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RESEARCH LETTER

Farmer perspectives on benefits of and barriers to extended crop rotations in Iowa, USA

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Abstract

The highly specialized maize (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] production system that dominates midwestern U.S. agriculture has led to widespread on-farm and off-farm degradation of and damage to natural resources. The practice of extending maize–soybean rotations with small grains and forages has great potential to balance production and environmental goals, but adoption of these practices is low. Because little is known about farmers' perspectives on extended rotations, we conducted social survey research with Iowa farmers to address this knowledge gap. Results show that farmers understand the potential benefits of extended rotations using small grains, but they perceive major barriers to use. The highest-rated barriers were structural, such as lack of markets. Structural barriers cannot be easily addressed by individual farmers, indicating that efforts to address negative impacts of specialized commodity production through extended rotations with small grains will require transformative changes in agri-food policies, programs, and ultimately markets.

1 | INTRODUCTION

The need for a cropping system paradigm based on strategies that meet human needs while operating within the planet's biophysical boundaries cannot be overstated (Rockstrom et al., 2017; Tamburini et al., 2020). The specialized maize (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] production system that dominates midwestern U.S. agriculture has led to on-farm and off-farm degradation of soil and freshwater resources, wildlife habitat and diversity, and air quality and has also contributed to climate change, the widespread development of pest resistance, and toxicological harm from pesticides on nontarget organisms, including human populations (Alexander et al., 2008; Broussard & Turner, 2009; Cardinale et al., 2012; Heathcote et al., 2013; Hill et al., 2019; Nowell et al., 2018; Rabalais et al., 2010; Samson & Knopf, 1994; Tranel et al., 2011; Tamburini et al., 2020; Wuebbles et al., 2017).

Within the vast agricultural region of the midwestern United States known as the Corn Belt, the practice of extending rotations of maize and soybean with small grains (primarily oat [*Avena sativa* L.] and wheat *Triticum aestivum* L.]) and hay/forages (primarily alfalfa [*Medicago sativa* L.] and several clover and grass species), has great potential to balance production and environmental goals (Bowles et al., 2020; Davis et al., 2012; Hunt et al., 2017, 2019, 2020; McDaniel et al., 2014). Extended rotation systems with smalls grains and forages were once commonplace in the Upper Midwest, as were integrated crop–livestock systems that included ruminant animals that consumed pasture species and annual

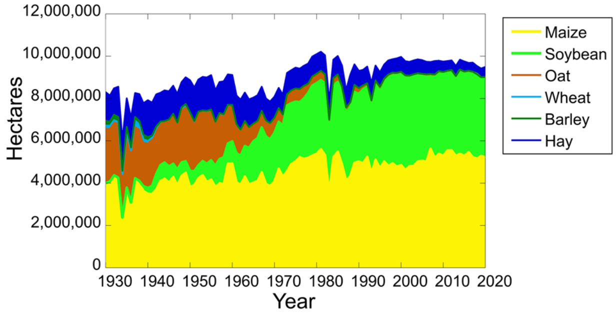

FIGURE 1 Hectares of maize, soybean, oat, wheat, barley, and hay grown in Iowa, 1930–2020. Source: USDA-NASS, 2021

Core Ideas

- Extending maize- and soybean-based rotations with small grains can ameliorate negative impacts.
- We conducted social survey research on farmers' views on benefits of and barriers to rotations.
- Highest-rated barriers and potential facilitators were structural, requiring policy changes.
- To attain agroecological benefits of rotations, transformative facilitating policies and programs are needed.

forages (Sulc & Tracy, 2007). However, socio-economic and technological changes in agriculture over the last 75 years have led to a reduction in the area planted to crops such as oat and hay and an increase in that used for soybean (Aguilar et al., 2015; Hijmans et al., 2016; Crossley et al., 2021). Between 1930 and 2020, area harvested of oat, wheat, or barley (*Hordeum vulgare* L.) declined from nearly 3 million ha to about 32,000 ha, and hay (including alfalfa) area harvested declined from 1.35 million ha to 469,436 (Figure 1; USDA-NASS, 2021).

Changes to livestock management have occurred in tandem, most notably an increase in the magnitude of confined animal production operations based on the feeding of maize and soybean products to cows, poultry, and swine (Winders & Ransom, 2019). This form of intensive specialization that developed over this period altered not just the distribution and abundance of different crops on the landscape but also the physical infrastructure around processing and distribution (Anderson, 2007). Additionally, a "knowledge infrastructure" around diverse systems, including crop breeding and agronomic research and development, extension, and outreach services, as well as intergenerational transfer of farmer knowledge also declined over this period (Frey, 1996; Olmstead & Brummer, 2008; Roesch-McNally et al., 2018). Consequently, potential for current or future changes to cropping system diversity will require significant modifications to current production practices, which may entail new knowledge, equipment, and risks for farmers. Yet little is known about what farmers think about extended rotations. The research presented here represents an initial effort to increase our understanding of farmers' perspectives on extended rotations, specifically those that include small grains.

1.1 | Agronomic benefits

The agronomic benefits of crop rotations are well documented (Bennett et al., 2012; Tamburini et al., 2020). Research shows that rotating crops can increase pools of soil carbon (C) and nitrogen (N) by 7 and 5% (West & Post, 2002; McDaniel, 2014), microbial biomass by 21% and diversity of soil microbes by 3% (McDaniel et al., 2014; Venter et al., 2016), and soil water content by 9% and porosity by 8% (Basche & Delong, 2017) (Figure 2). Crop rotations can also decrease the "less is better" indicators of soil health such as bulk density (−0.8%) (McDaniel et al., 2014). Furthermore, crop rotations have been found to decrease weed density by 49% (Weisberger et al., 2019) and certain soil-borne pathogens up to 17-fold (Leandro et al., 2018; Peralta et al., 2018; Raza et al., 2020). These effects in combination likely contribute to a 28% increase in maize yield (Bowles et al., 2020). Taken together, there is overwhelming evidence of agronomic benefits to diversifying cropping systems.

1.2 | Environmental benefits

Less is known about the environmental benefits of extended rotations, but some direct links between agronomic and environmental benefits can be drawn. Many noncrop studies point to increases in ecosystem services with greater plant diversity (Quijas et al., 2010), so we may expect similar results in agroecosystems with extended rotations. For example, if crop diversification increases soil C by 7.2% (Figure 2) on average, then we conclude that soil C is sequestered. However, CO_2 is not the only greenhouse gas with a global warming potential. A meta-analysis found extended crop rotations increase global warming potential by up to 41% on average, but interestingly, when small grains were included in rotation, this trend reverses to a 22% decline compared with monoculture crops (Sainju et al., 2016). Diverse crop rotations also have water quality benefits: crop rotations including a cover crop can substantially decrease nutrient loss via leaching (Qi & Helmers, 2010; Kaspar et al., 2012), and rotating maize and soybean with small grains and forages can also reduce nutrient loss (Tomer & Liebman, 2014; Hunt et al., 2019), although sometimes inclusion of N_2 fixing crops can promote

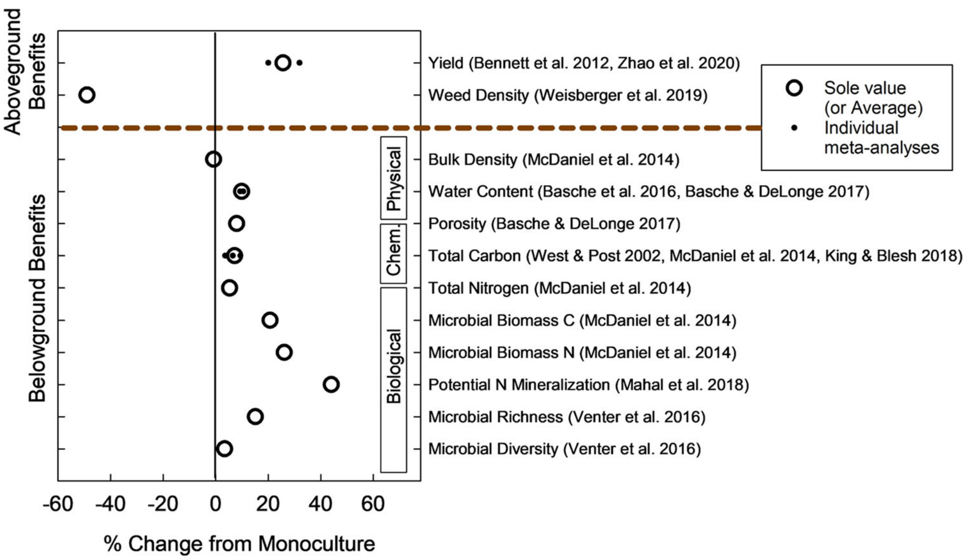

FIGURE 2 Biophysical benefits of crop rotations, summary of results from meta-analyses. Sources: Basche & DeLonge, 2017; Basche et al., 2016; Bennett et al., 2012; King & Blesh, 2018; Mahal et al., 2018; McDaniel et al., 2014; Venter et al., 2016; Weisberger et al., 2019; West & Post, 2020; Zhao et al., 2020

leaching (Askegaard et al., 2005). Thus, to ensure agronomic and environmental benefits (global warming potential and nutrient leaching and runoff), it seems imperative to include small grains in rotations.

1.3 | Farmer perspectives on the use of extended rotations

While evidence of the potential economic and environmental benefits of diversified, extended rotations in the U.S. Midwest is substantial, little research on farmer perspectives on this topic exists. A handful of published studies have contemplated potential barriers to and incentives for diversification from conceptual or theoretical perspectives (e.g., Bowman & Zilberman, 2013; Lin, 2011; Mortensen & Smith, 2020), but our literature review identified just three peer-reviewed empirical studies of diversification decisions and behavior among U.S. farmer populations (Blesh & Wolf, 2014; Cutforth et al., 2001; Roesch-McNally et al., 2018). A common conclusion across these studies was that further understanding of factors that facilitate or act as barriers to diversification is needed to inform development of policy, markets, supportive networks, and other facilitating infrastructure. This paper begins to address that gap in understanding through survey research on farmer perspectives. Drawing on data from a 2017 survey of farmers in Iowa—the leading U.S. producer of maize and soybean (USDA NASS, 2019)—this research represents the first major quantitative study to focus specifically on the perceived benefits, facilitators, and barriers to diverse, extended rotations, especially those that incorporate small grains.

2 | MATERIALS AND METHODS

The survey was conducted by the USDA National Agricultural Statistics Service. In February 2017, the National Agricultural Statistics Service mailed questionnaires to a statewide sample of 2,080 Iowa farmers. A total of 999 farmers completed the survey, resulting in a response rate of 48%. Our analysis only includes farmers who reported planting maize and/or soybean (n = 786) because use of extended rotations is most applicable to them and they are the primary target of outreach efforts. The survey contained two question sets to elicit farmers' perspectives regarding (a) potential benefits of and barriers to use of extended rotations in general and (b) potential barriers to and facilitators of incorporation of small grains into extended rotations (Table 1). We developed survey items based on findings from recent biophysical research, previous social science research, and discussion with extension professionals. The first question set used a five-point agreement scale and the second a four-point importance scale. The second question set focused specifically on small grains because, as noted above, including small grains in extended rotations has high potential to improve environmental quality, soil health, and economic returns to farmers over time.

3 | RESULTS AND DISCUSSION

Farmers were asked to rate their level of agreement with statements about the potential benefits of extended rotations. Substantial majorities of farmers either agreed or strongly agreed that extended rotations can improve soil health (83%),

TABLE 1 Farmer perspectives on benefits, barriers, and facilitators related to use of extended rotations and small grains

	Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
			%		
Perceived benefits of use of extended rotations					
Extended rotations can improve soil health	0.3	1.8	15.3	63.0	19.7
Extended rotations can decrease pesticide needs by controlling insect pests	0.6	5.8	27.4	55.8	10.3
Extended rotations can decrease herbicide needs by controlling weeds	1.1	8.2	26.4	54.5	9.8
Over the long term, extended rotations that include crops other than corn and soybeans can be as profitable as corn–corn or corn–soybean rotations	4.2	26.2	41.2	24.9	3.4
Perceived barriers to use of extended rotations					
The decline of mixed grain and livestock farming has made production of small grains and forages less viable	0.6	4.1	18.5	62.0	14.8
Extended rotations are risky due to lack of viable markets for crops other than corn and soybeans	1.7	8.3	22.3	57.4	10.4
If there were more robust markets for small grains and/or forages in my area, I would be more likely to use (or expand use of) extended rotations	1.2	6.4	25.4	55.9	11.2
Since agribusiness companies don't generally produce seeds and inputs for alternative crops, ag retailers are not likely to promote extended rotations	0.9	6.3	35.4	45.9	11.5
Agribusiness companies are not interested in crop rotations that reduce reliance on purchased inputs	0.8	9.0	35.2	40.4	14.5

	Not at all important	Somewhat important	Important	Very important
		%		
Potential barriers to use of small grains in extended rotations				
Lack of robust markets for small grains	4.9	13.0	41.2	40.9
Land rental rates are too high	8.0	11.3	34.3	46.4
Lack of small grain varieties with elite genetics for yield and pest and disease resistance	7.0	28.1	50.1	14.8
Lack of good technical support for small grain production	10.4	30.5	46.7	12.5
Lack of necessary equipment for planting, harvesting, etc.	16.2	25.6	36.9	21.3
Lack of experience with/knowledge of small grain production	26.6	37.7	30.1	5.6
Potential facilitators of use of small grains in extended rotations				
Development of robust markets	2.1	8.5	48.2	41.2
Facilitation of linkages with specialty crop buyers	3.0	18.0	56.6	22.4
Strong documentation of the economics/longer-term profitability	4.6	20.7	53.0	21.7
Research-based evidence of soil health benefits	3.4	22.8	56.2	17.6
Revenue protection crop insurance	6.9	23.9	45.7	23.5
Workshops, field days, and trainings on production practices	6.4	37.1	45.6	10.9
Technical assistance from local ag retailers	9.8	35.5	47.7	7.0
Cost share to offset short-term costs	8.9	37.6	42.0	11.5

decrease pesticide needs (66%), and decrease herbicide needs (64%) (Table 1). These findings align with the documented agronomic benefits of diversifying crop rotations (Figure 2). However, a fourth statement about the potential profitability of extended rotations relative to maize and soybean rotations received less agreement, at 28%, with a plurality of 41% expressing uncertainty about potential profitability. This uncertainty seems to align with the sparse existing economic analyses comparing diversified cropping systems to less diverse ones, which show mixed results. Olmstead and Brummer (2008) found that adding perennial forage (e.g., alfalfa) in a 5-yr rotation resulted in a 24% increase in net revenue compared with maize–soybean rotation in Iowa. On the other hand, a more recent Iowa study showed that while net returns can be equivalent in diversified versus conventional cropping systems, they may require greater capital and labor inputs than the conventional maize–soybean system (Poffenbarger et al., 2017). The farmer uncertainty in the survey results and mixed economic analysis results from previous research point to a need to better document both the annual profitability and long-term economic (e.g., yield potential related to soil quality) implications of diversified agroecosystems.

Among perceived barriers, 77% of farmers agreed that the decline of mixed grain and livestock farming has made production of small grains and forages—key candidates for extended rotations—less viable (Table 1). Farmers also tended to agree that lack of robust markets (67%) and lack of interest from agricultural retailers and agribusiness firms (58 and 55%, respectively) were barriers.

Farmer perspectives on barriers to use of small grains in extended rotations items were similar to those for extended rotations in general. Lack of markets for small grains (82%), high land rents (81%), lack of elite genetics for small grains (65%), lack of technical support (59%), and lack of necessary equipment (58%) were all rated as important or very important by a strong majority (Table 1). About a third (37%) rated lack of experience as a major impediment.

Most of these barriers represent contextual factors "shaped by larger societal forces that have particular goals and objectives. In agriculture, different stakeholder groups and social movement organizations are constantly working to shape the structure and behavior of public and private institutions" (NRC, 2010, p. 272). Forces such as concentration in the agri-food system, and research investments in specialized commodity crops and concentrated animal feeding operations have led to long-term shifts in the types of markets and production systems available to farmers (Hendrickson & James, 2005; NRC, 2010), which now form potent structural barriers to adoption of extended rotations and similar practices and strategies and their potential beneficial impacts (Houser & Stuart, 2020; Schewe & Stuart, 2017; Stuart & Gillon, 2013).

Not surprisingly, the potential facilitators that were rated as most important were those that would target those structural barriers such as lack of markets and supply chains (Table 1). The ratings of potential facilitators in order of importance were development of markets for small grains (89%), linkages with buyers (79%), documentation of economics and profitability (75%), documentation of soil health benefits (74%), crop insurance (69%), workshops and other training opportunities (57%), technical assistance from local agribusinesses (55%), and cost-share to offset initial costs (54%).

4 | CONCLUSIONS

Substantial evidence shows that extended rotations that incorporate small grains can offer significant agronomic and environmental benefits including increased soil health and yields, weed and pathogen suppression, as well as concomitant decline in pesticide use, and reduced nutrient loss into waterways (Bennett et al., 2012; Tamburini et al., 2020). Despite these clear benefits, diversity in crop rotations continues to decline, especially across the U.S. Midwest (Hatfield et al., 2009; Sulc & Tracy, 2007). Our research shows that most Iowa row crop farmers appreciate the potential benefits of extended rotations, with or without small grains, but they also perceive substantial barriers to implementation.

A critical finding is that the most significant perceived barriers to extended rotations are factors that cannot be addressed by individual farmers but, rather, will require changes in policies and research priorities. Although potential facilitating factors such as continued and improved documentation of agronomic and economic benefits and technical assistance and training were rated as important, the most important barriers and facilitators were structural in nature, and changes to such structures will require transformational actions (Roesch-McNally et al., 2018). As a recent National Academies report stated, "In the coming decade, stresses on the U.S. food and agricultural enterprise are unlikely to be resolved by farmers, the market, input suppliers, or by current public and private sector research efforts, if business as usual prevails" (National Acadamies of Science, Engineering, and Medicine, 2019, p. 1). To enable farmers and agricultural value chains to incorporate extended rotations and small grains, we will need a broad spectrum of transformative actions, including changes in federal, state, and local government policy, shifts in funding and focus of university research and extension programs, and value chain development by agribusinesses.

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AUTHOR CONTRIBUTIONS

David A. Weisberger: Conceptualization; Investigation; Methodology; Visualization; Writing-original draft; Writing-review & editing. Marshall D. McDaniel: Conceptualization; Investigation; Methodology; Visualization; Writing-original draft; Writing-review & editing. J.G. Arbuckle: Conceptualization; Data curation; Investigation; Methodology; Writing-original draft; Writing-review & editing. Matt Liebman: Conceptualization; Investigation; Methodology; Writing-original draft; Writing-review & editing.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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