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What would it look like? Visualizing a future US Corn Belt landscape with more table food production

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Abstract

Most farmland in the US Corn Belt is used to grow row crops at large scales (e.g., corn, soybean) that are highly processed before entering the human food stream rather than specialty crops grown in smaller areas and meant for direct human consumption (table food). Bolstering local table food production close to urban populations in this region through peri-urban agriculture (PUA) could enhance sustainability and resilience. Understanding factors influencing PUA producers' preferences and willingness to produce table food would enable supportive planning and policy efforts. This study combined land use visualization and survey data to examine the potential for increased local table food production for the US Corn Belt. We developed a spatial visualization of current agricultural land use and a future scenario with increased table food production designed to meet 50% of dietary requirements for a metropolitan population in 2050. A survey was administered to row crop (1360) and specialty crop (55) producers near Des Moines, Iowa, US to understand current and intended agricultural land use and factors influencing production. Responses from 316 row crop and 25 specialty crop producers were eligible for this analysis. A future scenario with increased table food production would require less than 3% of available agricultural land and some additional producers (approximately 130, primarily for grain production). Survey responses indicated PUA producers planned small increases in table food production in the next three to five years. Producer plans, including land rental for table food production, could provide approximately 25% of residents' fruit, vegetables, and grains, an increase from the baseline of 2%. Row crop producers ranked food safety regulations, and specialty producers ranked labor concerns as strong influences on their decision-making. Both groups indicated that crop insurance and processing facilities were also important. Increasing table food production by clustering mid-scale operations to increase economies of scale and strengthening supply chains and production infrastructure could provide new profitable opportunities for farmers and more resilient food systems for growing urban regions in the US Corn Belt. Continuing to address producer factors and landscape-scale environmental impacts will be critical in considering food system sustainability challenges holistically.

Introduction

The conventional global-scale food system has increased crop yields and improved human wellbeing by reducing food insecurity (Raudsepp-Hearne et al., 2010). However, as food systems have become more interconnected globally, together with shifts in populations toward urban areas, diets have shifted toward unhealthy, inexpensive, and convenient foods (Fanzo and Davis, 2019). The global food system also produces environmental and social impacts such as decreased water quality and biodiversity (Jarchow et al., 2012; Reich, Beck and Price, 2018). In the US Corn Belt in particular, subsidized production of row crops in large contiguous areas leads to the persistence of landscapes that lack plant diversity and infrastructure necessary for other types of production with a number of unintended environmental and social consequences (Prokopy et al., 2020). Regional infrastructure and rural economies in the US Corn Belt have evolved to support and depend on monoculture production systems, negatively impacting more diversified operations and ultimately reducing food system resilience (Duncan et al., 2018).

Peri-urban agriculture (PUA) is an agricultural practice or farm located near an urban area or city; metropolitan statistical areas (MSAs) have been used as boundaries to approximately define PUA (Rogus and Dimitri, 2015). MSAs are defined as areas containing a city ('population nucleus') having strong economic and social integration with nearby communities (U.S. Department of Commerce, 1994). Although their geographic areas may vary, the social integration within MSAs is an important feature for PUA. Localizing PUA could provide health benefits, including improvements in food access, vegetable consumption, food and health literacy, and even greater mental and physical well-being for consumers (Surls et al., 2015). Policymakers in urban areas increasingly view the use of local food production as an opportunity to address many urban problems simultaneously: food insecurity, lack of healthy, affordable food, lack of accessible green space, and lack of economic opportunity (Gray et al., 2014). Despite potential benefits of local food for consumers, current consumer expectations tend to prioritize low cost and homogeneity across seasons which benefit global- and national-scale commodity markets rather than local agricultural diversification (Bowman and Zilberman, 2013). In cities like Des Moines, Iowa, PUA production of food for direct human consumption (table food) is focused on niche markets at small scales, and despite an abundance of productive agricultural land, about 90% of food is imported into the state (Krouse and Galluzzo, 2007). Localizing table food PUA around urban centers is one strategy that could decrease negative externalities associated with the current food system (Thompson et al., 2021). Spatial visualization can be useful for understanding how changes could be made on the landscape, exploring food system scenarios and their consequences for producers and consumers alike (Jarchow et al., 2012; Nassauer and Corry, 2004; Santelmann et al., 2007).

Throughout this study we use the term ‘row crops’ to describe only the large production areas of corn and soybeans that are mostly highly processed before entering the human food stream. We use the term ‘table food’ to describe crops grown in the PUA that are meant for direct human consumption. Although these categories are not mutually exclusive, distinguishing between corn and soybean row crops and table foods including grains is useful from a food system perspective, as most corn and soybean production in Iowa is used for fuel (<50%), feed and export rather than for direct human consumption (Iowa Farm Bureau, 2022).

Spatial visualization of peri-urban food systems

Urban and PUA make up about 6% of all cropped areas globally (Thebo, Drechsel and Lambin, 2014). Without additional land dedicated to table food production and appropriate policy support, little progress will be made toward increasing the production of local foods near urban centers (Rogus and Dimitri, 2015). Geospatial analysis and visualization using geographic information systems (GIS) could reveal potential areas for table food production and provide important information to local policymakers (Saha and Eckelman, 2017). Researchers have used visualization tools to create scenarios and influence policy formulation to support local food production. For example, in northern Idaho, GIS was used to assess land use for food production, leading to models that indicated how local food demands could be met and environmental outcomes improved by taking marginal lands out of row crop production (Liao et al., 2019). In other states and cities across the USA, GIS studies have connected food production capacity and consumer food needs within defined urban and peri-urban areas, notably for the state of New York and the City of Boston, MA (Peters et al., 2009; Saha and Eckelman, 2017). Two local food system studies also built optimization models to quantify distances between potential production areas and nutritional needs of the local population in the state of New York and the City of Chicago, IL (Costello et al., 2021; Peters et al., 2009). Both studies developed spatial visualizations of local food system scenarios and the quantity of consumption that could be satisfied by local production.

Measures of perceptions are important in GIS-based food system studies because they can enable detection and interpretation of qualitative yet essential food system elements such as perceived availability and quality of healthy foods (Moore, Roux and Brines, 2008). One local food system study that incorporated stakeholder perceptions mapped food store locations and densities with measures of perceived healthy food availability in urbanized counties in North Carolina, Maryland, and New York (Moore, Roux and Brines, 2008). Another study mapped food access in Colorado, using GIS coordinates triangulated with qualitative and semi-structured interviews conducted to understand rural and urban food environments (Carolan, 2021). As perceptions of decision makers are difficult to capture using quantitative spatial measures alone, a mixed method approach can support deeper understanding of complex food system dynamics (Moore, Roux and Brines, 2008).

Economic, social, and environmental drivers for producers in the Des Moines metropolitan statistical area

Mid-scale agricultural production tends to diversify production at higher rates, which could improve all three components of sustainability (environmental, social, and economic; Esquivel et al., 2021). Mid-scale agricultural production is defined by the USDA as grossing between $350,000 and $999,999; however, farms grossing $50,000–$500,000 have particular livelihood potential for producers and can fill critical gaps in regional food systems (Peterson et al., 2022). In Iowa, horticulture producers have increased sales by 58% since 2000, yet an increasing number (90%) made less than 40% of their gross household income from the sale of horticulture crops in 2015 (Enderton et al., 2017). Decreasing sales for individual farms is a national trend in the USA where over 40% of farms generated less than $10,000 annually according to the 2017 Agricultural Census (Peterson et al., 2022). Iowa horticulture farms averaged just $25,773 in gross sales in 2015 (Enderton et al., 2017). Horticulture producers in Iowa still primarily sell direct-to-consumer even though the percent of producers using these channels decreased by 10% between 2000 and 2015, while wholesale markets grew by an equivalent amount in the same period (Enderton et al., 2017). Mid-scale operations that can access growing wholesale markets are better able to balance the needs of producers to make a living on their farms and of consumers for affordable table foods (Feenstra and Hardesty, 2016).

Mid-scale production of table foods could support environmentally beneficial practices as well as economic benefits for producers (Thompson and Gaskin, 2018). Environmentally, mid-scale agricultural producers in the USA more readily include ecological diversification and adopt conservation practices that could enhance ecosystem services which support increased social benefits (Esquivel et al., 2021). In Iowa, the average size of fruit and vegetable farms has become smaller over the past 15 years, decreasing from 5 to 3 ha between 2000 and 2015 (Enderton et al., 2017). Shifting from small- to mid-scale table food production can increase farm income and produce benefits, from supporting local economies and improving community vitality to reducing environmental impacts (Jablonski and Schmit, 2016; Kirschenmann et al., 2008). Increasing land used for producing table foods in the US Corn Belt would diversify the landscape and could reduce greenhouse gas emission, energy use, and water withdrawal (Stone et al., 2023).

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Close producer proximity provides unique benefits that are not possible in a widely distributed social network. For example, shared equipment and processing facilities could result in cost savings (labor and machinery) for individual producers. Value additions to crops (e.g., milling wheat or canning salsa) could also reduce the amount of land an individual needs to farm while maintaining a certain income. However, with mid-scale production, this would be most conducive in a cooperative or collective such as a food hub (e.g., ISU Extension, 2023). Social cohesion is also an important consideration for supporting producer diversification. Although organizations in Iowa can and do create 'communities' among table food producers that span the state, having similar producers nearby could provide additional benefits for social cohesion with neighbors, which was found to be important based on in-depth interviews of rural farmers in the Corn Belt region (Atwell, Schulte and Westphal, 2009).

Objectives

The present study focused on the six-county Des Moines, IA Metropolitan Statistical Area (DM-MSA) and had two principal objectives:

1) Visualize changes in agricultural land use within the DM-MSA by comparing current land use (baseline scenario) with possible future (2050) table food production that includes producing 50% of the local population's dietary requirements within the area (future scenario).
2) Identify the influence of nine factors on commodity and specialty PUA producers' willingness to add or increase table food production for local markets and explore how addressing these factors could enable more table food production in the DM-MSA.

Methods and materials

This study is focused on understanding current and future local table food scenarios in the DM-MSA through visualization while assessing the influence of factors that currently affect producers' willingness to grow table food crops for local markets. The table food production area for the 50% local diet scenario in 2050 was based on a life cycle assessment (LCA) study of the DM-MSA (Brighenti et al., 2022). Survey data were utilized to quantify near-future plans for table food production. A six-county map was developed to support visualization of how this shift could change agricultural land use.

Study area description

The DM-MSA includes the capitol of Iowa and is located in the US Corn Belt (Fig. 1). The DM-MSA is similar to many other metropolitan areas in the US Corn Belt, including Lansing, Michigan; Omaha, Nebraska; Dayton, Ohio; and Madison, Wisconsin, all of which have similar-sized human populations and agricultural systems (e.g., seasonal production, rainfed agriculture). The human population in the DM-MSA was 709,466 in 2020 (Woods and Poole Economics Inc., 2021). The total land area is 9300 km^2, with about 74% of the land area currently zoned agricultural (694,000 ha) and 560,000 ha used as cropland (USDA-NASS, 2019). Approximately 90% of DM-MSA cropland was used to produce corn and soybean (USDA-NASS, 2019). Currently, about 90% of food consumed in Iowa is imported from outside the state (Krouse and Galluzzo, 2007). Table foods are produced on just 0.2% of cropland in the DM-MSA (USDA-NASS, 2019). In Iowa, current median individual fruit and vegetable production areas are 0.8 ha in size and 50% of horticulture farmers in Iowa rely primarily on direct-to-consumer marketing (Enderton et al., 2017). There is no mid- or large-scale fruit and vegetable processing available in the state, and there are limited wholesale opportunities for small-scale producers (Enderton et al., 2017). The DM-MSA population is growing, with a population projected to be 877,459 (an increase of 24%) in 2050 (Woods and Poole Economics Inc., 2021).

Future scenario development

A combination of sources was used to build a future scenario (2050) for increased table food production in the DM-MSA. These sources include scientific literature, geospatial data, survey results, and interviews with local food system stakeholders that supported our understanding of how to balance economic, social, and environmental drivers in a future food system. This section focuses on how the social, economic, and environmental drivers we identified (section 'Economic, social, and environmental drivers for producers in the Des Moines metropolitan statistical area') shaped our future spatial visualization for the DM-MSA food system. (The amount of land required to meet 50% of dietary requirements for the MSA in 2050 is explained in section 'Spatial visualization').

Based on our study area definition in relation to the City of Des Moines and discussions with local producers and horticultural experts, we determined that mid-scale PUA producers would manage between 5 and 15 ha (approximately 25–49 acres) of fruits and vegetables with the size of operation based on revenue generated by the specific crop, its seasonality, and type of production. This is smaller than mid-scale production for fruits and vegetables in California of 8–101 ha (20–250 acres) for which production is year-round (Minor and Bond, 2017; Esquivel et al., 2021). Mid-scale fruit and vegetable production in our study area would be closer to the range of 4–20 ha (10–49 acres) used to characterize mid-scale production in the state of Georgia (Thompson and Gaskin, 2018). Urban expansion could likely necessitate buffering from roads and other surrounding infrastructure by 2050, an important consideration for future projections. Grains such as wheat and oat meant for human consumption would more likely be incorporated at a field scale by extending current row crop rotations. In our study area, table food farms with more than 20 ha would likely include small grains in extended rotations.

A key social driver that shaped our visualization was spatial proximity of similar producers to enable shared infrastructure for table food (e.g., equipment, processing, markets) that is currently lacking in our study area. Clustering similar producers (co-locating their operations) could be beneficial, enabling shared infrastructure and regional food networks (Duncan et al., 2018). Researchers conducting a case study in Pennsylvania analyzed urban and rural distribution networks of local food sold through a distributor to schools and restaurants and found producers were considered local if they were 16–97 km (10–60 miles) from the distributor and that shared ownership of key infrastructure (e.g., producers cooperatives) could support socially equitable and economically sustainable outcomes (Bloom and Hinrichs, 2011). In our study, clusters of fruit and vegetable producers were identified using manual post-processing, prioritizing the selection of

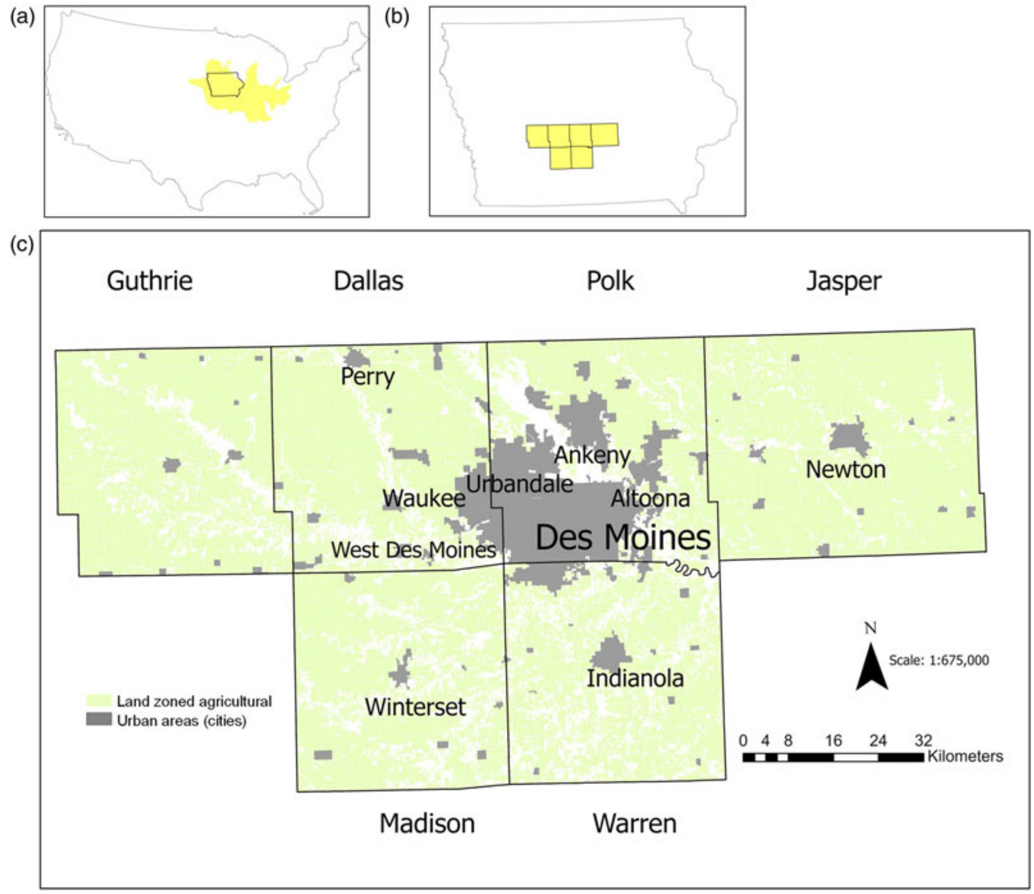

Figure 1. (a) Map of the contiguous United States with the US Corn Belt in yellow and the state of Iowa outlined in black. (b) State of Iowa with the six-county Des Moines Metropolitan Statistical Area (DM-MSA) in yellow. (c) Study area map for the six-county DM-MSA (Dallas, Guthrie, Jasper, Madison, Polk, Warren) in central Iowa with agricultural land (in green) and incorporated urban areas (in grey). Major cities include the state capitol, Des Moines.

biophysically suitable fields less than 30 km away from the Des Moines city center. Clustering efficiency was confirmed using both nearest average neighbor and by identifying those within a 30 km radius from the Des Moines city center.

Spatial visualization

Two spatial visualizations were developed to categorize agricultural land use for table food production in the DM-MSA. The baseline scenario was based on county-level table food production reported in the 2017 Agricultural Census (USDA-NASS, 2019). In the 50% local diet scenario, land use for production of table food to meet 50% of dietary requirements for the 2050 MSA population was based on a LCA of the study area for the quantity of land, which was combined with economic, social, and environmental drivers previously described (section 'Economic, social, and environmental drivers for producers in the Des Moines metropolitan statistical area') to inform individual operation size and clustering of operations for the future scenario (Brighenti et al., 2022; Thompson et al., 2021). In this Iowa-specific study researchers estimated that a total of 106,148 ha of DM-MSA agricultural land would be necessary to provide the MSA population with 50% of dietary requirements for seven food groups (fruit, vegetable, grain, oil, sugar, dairy, and meat/protein) by the year 2050. This study, similar to other studies developing future scenarios, is focused on exploring future pathways, highlighting critical uncertainties and is not meant for forecasting or predictive purposes (Jarchow et al., 2012). As table food production remains at scales too small to reliably detect based on remote-sensed satellite data, county information from the 2017 Agricultural Census was positioned on agricultural land based on a suitability score for both scenarios. Table foods were categorized as fruits/vegetables or grains. Fruit and vegetables were grouped into a single category in the visualizations to improve their visibility.

Spatial and census data were combined with survey results for the DM-MSA study area to enable visualization of agricultural land using ArcGIS Pro v.2.8.0 (ESRI Inc, 2020). Maps of county and city boundaries were based on open-source geospatial data (State of Iowa, 2020). Spatial data for agricultural fields with boundaries, the cropland data layer (2016–2021) (USDA-NASS, 2022), and custom soil tables (gSSURGO) were derived from datasets from the Agricultural Conservation Planning Framework (Tomer, James and Sandoval-Green, 2017). These data were combined into a suitability score using a weighted overlay tool in ArcGIS Pro v.2.8.0 (ESRI Inc, 2020), to determine which areas were biophysically suitable for fruit and vegetable production within the DM-MSA landscape (Table 1). The suitability score (ranging from 9 = most acceptable to 1 = not acceptable) positioned only fruits and vegetables on the landscape and did not consider small grains because they require conditions similar to those for crops currently grown throughout the landscape. The baseline for

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Table 1. Suitability scores based on five criteria with equal weights were used to locate table food production areas in the Des Moines Metropolitan Statistical Area

Criteria	Values	Score (1–9)
Land zoning	Zoned agricultural—row crops	9
	Zoned agricultural—pasture/forage	4
	Not zoned agricultural	1
Flood frequency	None	9
	Rare	4
	Occasional or frequent	1
Soil drainage class	Well drained	9
	Moderately well drained	7
	Somewhat excessively drained	4
	Poorly, somewhat poorly, or excessively drained	1
Slope	0–5%	9
	<5 to >10%	4
	+10%	1
Soil texture	Sandy loam, loam, silt loam	9
	Clay loam, sandy clay loam, loamy sand	4
	All other soil types	1

The scoring system is from 1 (not acceptable) to 9 (most acceptable).

table foodgrains included land that is currently in extended rotations (e.g., corn-soybean-grain) to create a realistic visualization and new fields were added to the future scenario. The suitability score incorporated only biophysical and current agricultural field boundaries. Features based on, and thus manipulated by, human inputs and management such as application of macronutrients (N-P-K), micronutrients, soil structure, and soil chemical properties (e.g., pH) were not included.

The most important biophysical variable for land selection for table food production in Iowa is drainage (Kistner et al., 2018; Nair, Kaspar and Nonnecke, 2015). This was accounted for by including geospatial data about flood frequency, soil drainage class, and soil texture (Tomer, James and Sandoval-Green, 2017). Since much of the agricultural landscape in Iowa is tile drained, all land with a dual drainage class was considered suitable for table food production (Tomer et al., 2020). Additional inputs for the suitability score included only land zoned agricultural and categories based on the mean slope of each field. The five criteria were equally weighted. Only areas with a total score of 8 or 9 were considered suitable for this analysis. To be suitable no criterion can score a one. Areas with a score of nine for all five criteria and areas with a score of nine for four criteria and either a seven or four for one criterion were considered suitable. Fields were prioritized for selection based on the percentage of land that was suitable on a field-by-field basis.

After suitable areas for table food production were identified, manual post-processing included selecting production area sizes. For visualization, suitable agricultural land was selectively converted to table food to represent each scenario and production category. According to the Iowa Commercial Horticulture Survey, the current median farm size (the baseline) is about 0.8 ha and the state average size is 3.2 ha (Enderton et al., 2017). We selected fruit and vegetable production area sizes to correspond with the averages in the Iowa Commercial Horticulture Survey and input from a Horticulture Extension Specialist (Enderton et al., 2017; Nair, 2022). The baseline production size ranges for grain were also set to correspond with current state wheat production area sizes (USDA-NASS, 2017).

Survey analyses

A mixed-mode survey (approved by the Iowa State University Institutional Review Board) of a random and representative sample of current PUA producers was administered in spring 2021 to 1363 row crop and 55 specialty crop producers in the DM-MSA by the Center for Survey Statistics and Methodology at Iowa State University. The survey was based on results of a series of focus groups (Dorneich et al., 2023) and designed to help researchers understand DM-MSA producers' willingness to grow specialty crops based on their current and intended agricultural land use and factors influencing their production decisions. Survey dissemination (multiple contacts, mail, and internet distribution methods) followed Dillman, Smyth and Christian (2014) and response rates were 32% for row crop producers ($n = 433$) and 53% for specialty crop producers ($n = 29$) (survey methodology and questions are available in Appendix A).

Although land used for livestock production was collected in the survey, we excluded it from our scenario visualizations because the USDA Agricultural Census does not include county-scale data for livestock production land use. The most current county Agricultural Census data were used for all other table food production categories, both for current production and to scale the future agricultural land use scenarios (USDA-NASS, 2019).

Results

Spatial analyses

Baseline scenario (year 2020)

The baseline scenario included 1027 ha (0.1% of DM-MSA agricultural land): 586 ha in production of grains such as wheat and oat used primarily for human consumption), 63 ha in fruit production and 378 ha in vegetable production, including dry beans and peas.

The baseline visualization shows how little fruit, vegetable, and grain production currently takes place in this landscape (based on 2017 Agricultural Census data). The baseline scenario also highlights the small scale of individual operations for fruit and vegetable production. For the baseline scenario, we modeled 214 farms growing fruits and vegetables and 59 farms growing table food grains (Fig. 2). For fruits and vegetables in the baseline scenario, approximately 80% of production was between 0 and 4 ha, the remaining 20% were between 5 and 15 ha. The size of fruit and vegetable areas per farm was 3.1 ha on average (median of 1.9 ha).

Fields selected for the baseline had an overall average suitability score of 8 or 9 for 96% of each field. The minimum percentage of suitable land for an individual field selected was 84%. The county average percent suitability was between 99 and 92% for fruit and vegetable production. Because wheat production does not require the same biophysical profile, the suitability score

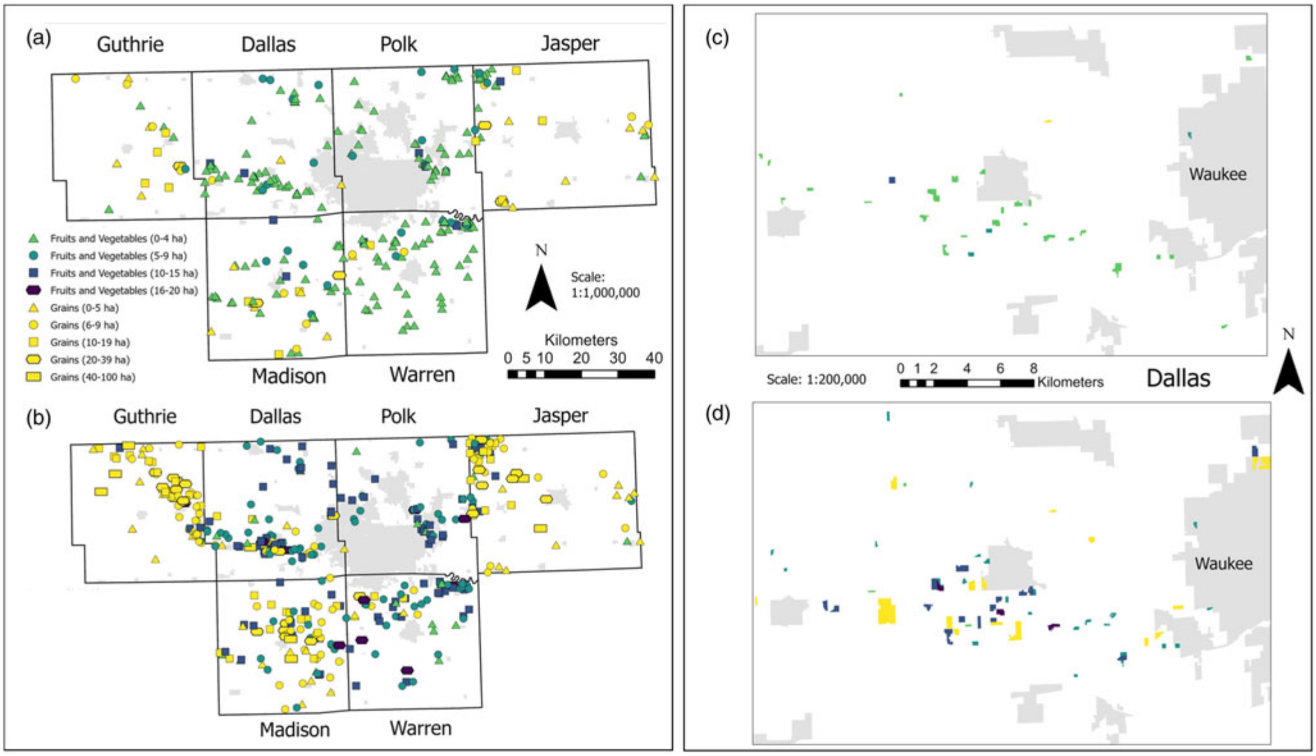

Figure 2. Spatial representation of the Des Moines Metropolitan Area for the baseline scenario (a) and a future scenario (b) where 50% of fruits, vegetables, and grains for the 2050 population are produced within the DM-MSA**.** Yellow represents grains at all scales with triangle (for 0–5 ha), circle (for 6–9 ha), square (for 10–19 ha), hexagon (for 20–39 ha), and rectangle (for 40–100 ha) in (a) and (b). Fruits and vegetables are green and triangle (for 0–4 ha), teal and circle (for 5–9 ha), blue and square (for 10–15 ha), and purple hexagon (for 16–20 ha) in (a) and (b). Field boundaries in southeastern Dallas County are displayed at a finer scale near the city of Des Moines for the baseline (c) and future (d) scenarios. The same colors represent grains (yellow), fruits and vegetables are colored by scale: green (for 0–4 ha), teal (for 5–9 ha), blue (for 10–15 ha), and purple (for 16–20 ha).

was not considered in land area selection for either scenario. For grains, the baseline size was 9.3 ha on average (median of 7.2 ha). Polk County (containing the City of Des Moines) reported no wheat production and was excluded from grain production analyses (USDA-NASS, 2019).

Future scenario (year 2050)

The future scenario included 17,752 ha total (2.5% of DM-MSA agricultural land): 13,264 ha for grains (a 23-fold increase from baseline), 1975 ha fruits (31-fold increase), and 2513 ha vegetables (7-fold increase). This future scenario would require converting just 2.6% (4026 ha) of agricultural land in the DM-MSA to meet 50% of current dietary consumption by the population in 2050 for fruits, vegetables, and small grains. This change represents a 17-fold increase from current level of table food production in the DM-MSA. The scale of individual operations was increased to represent mid-scale production of 9.2 ha on average for the study area (median of 8.6), county average field sizes were between 8.5 and 9.9 ha. Although typical corn and soybean production in the area would not be greatly reduced, increasing table food production could enhance rural and urban livelihoods in the DM-MSA. However, there are significant socio-political barriers to this change that are discussed in the following section.

For the 50% local diet scenario, fruit and vegetable farms increased in scale to meet the 50% local diet scenario with 4488 ha of production: an increase of 10-fold (Fig. 2). The number of fruit and vegetable farms for the future scenario was set to maximize mid-scale production. The average production area per farm increased from 3.1 ha in the baseline to 9.2 ha in the future scenario. This increase meant a small reduction in the number of farms (197 compared to 214 in the baseline) to maintain area requirements. The 50% local diet scenario maintained approximately 10% of farms in the small size category (0–4 ha), the remaining 90% of farms were mid-scale (between 5 and 15 ha) and large-scale (16–20 ha). Grain production in the future scenario included 191 farms, a threefold increase from the baseline, and larger operations (26.7 ha compared to 9.3 ha in the baseline). Fruit and vegetable fields selected for the future scenario had an overall average suitability score of 8 or 9 for 95% of each field. The minimum percentage of suitable land for an individual field selected was 76%. The county average percent suitability varied between 98 and 90% for fruit and vegetable production.

In this study, the level of clustering was determined using the average distance between areas of similar (fruits and vegetables) production. In the future scenario, the nearest average fruit and vegetable producer neighbor was 1.0 km. Thus, selecting based on high suitability scores and prioritizing near-urban areas for selection during post-processing led to significant clustering (z-score = −25.4, P-value < 0.001). In addition, of the 197 fruit and vegetable producers in the future scenario, 112 (57%) were within 30 km of the Des Moines city center.

Peri-urban producers' plans for near future table food production

Producers in three of the six counties (Dallas, Guthrie, and Polk) planned small reductions in table food production in the next three to five years (Fig. 3), which represents a 30% reduction from the baseline (USDA-NASS, 2019). Producers in the other three counties (Jasper, Madison, and Warren) planned increases ranging from 1048 ha (Warren County) to 195 ha (Jasper County). Operators in these three counties planned to increase table food production by 1444 ha representing a 328% increase compared to the current total of 440 ha of production area in those counties (USDA-NASS, 2019).

Producers' plans for growing table food in the next three to five years did not represent significant change across the DM-MSA. Approximately, 1400 ha in the study area would shift production, with 71% of the planned changes in Warren County alone. Producers primarily planned to increase vegetable (767 ha) and table food grain (488 ha) production areas, with little increase for fruit production areas (12 ha). Overall, commodity producers were willing to rent more land to table food producers (9300 ha) compared to growing table food themselves (1400 ha).

We did not include livestock production in our visualizations due to wide variation in the land area needed based on different possible management practices (e.g., confinement facilities versus free-range operations). However, we did ask about anticipated land use for livestock and found that in three counties (Dallas, Polk, and Warren) producers planned to decrease livestock land use in the next three to five years (by 144, 1734, and 6541 ha, respectively). Producers in the other three counties (Guthrie, Jasper, and Madison) planned modest increases for livestock land use (58, 489, and 858 ha, respectively). Overall, producers in the DM-MSA would reduce livestock land allocations by 7014 ha in the next three to five years based on producer plans. Concurrently, producers plan to increase commodity crop production by 5188 ha. It was interesting to note that Warren County producers (with large planned increases for table food) also had large planned increases for commodity production (5538 ha). Producers in two counties planned reductions in commodity production (Jasper County reduced by 751 ha and Madison County by 831 ha).

Sixty-nine commodity producers in our sample (22%) indicated they would be willing to lease an average of 10.8 ha to table food producers. For the DM-MSA, possible rentals to table food producers totaled 745 ha based on our survey (or an estimated 9300 ha for all producers in the DM-MSA). Producers in three counties had similar willingness to lease land to table food producers (Dallas, Jasper, and Warren) at an average of 2429 ha county^{-1} in the next three to five years. Producers in the other three counties (Guthrie, Madison, and Polk) were less willing (675 ha county^{-1}).

Factors influencing peri-urban producers

Of producers surveyed, 106 (105 row crop and 1 specialty crop producer) indicated that none of the nine factors we included influenced their decisions to increase table food production (31%). Only one producer who indicated they were not influenced by any factor listed identified an additional factor which they characterized as 'will not do'. The lack of additional factors identified by these producers may indicate they have a general lack of interest in growing table food.

For the remaining 235 producer respondents (211 row crop and 24 specialty crop producers) who indicated at least one factor was at least barely influential (2 of 7 on the Likert scale), the average and median values by factor ranged between 2 (barely influential) and 4 (somewhat influential) and the average rating across all factors was 3.6 (median of 4.0). Food safety regulations and access to processing facilities were considered very influential by both row crop and specialty producers (Fig. 4). For row crop producers, factors with the highest proportion of ratings 6 or greater on the Likert scale (very, or extremely influential) were (1) food safety regulations ($n = 63$, 30%), (2) access to processing facilities ($n = 61$, 29%), and (3) insurance ($n = 59$, 28%). For specialty crop producers, factors with the highest proportion of ratings 6 or greater were (1) access to processing facilities ($n = 10$, 42%), (2) land access ($n = 8$, 33%), and (3) food safety regulations ($n = 7$, 29%).

The factors with the most moderate to slightly influential ratings for both producer groups were labor and loan access (Fig. 4). For row crop producers, factors with the highest proportion of ratings 3–5 on the Likert scale (moderately to slightly influential) were (1) labor ($n = 108$, 51%), (2) loan access ($n = 105$, 50%), and (3) food safety regulations ($n = 103$, 49%). For specialty crop producers, factors with the highest proportion of ratings 3–5 on the Likert scale were (1) the ability to host on-farm events ($n = 10$, 42%), (2) labor ($n = 9$, 38%), and loans ($n = 9$, 38%). There were fewer total responses to the off-farm employment (Job) factor by both groups of producers. For specialty producers, off-farm employment was moderately important as the fourth most influential factor followed by insurance and labor (based on highest number of ratings 6 or greater). Row crop producers considered loans as moderately important (the fourth most influential factor) followed by land access and zoning.

The least influential factors for both producer groups were land access and zoning concerns (Fig. 4). The factors with the highest proportion of low ratings of 2 or less on the Likert scale (not at all or barely influential) for row crop producers were (1) the ability to host events on-farm ($n = 88$, 42%), (2) land access ($n = 83$, 39%), and (3) zoning ($n = 72$, 34%). For specialty producers, factors with the highest proportion of ratings 2 or less were (1) zoning ($n = 16$, 67%), (2) insurance ($n = 14$, 58%), and (3) land access ($n = 12$, 50%). Land access was both the second most highly rated factor (6 or greater) and the third most low rated factor (2 or less) indicating that the influence of this factor varies widely among our sample of specialty producers ($n = 24$).

Discussion

Our study includes a framework for selecting suitable land in the Corn Belt for PUA table food production based on biophysical characteristics. It also incorporates a shift to mid-scale production and clustering of similar farm operations to enhance profitability through shared infrastructure. Although current trends in the USA indicate decreases in mid-sized farms (determined based on sales, not land area), policy changes could create more opportunities for mid-sized farms and support their revitalization, which would likely benefit producers and consumers alike (Lev and Stevenson, 2011). In visualizing the 50% local diet, table food production area clusters could enable shared equipment and market infrastructure. Although our future scenario considers multiple objectives, a growing body of literature is developing socio-economic scenarios under a new paradigm using agent-based models to further integrate social and environmental impacts of food systems (Brown, Holman and Rounsevell, 2021; Thompson et al., 2021). However, given the small amount of land necessary to grow table food in the DM-MSA, additional land use changes will need to be considered to reduce landscape scale environmental impacts.

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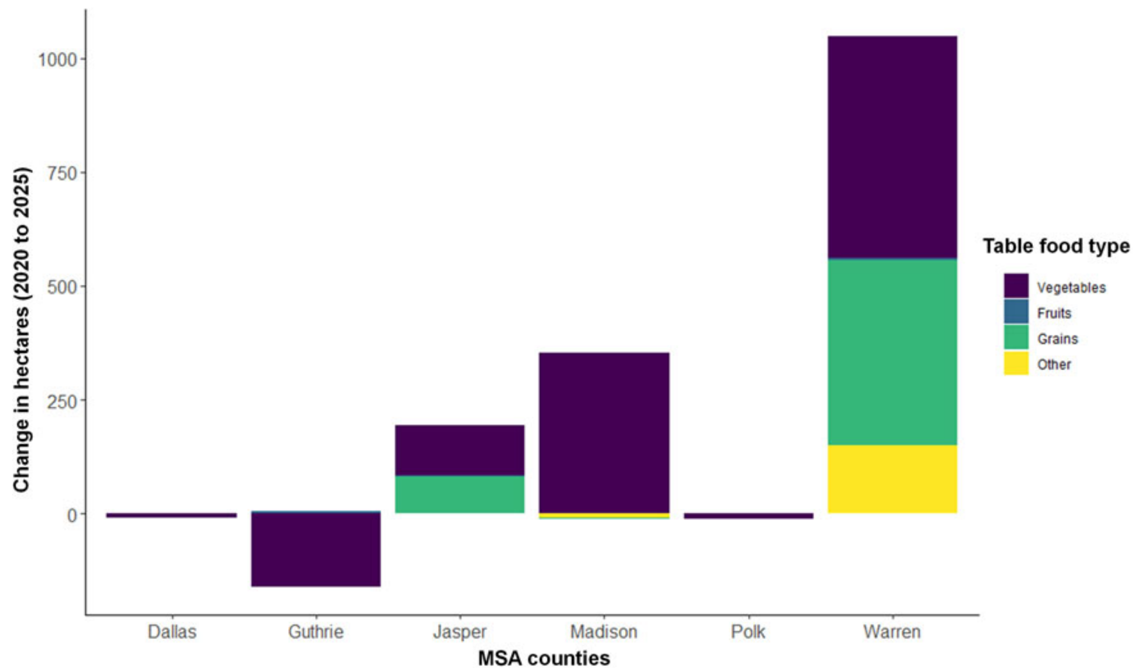

Figure 3. Table food production by county based on producer plans for the next three to five years.

Future land use scenarios with increased extensive livestock and native vegetation could support landscape scale sustainability

Authors of several studies have developed different food system scenarios for Iowa to visualize alternatives and chart a course toward increased environmental and social sustainability. In 2002, alternative future landscape scenarios for 2025 were developed for two Iowa watersheds; visualizing increased row crop production, increased hydrological function, and increased biodiversity to understand potential changes in environmental impacts, economic returns, and public acceptance (Nassauer

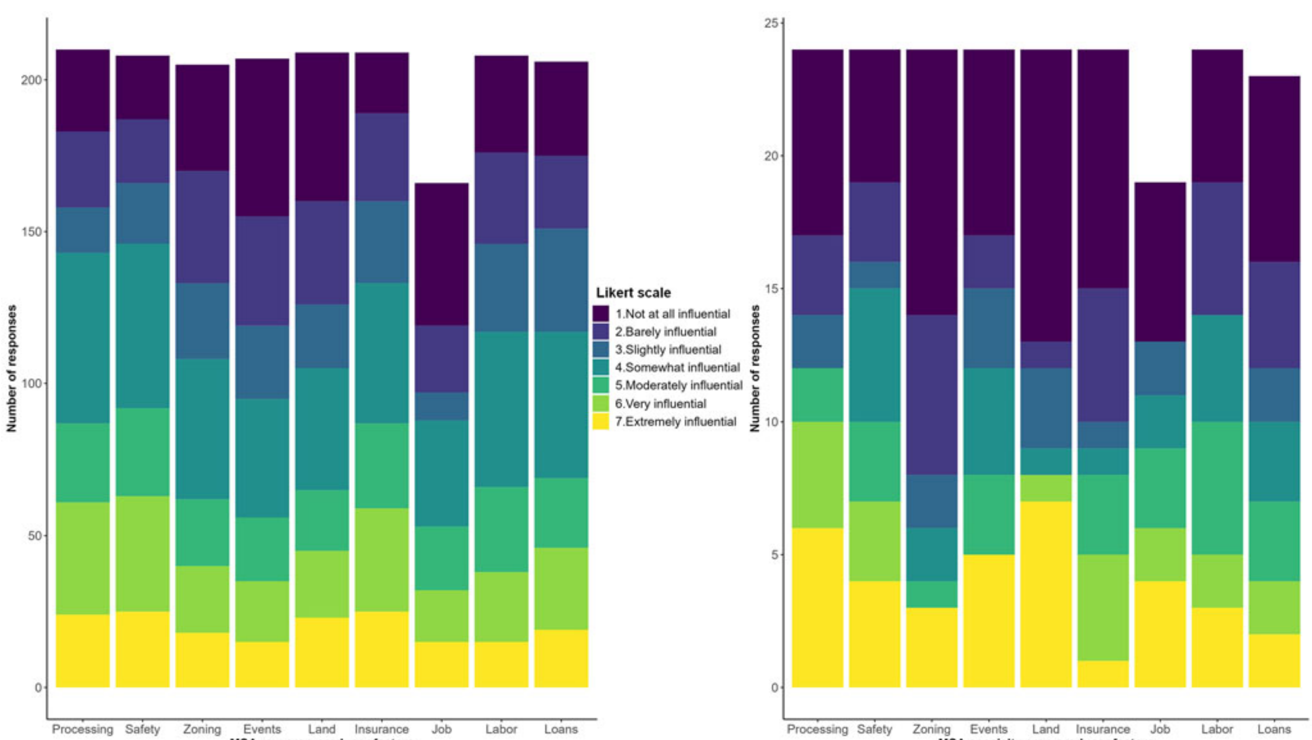

Figure 4. Row crop ($n = 211$) and specialty crop ($n = 24$) producers ranked nine factors (processing [food processing infrastructure], safety [food safety regulations], zoning, events [ability to host events on farm], land [access to land], insurance [crop insurance], job [needing to work a job off-farm], labor [accessibility of labor for the farm], loans [loan availability]) based on their influence in the decision to grow table food on a 7-point Likert scale (1 = not influential, 7 = extremely influential).

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and Corry, 2004). All three future scenarios identified set-aside land (not large changes in the types of crops produced on the landscape), and all involved significantly reducing the number of farmsteads (Nassauer and Corry, 2002). In subsequent interviews with farmers, the scenario that optimized row crop production was least preferred but seen as the most likely future scenario (Santelmann et al., 2007). Many farmers indicated a preference for the hydrological scenario where more farmers would remain on the landscape to support increased rotational grazing and farming with an extended crop rotation that included corn-soybean-oat-alfalfa, despite it being the least economically profitable for farm businesses (Santelmann et al., 2007). Other researchers designed alternative food system scenarios for three counties in Iowa (including Polk County) for the year 2100 (Jarchow et al., 2012). In two scenarios for which row crop production was prioritized, corn and soybean production would continue to dominate the landscape, while two other scenarios focused on improving human and environmental welfare. These scenarios included shifts in production to table food surrounding each city in the study area as well as increased perennial cover such as pastures and native vegetation (e.g., prairies and woodlands) (Jarchow et al., 2012). These researchers suggested that continued focus on high agricultural production and economic returns would limit environmental and social shifts, although fossil energy limitations might support changes toward sustainability by incorporating more natural areas such as wetlands, prairies, riparian buffers, and extensive grazing of livestock instead of confined feeding operations (Jarchow et al., 2012).

The future scenario in our study offers another alternative that would increase farm scale (from small to mid) and could improve economic viability of farm businesses if appropriate infrastructure and risk mitigation were available. However, our visualization did not incorporate livestock despite the economic and land footprint of livestock and livestock feed in the state (e.g., Schulz et al., 2017). Future research focused on local and regional food systems in our study area should include livestock and livestock feed production. A scenario integrating cropping systems with more extensive livestock production would require more land and could bolster local markets for more producers and begin to address landscape scale nitrogen loss and soil erosion (Burkart, 2005). However, it will also be important to understand how different livestock management scenarios will impact land use and a host of other environmental and social factors (Pelletier et al., 2010a; Pelletier, Pirog and Rasmussen, 2010b).

Although our study does not consider the significant energy requirements of row crop production, changing energy cost and availability is a critical consideration. Fuel ethanol used primarily for transportation is an important market for Iowa corn. This market is increasingly tenuous, as US electric power from natural gas is starting to shift transportation away from other fuels (fossil, ethanol) (EIA, 2021). Another important consideration that our study did not incorporate is an increase in land area for native vegetation—this will be an important consideration for future land use planning in the state as there is strong evidence that a sustainable agricultural production landscape should include at least 20% native habitat to support water quality and biodiversity objectives but can also produce economic and social benefits through ecologically responsible grazing, hunting, native fruit and plant harvest, and recreation (Garibaldi et al., 2021).

Peri-urban producers do not plan a large increase in table food production in the near future

Our results indicate that PUA producers in the DM-MSA plan only small shifts in land use to grow table food in the next three to five years (0.2%). There was more willingness to support local table food production if leasing of land was included (1.3%). Producers across all counties were willing to lease land to table food producers although these increases were not adequate to meet the 50% local scenario, representing only 30% of the change needed. There are also more significant barriers to producing fruits and vegetables compared to extending current rotations to include small grains.

However, an assessment of agricultural land use changes in east-central Iowa based on 2001–2012 spatial data showed that corn production has continued to grow because of the tendency away from extended rotations, partially based on biofuel policies and high grain prices, with variability that points to multiple contributing factors (Ren, Campbell and Shao, 2016). Our findings were that PUA producers' plans were inconsistent by county, for example, Warren County producers' plans to grow more table food made up 71% of total planned increases. Further studies to understand differentiating characteristics that may increase or decrease producers' willingness to grow table foods could help to uncover key factors for producers under current conditions.

A study of producers in an eastern Iowa watershed found that corn and soybean producers were more willing to extend current annual rotations with small grains compared to adding perennial crops (e.g., most fruit crops) (Bitterman, Bennett and Secchi, 2019). The benefits of extending corn and soybean crop rotations with oat and alfalfa could lead to benefits for crop yield and soil health while reducing negative environmental impacts and requirements for agricultural inputs without a tradeoff in farm profitability (Baldwin-Kordick et al., 2022). Economic benefits of both long-term profitability and income stability have also been supported for integrated cattle and extended crop rotation farming systems in Iowa, despite the larger labor requirement (Poffenbarger et al., 2017). Integrating livestock into future food system scenarios could highlight opportunities for more producers to benefit from localized table food as well as animal feed production.

Many factors impact current and future local table food production

Our results did not highlight specific factors of concern for producers in the context of adding or increasing table food production. Instead, there are interconnected factors based on biophysical and sociopolitical realities in our study areas. Differences were also evident between those already growing table foods and those considering their addition. Current row crop producers ranked insurance in their top three most important factors, while specialty crop producers ranked land access in their top three most important factors. Both groups included processing and food safety regulations among their top three most important factors. Based on these results, it will be important to address factors in tandem to support table food production levels that provide a future 50% local diet scenario.

Processing was highlighted as important for both row crop and specialty crop producers. This is important in Iowa because there is currently limited access to local fruit and vegetable processing facilities. Consumers in the USA typically eat between 26 and

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32% of their fruits and vegetables in a processed form (USDA-ERS, 2016). Given the seasonal nature of agriculture in Iowa, processing could provide an important season extension and a more stable market for producers as well as more variety year-round for consumers. The Iowa legislature has recently passed several policies (including House File 857) to improve conditions for local meat processing and cold storage in the state (Iowa House of Representatives, 2021). More local processing opportunities for fruits and vegetables could also enable larger-scale production of these crops without increasing marketing burdens for producers.

Processing is only one step in a food value chain. To be successful, processing needs to be integrated with accessible local markets, particularly wholesale markets. Although direct-to-consumer markets in Iowa have decreased 11% over the past 15 years, direct-to-consumer outlets are still the main market used by 54% of Iowa horticulture producers (Enderton et al., 2017). A survey of local Iowa producers also found that lack of dependable markets, year-round product availability, and the ability to make price adjustment were of great importance to producers when considering marketing to local institutions and restaurants (Gregoire, Arendt and Strohbehn, 2005). Limited processing and marketing infrastructure is not unique to Iowa—a Pennsylvania study found that producers engaged in local and regional food systems also lacked technical infrastructure in processing and distribution to scale up their operations (Bloom and Hinrichs, 2011). Appropriately scaled processing and distribution facilities could enable new opportunities for regional small- and mid-scale producers to expand into growing wholesale markets (Duncan et al., 2018).

Food safety regulations are an important factor for producers with plans to expand into mid-scale fruit and vegetable production. The US Food and Drug Administration's Federal Food Safety Modernization Act (FSMA) is a policy approved in 2016 based on the average monetary value of produce sold between 2018 and 2020 (FDA, 2016). Farms with less than $25,000 in fruit and vegetable sales over the previous three-year period are not required to comply with FSMA best practices (Enderton et al., 2017). It can be costly to comply with these regulations. These costs along with the steep learning curve can incentivize producers to remain below this regulatory threshold (MacDonald, Korb and Hoppe, 2015). Providing assistance to producers to comply with FSMA, as well as business planning to support new mid-scale fruit and vegetable producers could enable more mid-scale table food production across the Corn Belt. Another policy factor important to row crop farmers was federally subsidized crop insurance. This insurance is critical to sustaining corn and soybean producers in bad years by mitigating risks due to low prices or low yields (Bitterman, Bennett and Secchi, 2019). Yet many small-scale diversified table food operations struggle with high costs and insufficient insurance access (Bekkerman, Belasco and Smith, 2019). One way to reduce risks for table food producers in the region would be shifting subsidy payments to pay for farm system ecosystem services (Liebman and Schulte, 2015). This shift would be most beneficial if university extension services and agencies administering federal loans for producers followed a similar pathway to reduce informational and financing barriers for emerging table food producers in the region by providing targeted support.

Row crop producers we surveyed did not rate land access as an important factor and ratings were mixed for specialty crop producers with a large proportion of both high (33%) and low (50%) ratings. Row crop producers owned an average of 93 ha of the 165 ha they operate, while specialty producers owned on average 50 ha of the 72 ha they operate. Thus, it is unsurprising that this factor was not flagged as important among producers, most of whom already own land. In Iowa, the average age of producers was 57 years in 2017, and land ownership continues to be an important barrier to young farmers and producers without land assets (USDA-NASS, 2019). Renting land for table food production is an alternative that some landowners in our study area indicated they are open to. However, high cost and short-term land leasing options increase risks for resource-limited producers and reduce the kinds of practices producers can justify adopting (Esquivel et al., 2021). For example, renters would not likely experience the long-term benefits of incorporating compost on land from a short-term lease. Zoning and event permits were not key factors for DM-MSA producers, although they are potentially critical for urban producers. Willingness to zone land and provide secure tenure for urban producers could improve affordability and support flexibility for storage and season-extension structures (Filippini, Mazzocchi and Corsi, 2019). Event permits could also improve local producer and consumer relationships, which are particularly important for PUA and urban producers selling to local markets.

Farm labor was most commonly rated as a moderately influential factor by row crop and specialty crop producers. Row crop producers may not consider this factor as they typically have large harvests, often with little additional labor from outside the farm operation. Table food production, on the other hand, is often labor intensive and mechanization can be prohibitively expensive. For table food production, access to skilled farm labor is critical and considering complex local and international workforce dynamics is necessary to create a socially sustainable food system (Cleveland, Carruth and Mazaroli, 2015). Conversely, working off-farm jobs is important for many farm operators in Iowa (Bitterman, Bennett and Secchi, 2019). As the number of full-time producers in Iowa continues to decline, this has important social implications especially for small and shrinking rural communities (Zarecor, Peters and Hamideh, 2021). Scaling up table food production to improve social, economic, and environmental benefits will require a balanced approach where skilled agricultural labor is effectively managed with appropriate technologies to balance economic viability for agribusinesses with social and economic wellbeing of laborers (Cleveland et al., 2015; Vieira et al., 2018). Increasing our understanding of this balance offers an important opportunity for future research in the context of the Corn Belt.

A future metropolitan food system scenario balancing economic, social, and environmental drivers

We created a visualization (Fig. 2) and analyzed factors that may affect a future food system scenario in the US Corn Belt centered on increasing production of table food (Fig. 4). The Iowa agricultural landscape has been simplifying for decades, with just two annual crops grown on the majority of land leading to increased reliance on fertilizers, pesticides, and fossil fuel inputs (Liebman and Schulte, 2015). Supporting diversification of agroecosystems through extended rotations and strip cropping is tied to improving ecosystem function and can enhance resilience, which is critical to address challenges such as global pandemics and climate change (Liebman and Schulte, 2015). Mid-scale table food production could be another way to improve diversification on

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farms and increase sustainability by protecting crop genetic diversity and in turn food security for the region (Esquinas-Alcázar, 2005; Esquivel et al., 2021). However, producers in Iowa perceive major barriers, especially for accessing markets which makes incorporating small grains into extended rotations difficult (Weisberger et al., 2021). Uncertainties about climate change and infrastructure are additional barriers for fruit and vegetable producers (Johnson and Morton, 2015). Future-oriented and participatory approaches that include producer perspectives could enable development of a shared vision for increasing local table food production in Iowa and the US Corn Belt (Fazey et al., 2020). Based on producer input, infrastructure as well as social and political support will also be important.

The lack of effective supply chain opportunities and infrastructure for small- and mid-scale producers in the region impacts multiple factors assessed in our study (e.g., processing, off-farm jobs, loan access). Enabling mid-scale table food production must include addressing structural barriers as farmers will struggle to address them independently (Weisberger et al., 2021). Values-based supply chains could enable regional food systems to balance the needs of US producers and consumers (Feenstra and Hardesty, 2016). Concerns about the usefulness of farmer's markets and not-for-profit or temporary grant-supported market infrastructure could also be slowing down the development of more long-term intermediated market channels for mid-scale producers to access (Dimitri and Gardner, 2019). In our study area, lack of a middle-scale infrastructure for processing, distributing, and marketing diverse table food products, along with a lack of technical support currently limit opportunities to diversify (Liebman and Schulte, 2015).

For DM-MSA producers, there is no simple fix or single path toward producing 50% of table food in our study area. Factors maintaining current production practices in the region are bolstered by strong and interconnected political, economic, and social forces. Successful regional supply chains would be aided by consumer desire to balance cost with social and environmental values in our study area (Feenstra and Hardesty, 2016). Regional food networks also have the potential to support food system resilience; however, policies that support unique regional variability across scales would be necessary for this approach to improve food security and sustainability (Duncan et al., 2018).

Conclusion

In the US Corn Belt, mid-scale production and diversification supported by policies and local consumers are critical economic, social, and environment drivers of a regional food system. Despite the small amount of land area needed to grow 50% of fruits, vegetables, and table food grains for the urban population of the Des Moines Metropolitan Area in 2050, a combination of factors creates a system of barriers that make it difficult to increase local table food production. Key factors limiting table food production include lack of skilled labor, political support, processing, supply-chain infrastructure, and viable pathways to long-term land lease and ownership. Further research focused on building mutually beneficial land lease arrangements for current landowners and table food producers could be important for peri-urban areas in the Corn Belt. Incorporating livestock production for local markets in future visualizations could support more diversified crop rotations and economic opportunities for producers in our study area. This mid-scale production scenario around urban centers could be useful for local and regional officials to inform future municipal food plans and policies that support diversified cropping systems, rural vitality, and food system resilience across the Corn Belt region. However, it is essential for decision makers to address producer barriers across governance scales if regional food systems are to be sustainable in the future.

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