. Jin, R.B. Mitchell, and D.D. Redfearn. 2017. Corn residue use by livestock in the United States. *Agric. Environ. Lett.* 2:160043. doi:10.2134/ael2016.10.0043
- Stalker, L.A., H. Blanco-Canqui, J.A. Gigax, A.L. McGee, T.M. Shaver, and S.J. van Donk. 2015. Corn residue stocking rate affects cattle performance but not subsequent grain yield. *J. Anim. Sci.* 93:4977–4983. doi:10.2527/jas.2015-9259
- Sulc, R.M., and B.F. Tracy. 2007. Integrated crop–livestock systems in the U.S. Corn Belt. *Agron. J.* 99:335–345. doi:10.2134/agronj2006.0086
- Tracy, B.F., and Y. Zhang. 2008. Soil compaction, corn yield response, and soil nutrient pool dynamics within an integrated crop–livestock system in Illinois. *Crop Sci.* 48:1211–1218. doi:10.2135/cropsci2007.07.0390

- Ulmer, K.M., R.J. Rasby, J.C. MacDonald, H. Blanco-Canqui, M.K. Rakkar, J.L. Cox-O'Neill, R.G. Bondurant, K.H. Jenkins, and M.E. Drewnoski. 2019. Baling or grazing of corn residue does not reduce crop production in Central United States. *Agron. J.* 111:122–127. doi:10.2134/agronj2018.04.0226
- USDA Economic Research Service. 2010. Agricultural resource management survey corn production practices and costs report for 2010. Project 906, QID 072011. USDA. https://www.ers.usda.gov/webdocs/DataFiles/52816/27883_W_2010_Corn_Phase2_Questionnaire_Production_Practices_And_Costs_Q_COP_CPP.pdf?v=0 (accessed 25 Jan. 2019).
- USDA National Agricultural Statistics Service . 2018. Quick Stats. USDA-NASS. https://www.nass.usda.gov/Quick_Stats/ (accessed 1 Oct. 2018).
- Watson, A.K., J.C. MacDonald, G.E. Erickson, P.J. Kononoff, and T.J. Klopfenstein. 2015. Optimizing the use of fibrous residues in beef and dairy diets. *J. Anim. Sci.* 93:2616–2625. doi:10.2527/jas.2014-8780
- Wick, S.L., and B. Simon. 2018. 2017 leasing arrangements survey summary. K-State Research and Extension, Post Rock Extension District, Manhattan, KS.
- Wright, C.K., and M.C. Wimberly. 2013. Recent land use change in the western Corn Belt threatens grasslands and wetlands. *Proc. Natl. Acad. Sci. USA* 110:4134–4139. doi:10.1073/pnas.1215404110