Journal of Agriculture, Food Systems, and Community Development
ISSN: 2152-0801 online
https://foodsystemsjournal.org

Sustainability outcomes of the United States food system: A systematic review

C. B. Knox [a] * and Shelie A. Miller [b]
University of Michigan

Submitted December 1, 2020 / Revised February 19 and November 12, 2021, and March 28, 2022 / Accepted March 28, 2022 / Published online May 25, 2022

Citation: Knox, C. B., & Miller, S. A. (2022). Sustainability outcomes of the United States food system: A systematic review. *Journal of Agriculture, Food Systems, and Community Development, 11*(3), 259–289. https://doi.org/10.5304/jafscd.2022.113.010

Abstract
Food systems literature has shifted towards interdisciplinarity and the use of systems lenses but can still be disjointed and unconnected. To bring together disciplinary knowledge and establish a common understanding of food systems, we conducted a systematic review to inventory sustainability outcomes of the U.S. food system. The literature search returned 2,866 articles, which was reduced to 49, reviewed here. A qualitative content analysis process identified 93 outcomes. These were split across three main themes of environmental, socioeconomic, and health outcomes. This review also identified several trends in food systems literature, such as an underrepresentation of socio-economic outcomes and a lack of inclusion of social outcomes in natural science journals. The sustainability outcomes inventoried here may help to facilitate greater communication and collaboration in food systems research and situate current and future food systems studies within this inventory.

Keywords
Food Systems, Sustainability, Systematic Review, Sustainability Outcomes, Food Systems Literature, Food System Outcomes

Introduction
It is difficult to underestimate the complexity of the food system. A single meal consists of individual ingredients with pathways from farm to fork

[a] * *Corresponding author:* C. B. Knox, Ph.D. candidate, School for Environment and Sustainability, University of Michigan; 440 Church Street; Ann Arbor, MI 48109 USA; +1-812-219-9653; cbknox@umich.edu

[b] Shelie A. Miller, Director, Program in the Environment; Associate Professor, School for Environment and Sustainability, University of Michigan; Ann Arbor, MI, USA.

Disclosure
The authors declare that they received no financial support for this research from any entity and have no relevant conflicts of interest that relate to the research described in this paper.

that vary widely. Conceptualizations of food systems differ across disciplines and time, but recent definitions generally include the following: (1) processes or activities such as food production, processing, consumption, and disposal; (2) interactions among biogeophysical and human systems; and (3) environmental, socio-economic, and health outcomes (Béné et al., 2019a; Ericksen, 2008). Outcomes can be defined as the causal results of food system processes (Ericksen, 2008).

The term "food system" goes back several decades, but until more recently, most of the discussion was implicit or limited to a subsystem or a specific system element (Sobal et al., 1998). For example, agricultural and food security fields dominated early food systems literature and focused on topics such as production, distribution, consumption practices, or innovations that increased productivity and efficiency (Béné et al., 2019b; Reganold et al., 2011; Stephens et al., 2018). Much of the early conversation around sustainability focused on the environmental impacts of agriculture like soil erosion, climate change, or pollution (Béné et al., 2019b; Ericksen et al., 2009; Hallam et al., 1993; Hinrichs, 2012). Sustainability as a concept grew out of the two disconnected but parallel movements of environmental and social sustainability in the 1970s that critiqued capitalist economic growth (Purvis et al., 2019). The inclusion of health into the popularized, and criticized, "three pillars" or "three-legged stool" concept of social, economic, and environmental sustainability only began in the 1990s; it has gained prominence more recently and was accompanied by proponents of sustainable agriculture (Gillespie, 1995; Hancock, 1993; Purvis et al., 2019).

As an emerging field, writers of food systems literature aim to effectively incorporate multiple facets of sustainability through methods or lenses such as systems thinking and inter-/transdisciplinarity. However, a historical lack of interdisciplinarity in the food systems space, reflective of trends throughout scientific study, results in significant gaps in system understanding, theories, and methodologies (Béné et al., 2019a; Nelson et al., 2016a). For example, discussions of the impacts on health like income, social justice, and equity have become prevalent only more recently (Marmot, 2005; Solar & Irwin, 2006). Furthermore, much research that would fall within the food systems space (such as system aspects like agroecology or food science) retains a disciplinary focus and does not address the inherently interdisciplinary context of food systems (Béné et al., 2019a). These factors have resulted in food systems work that is fragmented and difficult to connect (Eakin et al., 2017; NRC, 2010;).

Food system scholars call for increasingly integrative and interdisciplinary research to fill the gaps by addressing the system's diverse, interacting elements and outcomes (Constance, 2010; Hinrichs, 2012; Nelson et al., 2016a). The authors of a literature review of food system drivers, defined in that review as processes that influence the food system durably and consistently, concluded that a collective understanding of food system elements and dynamics is underdeveloped and that establishing a common foundation of food system knowledge is important to better assist academics, experts, and decision-makers in the food systems space (Béné et al., 2019b). These gaps prompted the question: What are the prominent sustainability outcomes of the U.S. food system, and how does food systems literature address the diverse and interconnected issues?

Within the review, we provide a comprehensive inventory of recent scientific literature about how the U.S. food system results in sustainability outcomes. We identify, categorize, and calculate the frequency of sustainability outcomes of the U.S. food system that are reported in recent scientific literature to draw insights about interdisciplinarity and trends within food systems literature. Our goal is to advance food systems literature by compiling often disparate information about the sustainability outcomes and provide a holistic and accessible evaluation that could be used to inform or contextualize further food system work. For example, the inventory of outcomes could be the basis for developing interdisciplinary metrics for evaluating a community's food system. While information and shared understanding is only one aspect of successful collaboration and problem-solving, it is an initial step that is needed in the sustainable food systems space.

Methods

Reviewing the Literature

We use two main processes: (1) a systematic review to ensure a holistic information base, and (2) qualitative hand-coding to identify outcomes within the texts. The methods used were adapted from standard systematic review methodologies for formulating and conducting a search (Tsafnat et al., 2014; Uman, 2011). We developed search terms, performed the search, removed duplicate texts, and screened the remaining abstracts and full texts based on inclusion and exclusion criteria. Content analysis methods like qualitative hand-coding are effective ways to identify concepts in texts and are a common approach to revealing trends across and within bodies of literature (Berelson, 1952; Hsieh & Shannon, 2005; Weber, 1990). Hand-coding is when a researcher manually reviews data by identifying concepts and assigning a code, which is very time-intensive but results in more inclusive coding that can capture meaning that would be missed by computer programs (Grimmer & Stewart, 2013; Nelson et al., 2021; Weber, 1990). For more detailed information on the systematic review process and rationale for choosing these methodologies, see Appendix A.

Coding the Literature

We began the analysis process by copying the exact terminology or phrasing used in the texts to describe or identify sustainability outcomes to a Microsoft Excel file. We then simplified the exact phrasing into more abstract or generalized coding terms. For example, one text may discuss "pathogen contamination of food" while another uses "foodborne pathogen," both of which communicate the same outcome and would be grouped under the term "pathogen contamination of food." The code reduction and organization process sorted and refined the initial 191 outcomes into three overarching themes: environmental, socioeconomic, and health outcomes. In each theme, outcomes were organized into categories and subcategories.

Organization of Outcomes

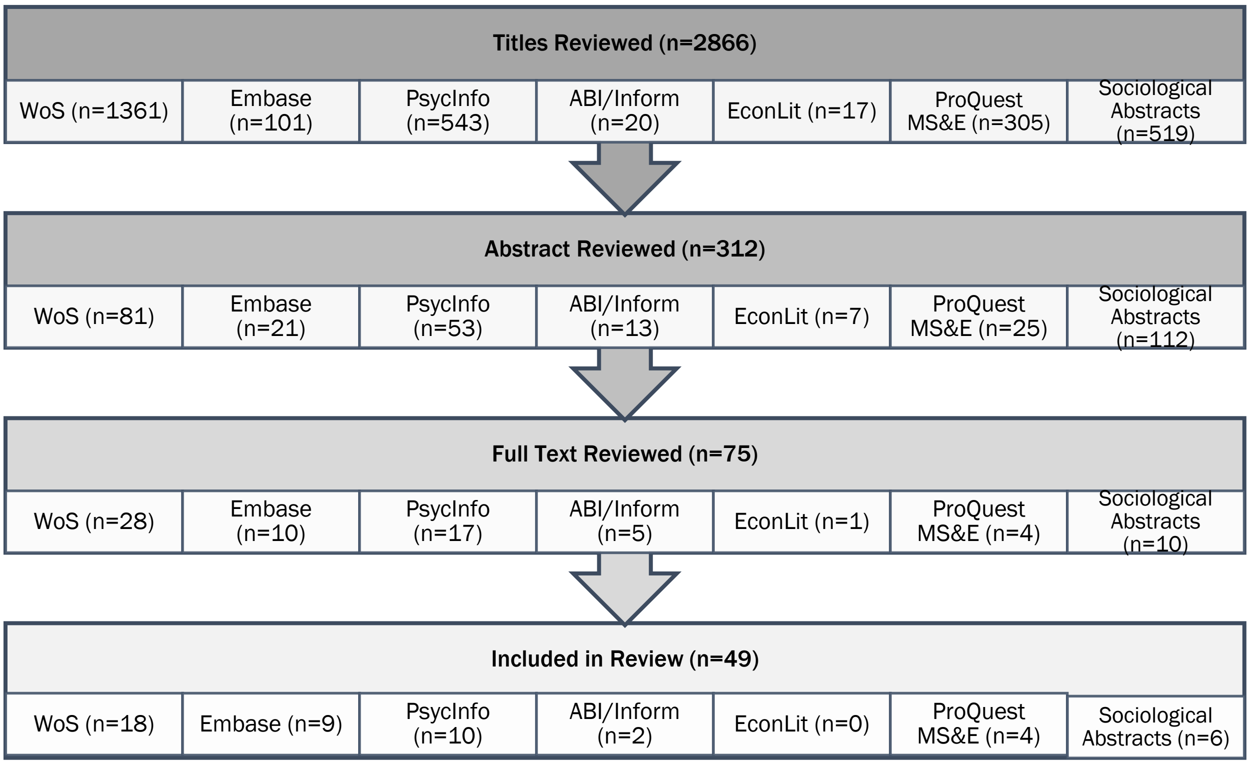
The organization of outcomes into themes, categories, and subcategories was based on common groupings or connections that emerged from the source literature. Thus, the organizational method used a 'grounded theory' approach, as the clustering of outcomes was developed from the data rather than fitting concepts into a preexisting or preestablished scheme (Glaser & Strauss, 1967). A primary goal of the organizational process was ensuring that each outcome could only be coded into one category (i.e., mutual exclusivity) (Weber, 1990). The final organization of codes and outcomes represents an inventory of the major themes and prominence of outcomes based on how often they occur in the reviewed literature. Expanding or excluding outcome categories could deepen or streamline the process depending on the field or focus of work.

Results

The database search resulted in the collection of 2,866 articles, which was reduced to 75 based on the titles and abstracts using the remaining inclusion and exclusion criteria. At the full text review stage, 26 additional articles were excluded (see Figure 1 and Appendix D for a full list of reviewed documents). Common reasons for exclusion were focusing at the wrong scope (*n*=7) or on one specific sustainability issue (*n*=8). Other reasons include papers focusing on methodologies or recommending metrics (*n*=4) or papers that simply did not address the research question of this review (n=3). The publishing dates ranged from 1993 to 2019, with the majority published after 2013.

The initial round of coding resulted in 1,074 instances of coding, which identified 191 outcomes. In this first step, the articles had an average of 16.7 outcomes, with a range of three to 56 outcomes. The prevalence of outcomes also varied, with greenhouse gas emissions and water quality being present in 22 articles, while 51 of the outcomes were only in one article. This list of outcomes was then narrowed by compiling redundant codes and simplifying longer phrases. For example, "unsafe working conditions" and "dangerous working conditions" were combined. Each outcome was then organized into the hierarchical structure of categories, subcategories, and specific outcomes (see Table 1).

Figure 1. Flow Chart of Articles Resulting from Systematic Review Process



This second step resulted in the organization of 93 outcomes into three main themes: environmental, socio-economic, and human health outcomes (see Figure 2). The average number of codes per outcome is 10.24, but there was variation among the themes. The number of articles per outcome, or density of codes, indicates how prevalent an outcome was in the literature. The environmental outcomes theme had the highest average density of codes per outcome with 11.8, with the health outcomes and socio-environmental outcomes themes having 10.3 and 8.75 codes per outcome, respectively. A detailed explanation of each outcome identified, summarized from the reviewed literature, is in Appendix B. This breakdown can be useful as an interdisciplinary introduction to the diversity of sustainability outcomes of the food system. For raw coding results, see Appendix C.

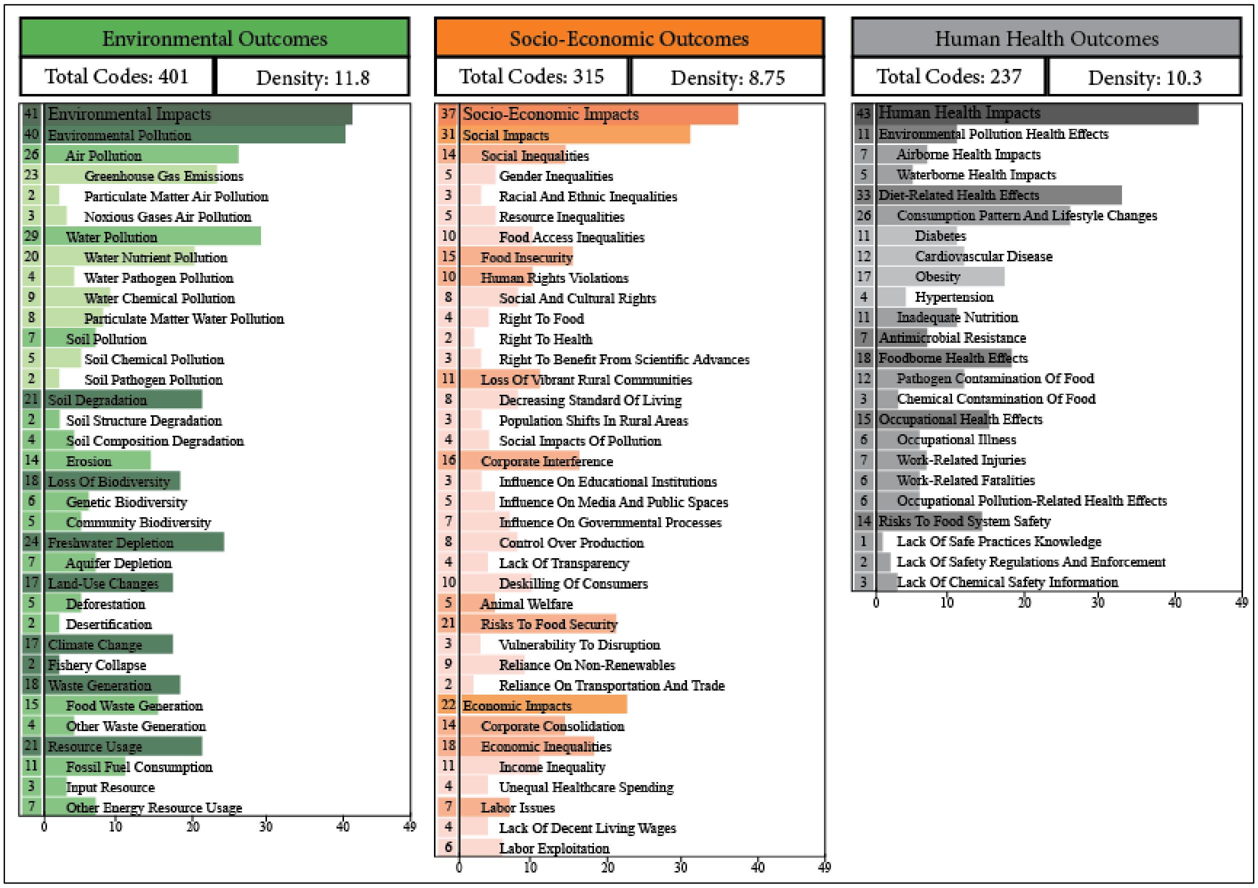
Thematic saturation occurred through 16 articles, with 33 contributing no novel outcomes. Of the selected articles, 59% identified at least one sustainability outcome in all three themes of environmental, socio-economic, and health outcomes, 29% identified two, and the remaining 12% identified only one. No article identified all 18 major categories; the articles ranged from 2 to 15 categories, with an average of 6.7 categories per document. Similarly, of a total possible 41 subcategories, the number of identifications ranged from 24 outcomes to one outcome and averaged 7.6.

Table 1. Outcome Organization Structure with Definitions and Examples

Definitions	Examples
Theme: Highest level of organization, contains the three main themes	Environmental Outcomes
Category: Concepts generally encompass many outcomes or cannot be sorted into another category	Environmental Pollution
Subcategory: Used when helpful to group similar outcomes within categories	Air Pollution
Specific Outcome: All outcomes within subcategories	Greenhouse Gas Emissions

Figure 2. Organization of Outcomes Identified by Systematic Review, Including Number of Coding Instances

Coding frequency is represented as a bar graph, with the hue of each bar representing the organizational structure (i.e., the darkest color is the theme, and the lightest is the specific outcome). Indentation also represents the structure, with the furthest indented being the specific outcomes.



Finally, we categorized each article as published in a natural science, social science, health, or interdisciplinary journal. While the discipline of the journal is not a perfect match for the disciplinary background of the authors or methods, this proxy was used because, ostensibly, the content of the articles needed to fit the purpose and scope of the journal, and journals contribute to the body of literature of the different fields. For both the environmental and socio-economic outcomes theme, the corresponding discipline (natural science and social science) had the highest percentage of identification. While social science did identify environmental outcomes less often than the other disciplines (60%), only 43% of the natural science journal articles identified an outcome in the socio-economic theme (see Figure 3).

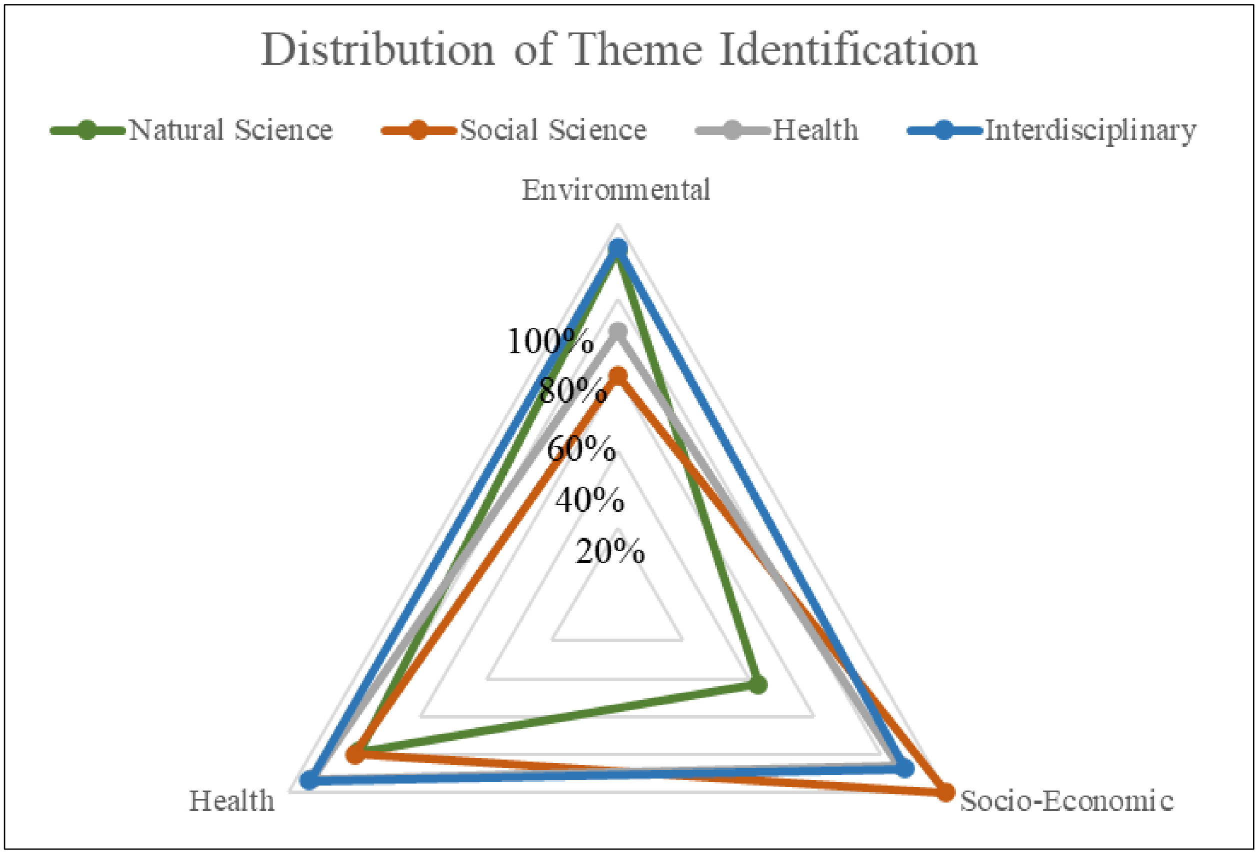
Discussion

High-Level Trends

No single article identified all categories, much less all 93 sustainability outcomes

These results justify, in part, this systematic review's goal of compiling disconnected information in food systems literature because no single article identified all categories or subcategories of outcomes. The systematic review and coding process also enabled the creation of a qualitative system map based on the connections drawn by the articles included in the systematic review (see Figure 4).

Figure 3. Percent of Papers in Each Discipline Category Identifying at Least One Outcome Within the Three Themes



Lack of disciplinary overlap between natural sciences and social sciences
By organizing the articles into disciplines, we were able to analyze trends within and between different disciplines. While the goal of the search terms was to return articles that used systems lenses and discussed the food system interdisciplinarity, the articles from social science journals included in this review discussed environmental outcomes to a higher degree than the natural science counterparts discussed socio-economic outcomes (see Figure 4). The distribution of theme identification by journal discipline also shows the success of interdisciplinary journals at identifying outcomes across the sustainability spectrum. This difference in the overlap between disciplines is prevalent throughout food systems literature, partially by nature of the disciplinary focuses and the dominant narratives that shaped early food systems work.

However, almost 60% of the articles included a sustainability outcome within all three themes, and almost every article published in an interdisciplinary journal included outcomes across the themes. This result speaks to the success and strength of current interdisciplinary work in the food systems space. While a common knowledge base is still developing for the field, research can and is connecting diverse outcomes using innovative methodologies and partnerships to understand complex socio-environmental systems.

High and low instances of coding
High or low instances of coding represent the relative prominence of outcomes within the surveyed work. The sample of articles does not encompass the entire field of food systems literature or work on these outcomes outside of the food systems space, so it does not imply that these concepts are understudied. For example, there is an entire body of work on animal welfare and ethics, but the outcome is comparatively less prevalent than issues such as environmental pollution or diet-related

health effects. However, the implication of lower or higher coding instances can speak to the pervasiveness or the relative importance placed on these outcomes in food systems literature.

System map

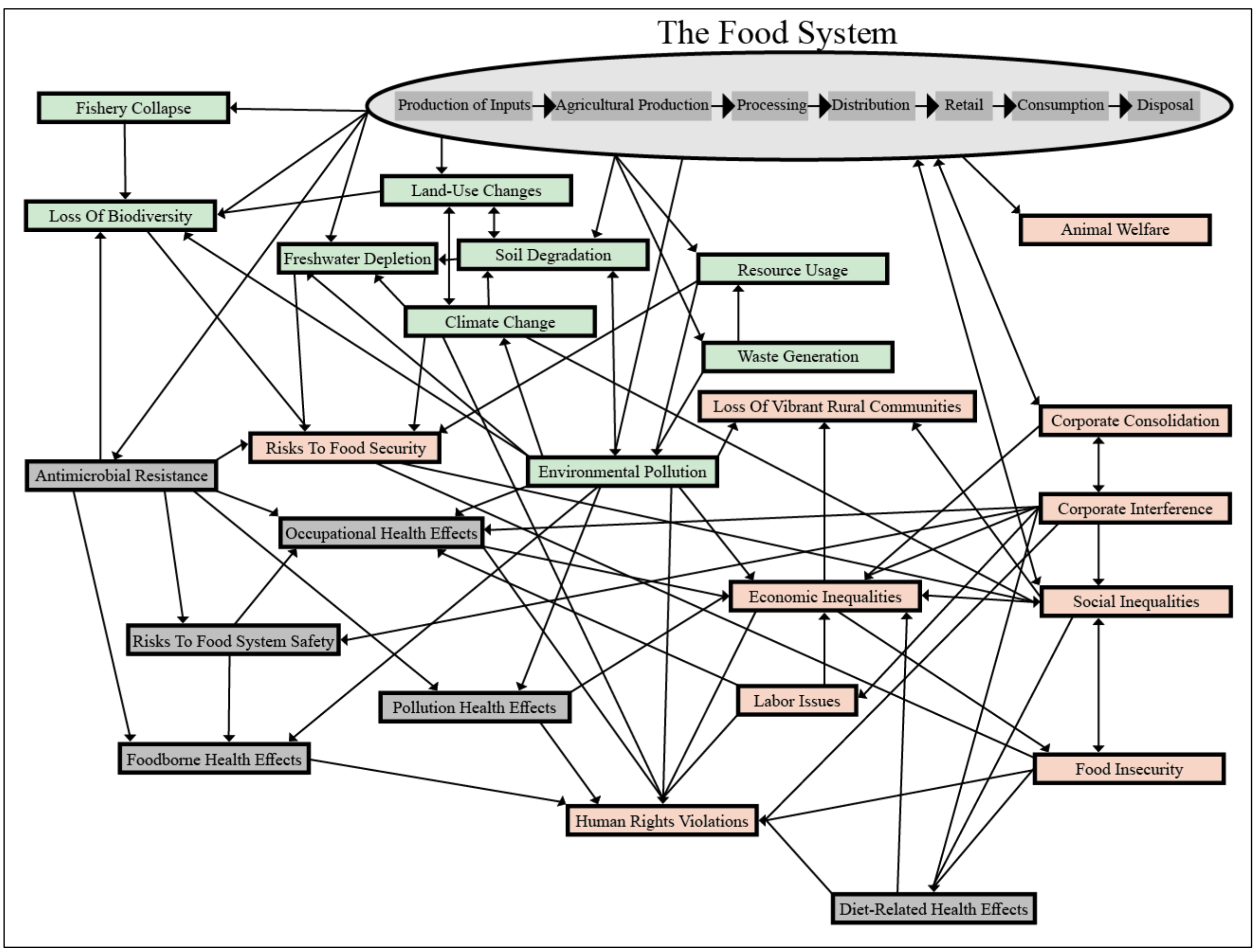
The relationships among outcomes were qualitatively assessed based on the connections described by the articles included in the systematic review. Causal loop diagramming (CLD) from qualitative data such as interview transcripts or text documents is one way of presenting results (Yearworth & White, 2013). The consolidation of diverse and complex information into a system map necessitates balancing fine details and readability and/or usability. The outcomes included in this map are the categories and subcategories, when appropriate, developed through this review. We organized the diagram specifically to be approachable, comprehensive, and useful for continuing conversations about food system dynamics (see Figure 5). As this is not a review of system dynamics, the connections were not quantitatively assessed, and important external relationships or trade-offs associated with the food system are outside the scope of this paper.

Limitations

A key limitation of this review is the selection of hand-coding as the data collection process. During the coding process, we inferred categories based on qualitative assumptions of similar meanings or con-

Figure 4. Sustainability Outcomes Map of the U.S. Food System

Connections are based on the reviewed literature, with arrows representing the direction of outcome. The colors represent the organizational structure; green is environmental outcomes, grey is health outcomes, and orange is socio-economic outcomes.



notations among concepts, which introduces limitations such as biases from personal lenses and reduced processing capabilities but enables the collection of more rich and complete data (Weber, 1990). However, these risks were addressed by generating the outcomes and organizational structure from the literature. The hand-coding process is also very time intensive, so several decisions, such as limiting the review to peer-reviewed articles and a limited list of databases, were made to focus on articles that would efficiently answer the research question. Sources outside of published, peer-reviewed articles likely use different terminology to discuss outcomes or contain more specialized outcomes that are relevant to specific fields, places, or subsystems. Finally, papers that would fit the inclusion criteria were likely published after the review was conducted. These limitations are managed through achieving data saturation, as more sustainability outcomes are unlikely to be identified by including more sources such as grey literature and studies from 2020/21. It is important to note that this review does not encompass the possibility of new outcomes that are connected to COVID-19.

A final limitation is the high-level view of the U.S. food system. Purposely taking a national lens and discussing a topic at a high level of abstraction is ill-suited to encompass all geographic and temporal heterogeneities in the food system. As such, the inventory of sustainability outcomes and connections drawn between them does not reflect all food systems within the U.S. but can be beneficial as a starting point or framework for further work to contextualize a smaller food system with specific actors, decision-makers, and system elements and behaviors. The corollary limitation of focusing on the U.S. is that the review did not include outcomes associated with the globalized food system. Some examples would be deforestation in other countries because of demand in the U.S. or increased water stress in the U.S. due to exported goods, but this was outside the scope of the systematic review and should be included in future related work.

Conclusions

This review identified 93 sustainability outcomes that represent the diversity of environments, workers, communities, and consumers involved in the food system. Sustainability outcomes influence each other and are deeply connected to the physical food system and social, environmental, and economic systems. As evidenced by the relative frequencies of coding in this review, some outcomes are more prevalent than others in the literature, but that does not imply that these are less significant. The goal of our review was to inventory the sustainability outcomes relevant at the national scale. While more depth or details could be added based on smaller-scale food systems (for example, specific chemical pollutants, pathogens, or health outcomes relevant to a system or locality), each would most likely fall under one of the established outcomes or categories.

Interdisciplinary research has become more prominent in the last few decades through academic institutionalization of interdisciplinarity and more focus on and funding for inter-/transdisciplinary food systems work, but disciplines can remain siloed, and information is still disparate (Hinrichs, 2012). This is demonstrated by the differences in outcome identification density across themes, as 12% of system-level articles only identified outcomes within one theme, and no article identified all 18 categories. This trend is certainly not unique to food systems work; much research has disciplinary foci. Food systems literature is also a relatively new, developing field, and through this review, we aim to contribute to building a common understanding and interdisciplinarity through the compilation and organization of sustainability outcomes and the discussion of the prevalence of different outcomes in the surveyed literature.

There are several ways in which this review could be used in future research or food systems work. Not all future food systems studies need to consider all the outcomes inventoried by this review, as many will be irrelevant or outside the scope of research projects or specific research questions. However, the holistic inventory can still be useful as a basis for the purposeful selection of what is or is not relevant to a project. The full list of outcomes can serve as an extensive list of which outcomes or categories could be considered, which may be out of the traditional disciplinary scope. A common example would be an agricultural evaluation considering not only the environmental outcome of a pollutant but also the effects on community health. Consulting the full inventory of outcomes may provide additional criteria to assess that would be potentially less intuitive or prevalent.

The inventoried sustainability outcomes can also be used to contextualize work within smaller scoped food systems, as it can provide a broad variety of outcomes upon which to have conversations about, for example, the outcomes of policies or management choices. Other possible uses include as the basis for an assessment tool to evaluate the current state of outcomes and track change over time or identify areas for improvement, as a benchmark of which outcomes have been identified as of 2019 (potentially relevant to studying the food system during or after COVID-19), or as a set of possible evaluation criteria for building a decision support tool based on stakeholder concerns.

Building a holistic understanding of the food systems field is an important first step to more effective and efficient work through directly incorporating inter-/multidisciplinary knowledge and skills and acknowledging and addressing the connections of disciplinary topics to other sustainability issues. One benefit of interdisciplinary work would be the ability to coordinate efforts to address multiple sustainability issues concurrently, which can result in efficiencies through goal alignment, selecting a portfolio of interventions, the creation of diverse alliances, and the ability to implement changes at multiple levels (Barnhill et al., 2018; Ruben et al., 2019). The inventory generated by this review can be used as a starting point for continued work in food systems and to contextualize changes. The complexity, interdisciplinarity, and scope of the food system tie directly to the extensive sustainability outcomes, which makes sustainable food systems a significant opportunity to impact the well-being of the environment and people in the United States.

Acknowledgments

We would like to thank the anonymous JAFSCD reviewers for their insightful comments.

References

Allum, N., Sturgis, P., Tabourazi, D., & Brunton-Smith, I. (2008). Science knowledge and attitudes across cultures: A meta-analysis. *Public Understanding of Science, 17*(1), 35–54. https://doi.org/10.1177/0963662506070159

Anderson, M. D. (2008). Rights-based food systems and the goals of food systems reform. *Agriculture and Human Values, 25*(4), 593–608. https://doi.org/10.1007/s10460-008-9151-z

Anderson, M. D. (2015). Roles of rural areas in sustainable food system transformations. *Development, 58*(2–3), 256–262. https://doi.org/10.1057/s41301-016-0003-7

Anderson, M. D., & Cook, J. T. (1999). Community food security: Practice in need of theory? *Agriculture and Human Values, 16*(2), 141–150. https://doi.org/10.1023/A:1007580809588

Bardenhagen, C. J., Pinard, C. A., Pirog, R., & Yaroch, A. L. (2017). Characterizing rural food access in remote areas. *Journal of Community Health, 42*(5), 1008–1019. https://doi.org/10.1007/s10900-017-0348-1

Barnhill, A., Palmer, A., Weston, C. M., Brownell, K. D., Clancy, K., Economos, C. D., Gittelsohn, J., Hammond, R. A., Kumanyika, S., & Bennett, W. L. (2018). Grappling with complex food systems to reduce obesity: A US public health challenge. *Public Health Reports, 133*(Supplement 1), 44S–53S. https://doi.org/10.1177/0033354918802793

Béné, C., Oosterveer, P., Lamotte, L., Brouwer, I. D., de Haan, S., Prager, S. D., Talsma, E. F., & Khoury, C. K. (2019a). When food systems meet sustainability—Current narratives and implications for actions. *World Development, 113*, 116–130. https://doi.org/10.1016/j.worlddev.2018.08.011

Béné, C., Prager, S. D., Achicanoy, H. A. E., Alvarez Toro, P., Lamotte, L., Bonilla Cedrez, C., & Mapes, B. R. (2019b). Understanding food systems drivers: A critical review of the literature. *Global Food Security, 23*, 149–159. https://doi.org/10.1016/j.gfs.2019.04.009

Berelson, B. (1952). *Content analysis in communication research*. Free Press.

Blair, D., & Sobal, J. (2006). Luxus consumption: Wasting food resources through overeating. *Agriculture and Human Values, 23*(1), 63–74. https://doi.org/10.1007/s10460-004-5869-4

Cachelin, A., Ivkovich, L., Jensen, P., & Neild, M. (2019). Leveraging foodways for health and justice. *Local Environment, 24*(5), 417–427. https://doi.org/10.1080/13549839.2019.1585771

Chapman, B., & Gunter, C. (2018). Local food systems food safety concerns. In S. Thakur & K. E. Kniel (Eds.), *Preharvest food safety* (pp. 249–260). ASM Press. https://doi.org/10.1128/9781555819644.ch13

Collier, D., & Mahoney, J. (1996). Insights and pitfalls: Selection bias in qualitative research. *World Politics*, *49*(1), 56–91. https://doi.org/10.1353/wp.1996.0023

Conrad, Z., Niles, M. T., Neher, D. A., Roy, E. D., Tichenor, N. E., & Jahns, L. (2018). Relationship between food waste, diet quality, and environmental sustainability. *PLoS ONE, 13*(4), Article e0195405. https://doi.org/10.1371/journal.pone.0195405

Constance, D. H. (2010). Sustainable agriculture in the United States: A critical examination of a contested process. *Sustainability, 2*(1), 48–72. https://doi.org/10.3390/su2010048

Eakin, H., Connors, J. P., Wharton, C., Bertmann, F., Xiong, A., & Stoltzfus, J. (2017). Identifying attributes of food system sustainability: Emerging themes and consensus. *Agriculture and Human Values, 34*(3), 757–773. https://doi.org/10.1007/s10460-016-9754-8

Elmes, M. B. (2018). Economic inequality, food insecurity, and the erosion of equality of capabilities in the United States. *Business & Society, 57*(6), 1045–1074. https://doi.org/10.1177/0007650316676238

Ericksen, P. J. (2008). Conceptualizing food systems for global environmental change research. *Global Environmental Change, 18*(1), 234–245. https://doi.org/10.1016/j.gloenvcha.2007.09.002

Ericksen, P. J., Ingram, J. S. I., & Liverman, D. M. (2009). Food security and global environmental change: Emerging challenges. *Environmental Science & Policy, 12(4),* 373–377. https://doi.org/10.1016/j.envsci.2009.04.007

Feenstra, G., & Ohmart, J. (2012). The evolution of the school food and farm to school movement in the United States: Connecting childhood health, farms, and communities. *Childhood Obesity, 8*(4), 280–289. https://doi.org/10.1089/chi.2012.0023

Finley, J. W., Dimick, D., Marshall, E., Nelson, G. C., Mein, J. R., & Gustafson, D. I. (2017). Nutritional sustainability: Aligning priorities in nutrition and public health with agricultural production. *Advances in Nutrition, 8*(5), 780–788. https://doi.org/10.3945/an.116.013995

Fraser, A. M., & Simmons, O. D. (2017). Food safety education: training farm workers in the US fresh produce sector. In R. Bhat (Ed.), *Sustainability challenges in the agrofood sector* (pp. 643–659). John Wiley & Sons. https://doi.org/10.1002/9781119072737.ch27

Garnett, T. (2011). Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? *Food policy, 36*(Supplement 1), S23–S32. https://doi.org/10.1016/j.foodpol.2010.10.010

Gelting, R. J., & Baloch, M. (2013). A systems analysis of irrigation water quality in environmental assessments related to foodborne outbreaks. *Aquatic Procedia*, *1*(2013), 130–137, https://doi.org/10.1016/j.aqpro.2013.07.011

Gephart, J. A., Troell, M., Henriksson, P. J. G., Beveridge, M. C. M., Verdegem, M., Metian, M., Mateos, L. D., & Deutsch, L. (2017). The 'seafood gap' in the food-water nexus literature—issues surrounding freshwater use in seafood production chains. *Advances in Water Resources, 110*, 505–514. https://doi.org/10.1016/j.advwatres.2017.03.025

Gillespie, G. W. (1995). Sustainable agriculture and prospects for rural community development in the United States. *Research in Rural Sociology and Development, 6,* 167–191.

Gilmore, R. (2004). US food safety under siege? *Nature Biotechnology, 22*(12), 1503–1505. https://doi.org/10.1038/nbt1204-1503

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Aldine. https://doi.org/10.1097/00006199-196807000-00014

Grimmer, J., & Stewart, B. M. (2013). Text as data: The promise and pitfalls of automatic content analysis methods for political texts. *Political Analysis*, *21*(3), 267–297. https://doi.org/10.1093/pan/mps028

Gruen, R. L., Elliott, J. H., Nolan, M. L., Lawton, P. D., Parkhill, A., McLaren, C. J., & Lavis, J. N. (2008). Sustainability science: An integrated approach for health-programme planning. *The Lancet, 372*(9649), 1579–1589. https://doi.org/10.1016/S0140-6736(08)61659-1

Guest, G., Bunce, A., & Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field Methods, 18*(1), 59–82. https://doi.org/10.1177/1525822X05279903

Guo, L. B., & Gifford, R. M. (2002). Soil carbon stocks and land use change: A meta analysis. *Global Change Biology, 8*(4), 345–360. https://doi.org/10.1046/j.1354-1013.2002.00486.x

Hall, K. D., Guo, J., Dore, M., & Chow, C. C. (2009). The Progressive increase of food waste in America and its environmental impact. *PLoS ONE*, *4*(11), Article e7940. https://doi.org/10.1371/journal.pone.0007940

Hallam, A., Dibooglu, S., & Tweeten, L. (1993). Sustainable food and agricultural policies: A U.S. perspective. In L. Tweeten, C. L. Dishon, W. S. Chern, N. Imamura & M. Morishima (Eds.), *Japanese and American agriculture: Tradition and progress in conflict* (pp. 97–116). Westview Press.

Hancock, T. (1993). Health, human development and the community ecosystem: Three ecological models. *Health Promotion International, 8*(1), 41–47. https://doi.org/10.1093/heapro/8.1.41

Heller, M. C., & Keoleian, G. A. (2003). Assessing the sustainability of the US food system: A life cycle perspective. *Agricultural Systems, 76*(3), 1007–1041. https://doi.org/10.1016/S0308-521X(02)00027-6

Hickey, M. E., & Ozbay, G. (2014). Food waste in the United States: A contributing factor toward environmental instability. *Frontiers in Environmental Science, 2,* Article 51. https://doi.org/10.3389/fenvs.2014.00051

Hinrichs, C. C. (2012). Conceptualizing and creating sustainable food systems: How interdisciplinarity can help. In A. Blay-Palmer (Ed.), *Imagining sustainable food systems: Theory and practice* (pp. 17–36). Ashgate. https://doi.org/10.4324/9781315587905-2

Hinrichs, C. C., & Welsh, R. (2003). The effects of the industrialization of US livestock agriculture on promoting sustainable production practices. *Agriculture and Human Values, 20*(2), 125–141. https://doi.org/10.1023/A:1024061425531

Hoetzel, M. J. (2014). Improving farm animal welfare: Is evolution or revolution needed in production systems? In M. C. Appleby, D. M. Weary, & P. Sandøe (Eds.), *Dilemmas in animal welfare* (pp. 67–84). CAB eBooks. https://doi.org/10.1079/9781780642161.0067

Horst, M., & Marion, A. (2019). Racial, ethnic and gender inequities in farmland ownership and farming in the U.S. *Agriculture and Human Values, 36*(1), 1–16. https://doi.org/10.1007/s10460-018-9883-3

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research, 15*(9), 1277–1288. https://doi.org/10.1177/1049732305276687

Jaffe, J., & Gertler, M. (2006). Victual vicissitudes: Consumer deskilling and the (gendered) transformation of food systems. *Agriculture and Human Values, 23*(2), 143–162. https://doi.org/10.1007/s10460-005-6098-1

Johnston, J. L., Fanzo, J. C., & Cogill, B. (2014). Understanding sustainable diets: A descriptive analysis of the determinants and processes that influence diets and their impact on health, food security, and environmental sustainability. *Advances in Nutrition, 5*(4), 418–429. https://doi.org/10.3945/an.113.005553

Jones, P. & Bhatia, R. (2011). Supporting equitable food systems through food assistance at farmers' markets. *American Journal of Public Health, 101*(5), 781–783. https://doi.org/10.2105/AJPH.2010.300021

Kearney, J. (2010). Food consumption trends and drivers. *Philosophical Transactions of the Royal Society B: Biological Sciences, 365*(1554), 2793–2807. https://doi.org/10.1098/rstb.2010.0149

Koc, M., & Dahlberg, K. A. (1999). The restructuring of food systems: Trends, research, and policy issues. *Agriculture and Human Values, 16*(2), 109–116. https://doi.org/10.1023/A:1007541226426

Kocher, M., & Kelly, J. A. (2015). Food Systems citation analysis: Trends in an emerging interdisciplinary field. *Agricultural Information Worldwide, 7,* 10–16. http://hdl.handle.net/11299/177216

Lal, R. (2007). Soil science and the carbon civilization. *Soil Science Society of America Journal, 71*(5), 1425–1437. https://doi.org/10.2136/sssaj2007.0001

Lathers, C. M. (2001). Role of veterinary medicine in public health: Antibiotic use in food animals and humans and the effect on evolution of antibacterial resistance. *Journal of Clinical Pharmacology, 41*(6), 595–599. https://doi.org/10.1177/00912700122010474

Libby, L. W. (1993). The natural-resource limits of United-States agriculture. *Journal of Soil and Water Conservation, 48*(4), 289–294. https://www.jswconline.org/content/48/4/289

Lo, J., & Delwiche, A. (2016). The good food purchasing policy: A tool to intertwine worker justice with a sustainable food system. *Journal of Agriculture, Food Systems, and Community Development, 6*(2), 185–194. https://doi.org/10.5304/jafscd.2016.062.016

MacDonald, J. M., Ollinger, M., Nelson, K. E., & Handy, C. R. (1999). *Consolidation in US meatpacking* (No. AER-785). U.S. Department of Agriculture Economic Research Service. https://www.ers.usda.gov/publications/pub-details/?pubid=41120

Maffini, M. V., Neltner, T. G., & Vogel, S. (2017). We are what we eat: Regulatory gaps in the United States that put our health at risk. *PLoS BIOLOGY, 15*(12), e2003578–e2003578. https://doi.org/10.1371/journal.pbio.2003578

Marmot, M. (2005). Social determinants of health inequalities. *The Lancet, 365*(9464), 1099–1104. https://doi.org/10.1016/S0140-6736(05)74234-3

McInnes, A., & Mount, P. (2017). Actualizing sustainable food systems. In A. Winson & M. Koç (Eds.), *Critical perspectives in food studies* (Second edition ed.) (pp. 332–347). Oxford University Press.

Meijer, M., Röhl, J., Bloomfield, K., & Grittner, U. (2012). Do neighborhoods affect individual mortality? A systematic review and meta-analysis of multilevel studies. *Social Science & Medicine, 74*(8), 1204–1212. https://doi.org/10.1016/j.socscimed.2011.11.034

Merrigan, K., Griffin, T., Wilde, P., Robien, K., Goldberg, J., & Dietz, W. (2015). Designing a sustainable diet. *Science, 350*(6257), 165–166. https://doi.org/10.1126/science.aab2031

Mohareb, E. A., Heller, M. C., & Guthrie, P. M. (2018). Cities' role in mitigating United States food system greenhouse gas emissions. *Environmental Science & Technology, 52*(10), 5545–5554. https://doi.org/10.1021/acs.est.7b02600

Morawicki, R. O., & Díaz González, D. J. (2018). Food sustainability in the context of human behavior. *The Yale Journal of Biology and Medicine, 91*(2), 191–196. PMCID: http://www.ncbi.nlm.nih.gov/pmc/articles/pmc6020726/

Morton, S., Berg, A., Levit, L., & Eden, J. (2011). *Finding what works in health care: Standards for systematic reviews*. National Academies Press.

National Research Council [NRC]. (2010). *Toward sustainable agricultural systems in the 21st century*. The National Academics Press. https://doi.org/10.17226/12832

Neff, R. A., Merrigan, K., & Wallinga, D. (2015). A food systems approach to healthy food And agriculture policy. *Health Affairs, 34*(11), 1908–1915. https://doi.org/10.1377/hlthaff.2015.0926

Nelson, L. K., Burk, D., Knudsen, M., & McCall, L. (2021). The future of coding: A comparison of hand-coding and three types of computer-assisted text analysis methods. *Sociological Methods & Research*, *50*(1), 202–237. https://doi.org/10.1177/0049124118769114

Nelson, M., Zak, K., Davine, T., & Pau, S. (2016a). Climate change and food systems research: Current trends and future directions. *Geography Compass, 10*(10), 414–428. https://doi.org/10.1111/gec3.12281

Nelson, M. E., Hamm, M. W., Hu, F. B., Abrams, S. A., & Griffin, T. S. (2016b). Alignment of healthy dietary patterns and environmental sustainability: A systematic review. *Advances in Nutrition, 7*(6), 1005–1025. https://doi.org/10.3945/an.116.012567

Newman, K. L., Leon, J. S., & Newman, L. S. (2015). Estimating occupational illness, injury, and mortality in food production in the United States A farm-to-table analysis. *Journal of Occupational and Environmental Medicine, 57*(7), 718–725. https://doi.org/10.1097/JOM.0000000000000476

Osbaldiston, R., & Schott, J. P. (2012). Environmental sustainability and behavioral science: Meta-analysis of proenvironmental behavior experiments. *Environment and Behavior, 44*(2), 257–299. https://doi.org/10.1177/0013916511402673

Pelletier, N., Audsley, E., Brodt, S., Garnett, T., Henriksson, P., Kendall, A., Kramer, K. J., Murphy, D., Nemecek, T., & Troell, M. (2011). Energy intensity of agriculture and food systems. In A. Gadgil & D. M. Liverman (Eds.), *Annual Review of Environment and Resources, Vol. 36* (pp. 223–246). https://doi.org/10.1146/annurev-environ-081710-161014

Pilgeram, R. (2011). "The only thing that isn't sustainable . . . is the farmer": Social sustainability and the politics of class among Pacific Northwest farmers engaged in sustainable farming. *Rural Sociology, 76*(3), 375–393. https://doi.org/10.1111/j.1549-0831.2011.00051.x

Purvis, B., Mao, Y., & Robinson, D. (2019). Three pillars of sustainability: In search of conceptual origins. *Sustainability Science, 14*(3), 681–695. https://doi.org/10.1007/s11625-018-0627-5

Reganold, J. P., Jackson-Smith, D., Batie, S. S., Harwood, R. R., Kornegay, J. L., Bucks, D., Flora, C. B., Hanson, J. C., Jury, W. A., Meyer, D., Schumacher, A., Sehmsdorf, H., Shennan, C., Thrupp, A. A., & Willis, P. (2011). Transforming US agriculture. *Science, 332*(6030), 670–671. https://doi.org/10.1126/science.1202462

Rose, D., Heller, M. C., & Roberto, C. A. (2019). Position of the society for nutrition education and behavior: The importance of including environmental sustainability in dietary guidance. *Journal of Nutrition Education and Behavior, 51*(1), 3–15. https://doi.org/10.1016/j.jneb.2018.07.006

Rossi, J., & Garner, S. A. (2014). Industrial farm animal production: A comprehensive moral critique. *Journal of Agricultural and Environmental Ethics, 27*(3), 479–522. https://doi.org/10.1007/s10806-014-9497-8

Ruben, R., Verhagen, J., & Plaisier, C. (2019). The challenge of food systems research: What difference does it make? *Sustainability, 11*(1), Article 171. https://doi.org/10.3390/su11010171

Saldaña, J. (2016). *The coding manual for qualitative researchers* (Third edition). SAGE.

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B., Burroughs, H., & Jinks, C. (2018). Saturation in qualitative research: Exploring its conceptualization and operationalization. *Quality & Quantity, 52*(4), 1893–1907. https://doi.org/10.1007/s11135-017-0574-8

Shannon, K. L., Kim, B. F., McKenzie, S. E., & Lawrence, R. S. (2015). Food system policy, public health, and human rights in the United States. *Annual Review of Public Health*, *36*(1), 151–173. https://doi.org/10.1146/annurev-publhealth-031914-122621

Sobal, J., Khan, L. K., & Bisogni, C. (1998). A conceptual model of the food and nutrition system. *Social Science & Medicine, 47*(7), 853–863. https://doi.org/10.1016/S0277-9536(98)00104-X

Solar, O., & Irwin, A. (2006). Social determinants, political contexts and civil society action: A historical perspective on the Commission on Social Determinants of Health. *Health Promotion Journal of Australia, 17*(3), 180–185. https://doi.org/10.1071/HE06180

Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B. L., Lassaletta, L., de Vries, W., Vermeulen, S. J., Herrero, M., Carlson, K. M., Jonell, M., Troell, M., DeClerck, F., Gordon, L. J., Zurayk, R., Scarborough, P., Rayner, M., Loken, B., Fanzon, J . . .Willett, W. (2018). Options for keeping the food system within environmental limits. *Nature, 562*(7728), 519. https://doi.org/10.1038/s41586-018-0594-0

Stephens, E. C., Jones, A. D., & Parsons, D. (2018). Agricultural systems research and global food security in the 21st century: An overview and roadmap for future opportunities. *Agricultural Systems, 163*, 1–6. https://doi.org/10.1016/j.agsy.2017.01.011

Stuart, D., & Worosz, M. R. (2012). Risk, anti-reflexivity, and ethical neutralization in industrial food processing. *Agriculture and Human Values, 29*(3), 287–301. https://doi.org/10.1007/s10460-011-9337-7

Taylor, M. R., & Hoffmann, S. A. (2001). *Redesigning food safety: Using risk analysis to build a better food safety system* (Discussion Paper 01–24). Resources for the Future. https://doi.org/10.22004/ag.econ.10784

Thyberg, K. L., & Tonjes, D. J. (2016). Drivers of food waste and their implications for sustainable policy development. *Resources, Conservation and Recycling, 106*, 110–123. https://doi.org/10.1016/j.resconrec.2015.11.016

Tsafnat, G., Glasziou, P., Choong, M. K., Dunn, A., Galgani, F., & Coiera, E. (2014). Systematic review automation technologies. *Systematic Reviews, 3*(1), 74. https://doi.org/10.1186/2046-4053-3-74

Udeigwe, T. K., Teboh, J. M., Eze, P. N., Stietiya, M. H., Kumar, V., Hendrix, J., Mascagni, H. J., Ying, T., & Kandakji, T. (2015). Implications of leading crop production practices on environmental quality and human health. *Journal of Environmental Management, 151*, 267–279. https://doi.org/10.1016/j.jenvman.2014.11.024

Uman, L. S. (2011). Systematic reviews and meta-analyses. *Journal of the Canadian Academy of Child and Adolescent Psychiatry*, *20*(1), 57–59. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3024725/

Urquhart, C., (2012). *Grounded theory for qualitative research: A practical guide*. SAGE.

U.S. Department of Agriculture Economic Research Service [USDA ERS]. (2021a). *Ag and food sectors and the economy*. https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/ag-and-food-sectors-and-the-economy/

USDA ERS. (2021b). *Farming and farm income.* https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/farming-and-farm-income/

von Keyserlingk, M. A. G., Martin, N. P., Kebreab, E., Knowlton, K. F., Grant, R. J., Stephenson, M., Sniffen, C.J., Harner, J.P. III, Wright, A.D., Smith, S. I. (2013). Invited review: Sustainability of the US dairy industry. *Journal of Dairy Science, 96*(9), 5405–5425. https://doi.org/10.3168/jds.2012-6354

Wallinga, D. (2009). Today's food system: How healthy is it? *Journal of Hunger & Environmental Nutrition, 4*(3–4), 251–281. https://doi.org/10.1080/19320240903336977

Weber, R. P. (1990). *Basic content analysis*: Sage. https://doi.org/10.4135/9781412983488

Wilkins, J. L., Lapp, J., Tagtow, A., & Roberts, S. (2010). Beyond eating right: The emergence of civic dietetics to foster health and sustainability through food system change. *Journal of Hunger and Environmental Nutrition, 5*(1), 2–12. https://doi.org/10.1080/19320240903573983

Yang, Y., & Suh, S. (2015). Changes in environmental impacts of major crops in the US. *Environmental Research Letters, 10*(9), Article 094016. https://doi.org/10.1088/1748-9326/10/9/094016

Yearworth, M., & White, L. (2013). The uses of qualitative data in multimethodology: Developing causal loop diagrams during the coding process. *European Journal of Operational Research, 231*(1), 151–161. https://doi.org/10.1016/j.ejor.2013.05.002

Appendix A. Methodology Details

Systematic reviews originated largely in health care as a methodology to critically review literature, conduct meta-analyses, and reach clinical conclusions but have been applied to other fields (Morton et al., 2011). The methodology behind systematic reviews was designed to create an explicit process for informed choices about the research design, which reduces some selection biases (e.g., unrepresentative or biased selection of articles to be reviewed) that can be present in narrative reviews (Collier & Mahoney, 1996; Uman, 2011). The systematic review steps we took were: (1) formulate a review question, (2) search for existing systematic reviews, (3) write a protocol, (4) devise a search strategy, and (5) execute the search (Tsafnat et al., 2014; Uman, 2011).

Qualitative hand-coding is one common way to examine textual data (Berelson, 1952; Hsieh & Shannon, 2005). Codes can be a word or short phrases that capture the meaning of that segment of text (Nelson et al., 2021; Saldaña, 2016). Hand-coding, as opposed to computer-aided content analysis, comes with trade-offs. Manually reviewing and iteratively coding texts is very time intensive, which can limit the number of texts that can be analyzed (Grimmer & Stewart, 2013; Nelson et al., 2021). However, hand-coding results in more inclusive coding that can capture meaning that computer programs can miss. Computer programs can quickly process many texts for common words but, without more complex processes like machine learning, are ill-equipped to manage phrases, indirect references, or other ambiguities (Nelson et al., 2021; Weber, 1990). Hand-coding allows meaning to be analyzed beyond specific words to identify concepts that are communicated through sentences, paragraphs, or with different phrasing (Weber, 1990). This advantage of hand-coding is necessary for the interdisciplinary scope of this review and outweighs the trade-off of additional time.

We developed the search terms to gather papers that focus on the food system in the United States and either discuss or provide some assessment of sustainability outcomes, if not directly using the term sustainability. The final search terms used were food system* AND (assessment OR sustainability*) AND United States*. Asterisks were used at the end of the terms, allowing multiple forms of the word to be present in the search results. An OR qualifier was used to account for some temporal variation or disciplinary conventions, as "sustainability" is not a pervasive term across time or disciplines. The use of "food system" was used to focus the search on papers in the food systems field or that discuss sustainability outcomes at a system-level. For the purpose of this review, the system level is broadly categorized as the inclusion of multiple system elements and their interactions that are relevant to the U.S. food system. As hundreds of thousands of papers address, to some degree, the sustainability of the food system through work at smaller scopes and/or with higher resolution, our primary rationale for choosing system-level sources was to enable a broad, holistic analysis within the logistical bounds of qualitative hand-coding.

The inclusion criteria were developed based on best practices in other peer-reviewed systematic reviews and the scope of the specific research question (Allum et al., 2008; Gruen et al., 2008; Guo & Gifford, 2002; Meijer et al., 2012; Osbaldiston & Schott, 2012). To be included in the review, content must be peer-reviewed, written in English, and published in the last 30 years (1989-2019). The final inclusion criterion limits possible results to focus on more recent articles and thus on the most current and relevant outcomes of the food system (Osbaldiston & Schott, 2012). The articles must encompass the U.S. food system, either by focusing specifically on the U.S. or North America or cover the global food system. Studies focusing on a single commodity or localized food system were excluded from the analysis.

Several of our choices, such as limiting the sources to peer-reviewed articles and excluding very narrow scopes, were shaped by the time intensity of hand-coding. However, some risks are allayed by necessitating data saturation. Data saturation, in this case, inductive thematic saturation, is when there is consistent evidence of the same codes being used across documents so that additional data collection (review of more articles) would likely not result in the identification of new themes (Guest et al., 2006; Saunders et al., 2018). We calculated saturation by determining which of the reviewed articles contained no new or novel outcomes (i.e., can be coded using existing outcomes), as thematic saturation necessitates finding consistent evidence of the same codes being used across documents (Urquhart, 2012). Achieving thematic saturation means the collected outcomes can be considered a comprehensive inventory.

Database selection was based on coverage of the core disciplines and bodies of knowledge associated with the food system, including natural sciences, social sciences, health, and engineering. Seven databases were chosen based on previous systematic reviews related to food systems: Web of Science, Embase, PsycInfo, ABI/Inform, EconLit, ProQuest Materials Science and Engineering, and Sociological Abstracts. While many other databases exist that also contain food systems papers, these seven covered the core disciplines and thus would likely return enough articles to achieve data saturation. If data saturation were not reached within the initially collected articles, we would search additional databases.

Journal of Agriculture, Food Systems, and Community Development
ISSN: 2152-0801 online
https://foodsystemsjournal.org

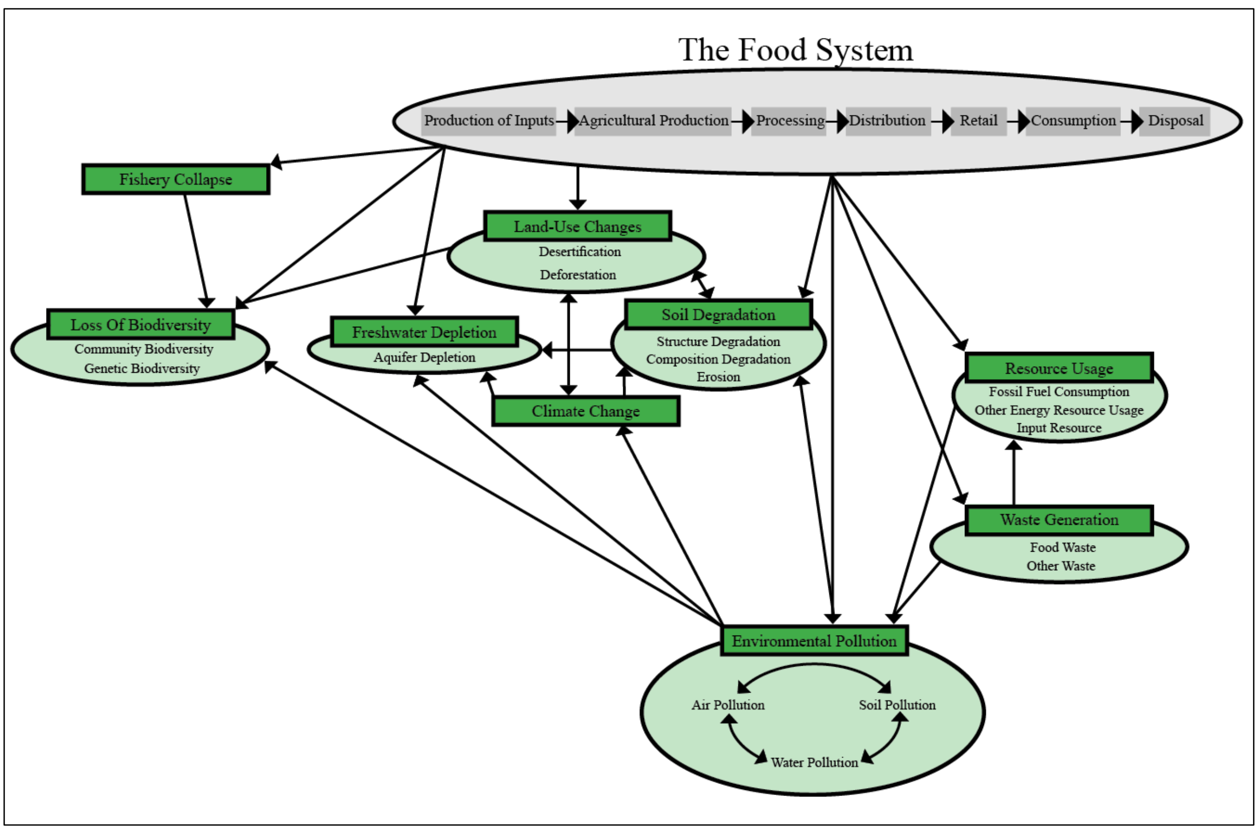
Appendix B. Explanation of Outcomes

The following discussion of the inventoried sustainability outcomes is organized into the three main themes: environmental, socio-economic, and human health outcomes. Each section details each outcome and visualizes the categories and subcategories to provide an overview and explanation of each identified outcome and provide connections among outcomes and the food system.

Environmental Outcomes

The theme of environmental outcomes is split into nine categories: environmental pollution, soil degradation, loss of biodiversity, freshwater depletion, land-use changes, climate change, fishery collapse, waste generation, and resource usage (see Figure B1). **Environmental pollution** was the most often identified category, with 40 out of 49 articles mentioning a concept within that category. The category is split into the three subcategories of **air, water, and soil pollution.** Beginning with air pollution, the food system is a major contributor to **greenhouse gas (GHG) emissions** in the U.S. and is a significant component of the global carbon cycle. Greenhouse gas emissions occur through many processes, such as methane emissions from ruminant animals and decomposing organic materials, fossil fuels usage throughout the system, and the burning of crop residue (Heller & Keoleian, 2003; Hickey & Ozbay, 2014; Udeigwe et al., 2015; Wallinga, 2009). The burning of crop residue is also linked to **particulate matter (PM) air pollution,** which can also result from conventional tilling practices, applying biosolids and agricultural chemicals to fields, and feedlot emissions (Rossi & Garner, 2014; Udeigwe et al., 2015; Wallinga, 2009). The final specific outcome within air pollution, **noxious gases,** can also be emitted from food system processes, such as ammonia from live-

Figure B1. Environmental Outcomes Map of the U.S. Food System, Outcomes Derived from the Literature Review



stock rearing (Rossi & Garner, 2014; Udeigwe et al., 2015).

Soil pollution, water pollution, and, to a lesser extent, air pollution are tightly linked due to biogeochemical cycles. As such, the three pollution mediums are circuitously linked in Figure B1. Pollution in one medium often leads to pollution in another, especially in agricultural systems where irrigation or rain carries soil pollutants to water bodies. Pesticides, fertilizers, and biosolids applied to soils, common practices in conventional agriculture, run off through rain or irrigation and pollute surface and groundwater (Udeigwe et al., 2015; Wallinga, 2009). Other pollutants can be present in soils from the use of agricultural **chemicals** or polluted irrigation water (Johnston et al., 2014; Udeigwe et al., 2015). Another source of contamination is **pathogens** that are spread through the application of biosolids or animal manure to agricultural fields, from direct runoff of leakage from livestock operations or mismanaged manure, or through the irrigation of fields by contaminated water (Chapman & Gunter, 2018; Udeigwe et al., 2015). Water and soil pollutants are tightly linked, as **nutrient** runoff from soils can lead to eutrophication events that damage the health of local flora and fauna (Wallinga, 2009). Water can also become polluted by **particulate matter,** particularly through sediment deposition from erosion (Rossi & Garner, 2014).

The second category is **soil degradation,** which, while linked to soil pollution, focuses on the loss of healthy soil **structure** and **composition** and the loss of agricultural soils through **erosion.** Soil health is determined by complex interactions between soil biodiversity and soil structures and functions. Biodiversity within soils, for example, earthworms, ants, and microbial diversity, impacts net primary productivity, which has huge implications for agriculture (Lal, 2007). Certain cropping or grazing practices accelerate rates of erosion and the loss of soil organic matter and other crucial nutrients (Rossi & Garner, 2014; Wallinga, 2009). Soil degradation is a significant problem because soil quality affects the water passing through or over it and the capacity of soils to retain water, which has implications for water pollution, yield, and resiliency to water scarcity (Lal, 2007).

The **loss of biodiversity** category is split into two subcategories: **genetic biodiversity** and **community biodiversity.** Environmental pollution is a significant driver of biodiversity loss, as it has the potential to damage the local ecosystem through direct events like hypoxia or toxic algae blooms or through weakening the defenses of organisms and making them more vulnerable to stressors or infection (Wallinga, 2009). Pesticides, pollution from waste generated by the food system, and exposure to antimicrobial resistant bacteria affect community biodiversity (Hickey & Ozbay, 2014; Mohareb et al., 2018; Wallinga, 2009). Several factors influence genetic biodiversity. Firstly, as community biodiversity degrades, the genetic pool shrinks. Secondly, the genetic diversity decreases through selective breeding and genetically modified organisms (GMOs), which are increasingly prevalent. Low genetic diversity increases the risk for catastrophic losses from diseases or pests, as there is little to no variation in defensive mechanisms or immunities. Furthermore, the loss of genetic biodiversity in agricultural species, and the ecosystem at large, lowers the adaptive capacities of organisms and their abilities to handle shocks like climate change (Lal, 2007; Shannon et al., 2015). The importance of resilience is reflected in another category, **fishery collapse.** Overfishing can lead to the collapse of many aquatic species and a limited ability to survive additional shocks (Johnston et al., 2014).

Several interconnected categories include **freshwater depletion, land-use changes**, and **climate change.** Climate change and the food system are highly linked. The food system accelerates climate change by emitting GHGs and is vulnerable to the predicted impacts of global climate disruption. As temperatures rise and weather patterns change, it is predicted there will be a loss of soil fertility and disruptions to hydrological cycles, reducing freshwater availability and increasing the need for irrigation (Lal, 2007; Wallinga, 2009). Food production is currently a water-intensive industry, and freshwater depletion through water usage, especially irrigation, and water pollution, is a serious concern (Lal, 2007). In particular, **aquifers** are a slowly replenishing source of freshwater, and withdrawals for irrigation are, in some locations, higher than regeneration rates (Heller & Keoleian, 2003; Udeigwe et al., 2015; Wallinga, 2009). Loss of soil fertility due to the effects of climate change and agricultural processes lower both the ability to produce crops as well as soils' resistance to **desertification** (Lal, 2007). Desertification is just one pressure for land-use change related to agriculture. Urbanization removes potential farmland and reduces viable crop area, while **deforestation** to clear for agricultural land affects global carbon sequestration (Hickey & Ozbay, 2014; Lal, 2007). In addition, land-use change can result in the loss of biodiversity, disruption of natural ecosystems, and overall degradation of the environment (Thyberg & Tonjes, 2016). Land is a stock of carbon that fluctuates based on land-use and treatment, so the usage of land and agricultural practices can be a contributor or detractor to climate change.

The next category, **waste generation,** largely focuses on **food waste and/or loss.** Food waste can occur at any stage of the food system, but emphasis is often placed on post-consumer edible waste as it can be minimized through behavior changes (Conrad et al., 2018). The environmental outcomes are twofold. Firstly, the disposal of food waste through the municipal waste stream uses resources and landfill space, and the decomposition generates methane (Mohareb et al., 2018; Thyberg & Tonjes, 2016). Secondly, the resources, such as water, soil, fossil fuels, and agricultural chemicals used to produce the food, are wasted (Hickey & Ozbay, 2014; Thyberg & Tonjes, 2016). This reduces the efficiency of the food system and increases the environmental burden. **Other wastes** generated by the food system include packaging wastes from transportation and shipping or food packaging like plastic wraps, corrugated boxes, etc. (Heller & Keoleian, 2003; Mohareb et al., 2018). Waste, from litter to microplastics or organic pollutants in wastewater, has diverse impacts on ecosystem health.

The final category in the environmental outcome theme is **resource usage,** specifically nonrenewable resources. As discussed previously, the food system is largely dependent on **fossil fuels** to produce agricultural inputs, irrigate fields, operate machinery, house animals, and transport, process, retail, store, and prepare food (Johnston et al., 2014; Shannon et al., 2015). **Other energy resources** like electricity are used for several of those processes, including irrigation, food processing machinery, refrigeration, and at-home appliances, and depending on electricity grid emissions factor, are associated with GHG emissions (Heller & Keoleian, 2003; Mohareb et al., 2018). Other nonrenewable **input resources** include phosphate rocks mined for fertilizers, chemicals such as pesticides, and pharmaceuticals like antibiotics (Lal, 2007; Shannon et al., 2015; Wallinga, 2009).

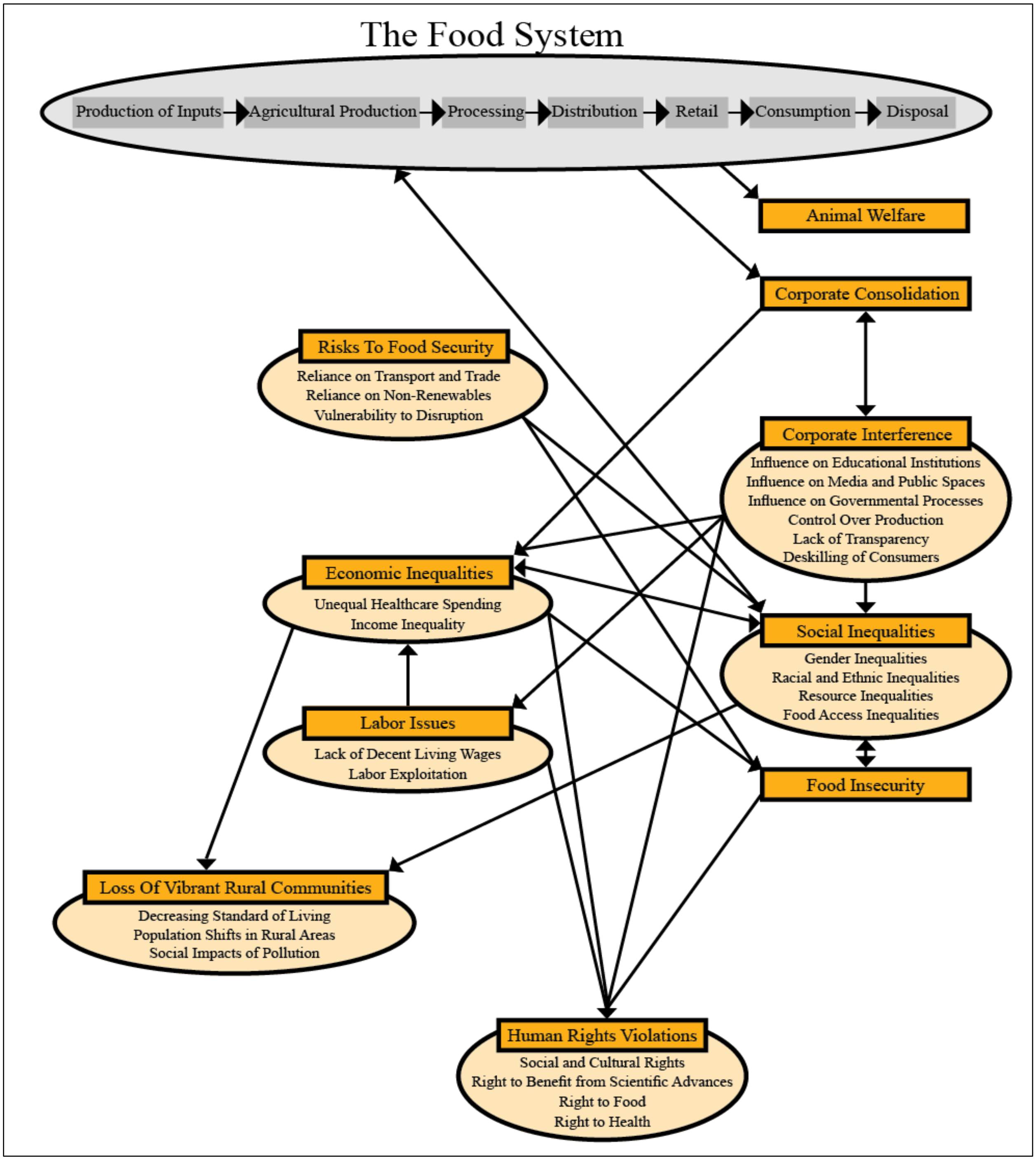
Socio-Economic Outcomes

The theme of socio-economic outcomes is split into three categories: **social outcomes, economic outcomes,** and **risks to food system security** (Figure B2). Many social, economic, and health outcomes are circuitously linked, as systemic discrimination and disenfranchisement drive economic inequalities and disproportionate health outcomes, which in turn serve as barriers to equity and justice. There are also many trade-offs associated with social and economic systems, as benefits for one group of people, for example, employees in a sector, residents of an area, or social identity group, may be at the detriment of another. While some of these nuances will be discussed below, there are many aspects of society, economics, and politics in the U.S. relevant to the food system that are not encompassed by this review. For example, the social, economic, and health outcomes for workers will be discussed, but further details on the drivers of these conditions, such as immigration and labor laws, will not be explored in depth. As previously stated, a primary goal is to inventory the outcomes of the food system, and a comprehensive analysis of system drivers is beyond the scope of this review.

Social Outcomes

The social outcomes category contains six subcategories: social inequalities, food insecurity, human rights violations, loss of vibrant rural communities, corporate interference, and animal welfare. **Social inequalities** are a broad subcategory that spans **gender, racial and ethnic, resource, and food access inequalities.** The food system is both subject to and upholds structural discrimination. Discriminatory pressures and historical disenfranchise-

Figure B2. Socio-Economic Outcomes Map of the U.S. Food System, Outcomes Derived from the Literature Review



ment have influenced the food system structure, but the behavior of the food system maintains inequalities through the distribution of or access to resources and opportunities. Agricultural practices in the U.S. have a deep history of discrimination and colonization through the privatization and commodification of land by white and wealthy individuals (Horst & Marion, 2019). The United States exists because of the dispossession of land from indigenous peoples through physical violence and manipulation. The development and execution of agriculture and the food industry in the United States have depended on the exploitation of marginalized groups throughout history, including the enslavement of millions of Africans and discriminatory treatment of immigrants (Horst & Marion, 2019). These practices, for example, policies in the late 19th and early 20th century banning Asian Americans from owning land, inheritance laws that made it difficult for women to possess land, or complex immigration policies, shaped who is allowed or able to own land (Horst & Marion, 2019). Women historically shoulder the brunt of food procurement and preparation responsibilities in the home, which is economically undervalued labor, knowledge, and skills (Jaffe & Gertler, 2006). Gender, racial, and ethnic inequalities exist throughout the food system and are connected to other social, economic, and health outcomes.

The final two subcategories of social inequalities are **resource** and **food access inequalities.** Resource inequalities include aspects like education, healthcare, and opportunities (Cachelin et al., 2019). Unequal distribution of resources can impact people's health, well-being, and ability to pursue their desires. For example, women and people of color are less likely to be recipients of lending from the USDA, an opportunity to gain the capital necessary to start an agricultural operation (Horst & Marion, 2019). Food access, both amount and types of food, is not equitable. City planning, private sector investment, and federal subsidies led to supermarkets being largely located in suburbs, lowering the accessibility of fresh produce in city centers and rural areas (Anderson, 2008; Elmes, 2018). The food available in these underserved areas is more often processed, convenience food that is high calorie and nutrient-poor, the consumption of which can lead to negative health outcomes (Anderson, 2008; Cachelin et al., 2019).

Food insecurity affects millions of households in the United States every year and disproportionately affects women, people of color, and recent immigrants (Anderson, 2008; Cachelin et al., 2019). Food insecurity can be influenced by food access inequalities and is influenced by income, food price, cultural suitability of food, and food preparation knowledge and skills. The outcomes of food insecurity are multifold, as hunger impacts individuals' ability to focus (particularly damaging for food insecure students), cognition, decision-making, and risk-taking behavior (Elmes, 2018). Government nutritional assistance programs like SNAP or WIC, while important stopgaps, do not address the root of the problem, like economic inequalities, and often do not provide recipients with the necessary funds to purchase more expensive, healthy foods (Anderson, 2008). There is a relationship between poverty, food insecurity, and obesity as filling, processed foods are often both cheap and unhealthy (Elmes, 2018). Some potential benefits of reducing food waste would be that the diverted waste could be used to reduce food insecurity or that avoided food waste increases food availability (Hickey & Ozbay, 2014). However, global agriculture produces enough calories to sustain the population, which implies that food insecurity is more likely a distributional and economic issue than a lack of production quantity (McInnes & Mount, 2017).

The next category is **human rights violations,** which does not have a universal definition; there is disagreement about what constitutes a human right (Anderson, 2008). Economic, social, and cultural rights like the **right to food, health, or a livable income** are violated by the food system through outcomes like food insecurity and access inequalities, environmental pollution, unsafe workplaces, and lack of decent living wages. **Social and cultural rights** include aspects like intergenerational justice, the right to participate in cultural life, and the right to democratic participation in decisions about the food system (Anderson, 2008). Climate change, which the food system accelerates, fundamentally impinges upon intergenerational justice. The loss of traditional foodways—the cultural practices surrounding food—reduces people's ability to practice and enjoy their culture (Anderson & Cook, 1999; Cachelin et al., 2019). Food is not simply a nutritional input necessary for physical functioning but an aspect of identity, family, and community. The concept of food sovereignty includes the right of people to have culturally appropriate foods but also their right to democratically shape the food system to suit social and environmental values, which is difficult due to lack of information about the food system and corporate interference with the policy process (Anderson & Cook, 1999; Cachelin et al., 2019). The final outcome under the subcategory of human rights violations is the **right to benefit from scientific advances.** Much of the public funding for food systems research and technological advances focuses on cropping methods like genetically engineered monocrops and mechanization, which economically undermine mid-/small-scale and/or sustainable farmers (Anderson, 2008).

The following category, **loss of vibrant rural communities,** contains the subcategories of **decreased standard of living, population shifts**, and **negative social impacts of pollution,** which are driven in part by the food system. Trends like industrialization and urbanization shifted populations, especially young people, from rural to urban areas (Anderson, 2015). While population shifts are not by definition negative, and advances in mechanization have freed up individuals to pursue other jobs, both trends have directly and indirectly impacted rural areas. Rural areas have fewer job opportunities, and the industries that moved into rural areas tend to be less skilled work and have lower wages, like call centers, prisons, and factories (Anderson, 2008). The lower economic value and dispersed population in rural areas led to lower quality public services, like education and public transportation, and access to health care and retail services (Anderson, 2008; Bardenhagen et al., 2017; Hallam et al., 1993). The lack of well-paying jobs, and more localized environmental pollution, have made rural areas undesirable to many (Anderson, 2008; Hallam et al., 1993; Rossi & Garner, 2014). The "hollowing out" of rural areas impacts the social well-being of rural occupants and their ability or willingness to participate in community institutions (Anderson, 2008, 2015; Hallam et al., 1993; Rossi & Garner, 2014). Although the shift to urban centers has slowed considerably, rural populations are aging, have declining birth rates, and face inequalities in income, health outcomes, and resource and food distribution (Anderson, 2015).

Animal welfare is also a significant concern in the food system. There are many dimensions to animal welfare, including living conditions, treatment, and genetic selection (Hoetzel, 2014). While there are arguments that killing living creatures can never be ethical, it is undeniable that industrial livestock production is inhumane. Selective breeding is used for traits like higher body weight or quicker egg production, but these changes can result in discomfort and loss of quality of life as, for example, broiler chickens have difficulty moving around with enlarged breast tissue (Hoetzel, 2014; Rossi & Garner, 2014). Efficiency-focused industrialization led to compact and mechanized rearing systems that rely on antimicrobials and growth hormones to maximize net yield and manage diseases in overcrowded and immunologically stressful conditions (Hoetzel, 2014; Rossi & Garner, 2014). These conditions restrict movement and generate mental distress for animals. Animals undergo other inhumane treatments during rearing, transportation, and processing in slaughterhouses, such as cutting off tails, beaks, and horns or scaling, skinning, or dismemberment, often without anesthesia or while animals are conscious (Hoetzel, 2014; Rossi & Garner, 2014).

The final subcategory is **corporate interference.** The food system is a highly industrialized, corporatized, and capitalized industry. Food is a commodity, a product with which to extract value through private ownership of land and the means of production (Elmes, 2018). The accumulation and abuse of power by firms in the food system are critiqued for several reasons, including the privatization of natural resources, unequal distribution of food, and the **manipulation of political, educational, and social systems** for financial gain. Corporations can privately fund research that provides them with advantages, which can, in turn, further wealth gaps or monopolies of large firms and violates the right to benefit fairly from scientific advances (Anderson, 2008; Elmes, 2018). Firms can also capture the policy process through political donations and pressures from lobbyists to, for example, roll back environmental legislation, weaken anti-trust laws, or influence the allocation of public research dollars (Elmes, 2018; Wallinga, 2009).

Consumers can be influenced through advertising, branding, labeling, and news in media and public spaces. The agro-food industry spends billions of dollars on marketing its products, which can be misleading or manipulative (Anderson, 2008; Elmes, 2018; Jaffe & Gertler, 2006; Shannon et al., 2015). Branding and labeling may also be used as a purposeful **lack of transparency,** which can make it difficult for consumers to understand the health or sustainability impacts of their food choices (Elmes, 2018). There is also a lack of transparency around agricultural practices, value chains, or brand ownership which removes the information and understanding of the food system necessary for consumers to make informed decisions in line with their values (Jaffe & Gertler, 2006). The disconnect of consumers from the production of food, and thus their awareness of the process and understanding of environmental and social externalities, is a form of **deskilling consumers** (Anderson, 2008; Jaffe & Gertler, 2006). The shift towards convenience foods, both through changing lifestyles and pressures from food firms, also deskilled consumers as they lose knowledge and skills about how to prepare food, nutrition and the health of foods, and freshness and spoilage (Elmes, 2018; Heller & Keoleian, 2003; Jaffe & Gertler, 2006). The deskilling of consumers affects health, participation in cultural traditions, and the ability of consumers to recognize problems and advocate for solutions within the food system (Jaffe & Gertler, 2006).

Risks to Food Security

The category **risks to food security** is in the socio-economic theme because a loss of food security would result in increased food insecurity or food access inequalities. The three specific outcomes discussed in the reviewed literature are the food system's **vulnerability to disruption, reliance on non-renewables**, and **reliance on transportation and trade.** The food system is a highly complicated set of interconnected systems that largely cannot operate alone. As such, the food system is vulnerable to disruption at many points and scales, such as natural disasters, climate change, freshwater depletion, emergent pests or diseases, or bioterrorism (Gilmore, 2004). The intensive use of non-renewable resources, such as fossil fuels and antibiotics, endangers the longevity of the food system as these resources will eventually run out (Blair & Sobal, 2006; Conrad et al., 2018; Wallinga, 2009). Finally, the U.S. food system is highly dependent on national and international transportation and trade to provide adequate nutrition and diet diversity to its citizens (Gilmore, 2004; Koc & Dahlberg, 1999). In the event of halted or disturbed transportation and trade, much of the United States would not be able to provide adequate food to its citizens.

Economic Outcomes

While the ultimate negative outcomes of economic issues are most often the resulting social or health issues, such as damages to mental, social, or physical well-being, it can be useful to discuss economic outcomes as individual issues and precursors to further problems. In addition, many consider fair employment to be a human right. The subcategories in the economic outcome category are corporate consolidation, economic inequalities, and labor issues.

Corporate consolidation is rampant throughout the food system, like agrochemical or biotechnology companies that produce agricultural inputs, agrobusinesses that produce food, food processors, transportation and multinational trade firms, grocery retailers, and restaurants. In 2020, about 3% of farms generated 46% of the value of production (USDA ERS, 2021b). Both vertical and horizontal integration exist in the food system, which refers to integration either along the food system (i.e., a firm that produces, processes, and sells a product) or within a system stage (i.e., a firm that owns a large market share of a particular industry) respectively. The consolidation process is in a positive feedback loop with corporate interference, as the power gained through consolidation can be leveraged to influence the mechanisms that would decrease power, such as anti-trust legislation. The most obvious examples of consolidation are large food brands or retailers, but less consumer-facing aspects of the food system, such as wholesale and food distribution firms, are also consolidated (Elmes, 2018). Livestock slaughtering and packing is also a consolidated industry, with dramatic trends toward larger factories and fewer firms (MacDonald et al., 2000).

Corporate consolidation is not inherently negative, and this outcome refers specifically to the negative sustainability outcomes enabled by concentration that are pervasive in the U.S. food system. In isolation, consolidation presents a risk that if the needs and desires of a population change, entities with highly consolidated power can resist change, dictate conditions, and act out of line with social and environmental good. Corporate consolidation concentrates power which enables impactful decision-making but runs the risk of being abused (Anderson, 2008, 2015; Elmes, 2018). There is reduced competition, either through mergers, takeovers, or difficulties entering the market, which entrenches the control of consolidated firms and removes the ability of consumers to express values through purchasing decisions (Anderson, 2015; Elmes, 2018; Jaffe & Gertler, 2006). Consolidation also weakens local markets, which impacts local economies and takes wealth out of communities that they are unlikely to recoup (Anderson, 2015; Johnston et al., 2014; Yang & Suh, 2015).

The final two subcategories are **economic inequalities** and **labor issues.** Economic inequalities exist in the food system, including **income inequality** and **unequal healthcare spending.** Income inequality is a significant issue for farmers, food processing workers, and food service workers, as they do not benefit fairly from the wealth generated by the food system (Anderson, 2008; Heller & Keoleian, 2003; Horst & Marion, 2019; Wallinga, 2009). Agriculture and food-related industries contributed US$1.055 trillion, or 5%, to the U.S. gross domestic product and 10.3% of employment, 19.7 million jobs, in 2020 (USDA Economic Research Service [ERS], 2021a). In addition, rural areas face higher income inequality and unemployment than their metropolitan counterparts (Hallam et al., 1993; Rossi & Garner, 2014). Unequal healthcare spending due to health burdens caused by the food system, mainly environmental pollution and occupational health effects, can be worsened by distributional inequalities of healthcare services, especially in non-metro areas, and low quality or lacking health insurance for food system employees (Blair & Sobal, 2006; Rossi & Garner, 2014; Wallinga, 2009).

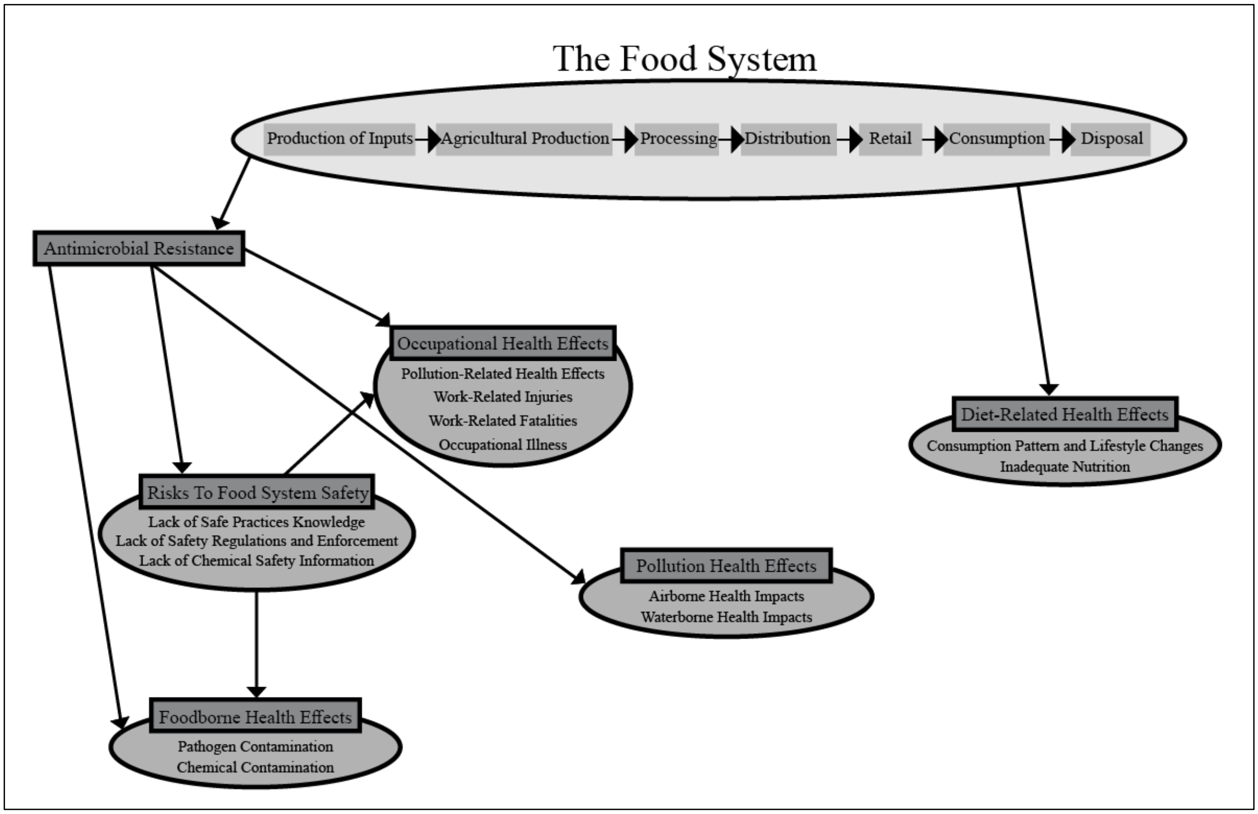
Income inequality is a prominent issue due to the lack of living wages provided to food system employees (Anderson, 2008, 2015; Horst & Marion, 2019; Lo & Delwiche, 2015). **Decent living wages** are a cornerstone of fair employment (Anderson, 2008). Beyond lower wages, but contributing to economic inequalities, is **labor exploitation** (Elmes, 2018; Horst & Marion, 2019). This includes practices like unpaid labor, forced labor, wage theft, the inability to form labor unions, child labor, or other forms of exploiting vulnerable populations such as immigrants, and particularly undocumented workers (Anderson, 2008; Heller & Keoleian, 2003; Lo & Delwiche, 2015; Pilgeram, 2011). Suppressing labor unions, a practice that is aided by corporate consolidation and interference, is particularly harmful because it removes the ability of workers to advocate for themselves and improve aspects like wages or workplace health and safety (Anderson, 2008). Thus, while labor issues are linked to economic outcomes, they can also result in outcomes to physical and mental well-being.

Human Health Outcomes

The theme of human health outcomes covers the categories of health effects from environmental pollution, diet-related health effects, antimicrobial resistance, foodborne health effects, occupational health effects, and risks to food system safety (see Figure B3). **Environmental pollution** affects communities surrounding food system activities through two main pathways: **air and water.** Air pollution such as particulate matter and noxious gases can contribute to respiratory issues like asthma, while both inhaled or consumed agricultural chemicals, like pesticides, can contribute to health issues, such as cancer and neurologic diseases, or act as endocrine disruptors (Blair & Sobal, 2006; Rossi & Garner, 2014; Udeigwe et al., 2015; Wallinga, 2009). Pathogen pollutants in water can spread zoonotic diseases or other pathogens (Hallam et al., 1993; Rossi & Garner, 2014). In some cases, eutrophication events from nutrient pollution can create toxic algae blooms that render drinking water unconsumable.

Diet-related health effects are separated into the two categories of **consumption pattern and lifestyle changes** as well as **inadequate nutrition.** The interplay among consumption patterns, lifestyle choices, and individual physiology is com-

Figure B3. Human Health Outcomes Map of the U.S. Food System, Outcomes Derived from the Literature Review



plex and highly variable. While diet does not impact all people equally, it does have a significant impact on health. **Consumption patterns** in the United States shifted over time to include more processed calorie-dense, nutrient-poor foods, animal products, larger portion sizes, and more meals eaten outside of the home (Hickey & Ozbay, 2014; Rossi & Garner, 2014; Wallinga, 2009). Simultaneously, **lifestyles** have become more sedentary (Kearney, 2010). These factors have a direct link to obesity, which is a significant public health concern in the United States and is a contributor to other diet-related health issues like diabetes, cardiovascular disease, and hypertension (Blair & Sobal, 2006; Finley et al., 2017; Johnston et al., 2014; Neff et al., 2015; Nelson et al., 2016b). Dietary choices can influence a range of health concerns, from kidney disease to arthritis to cancer (Nelson et al., 2016b; Shannon et al., 2015). **Inadequate nutrition** includes malnutrition through a lack of sufficient food or micronutrient deficiencies (Johnston et al., 2014; Merrigan et al., 2015; Rose et al., 2019; Wilkins et al., 2010).

A common influence on human health is foodborne contaminants like pathogens and chemicals. Pathogens can be present in animal products and transferred to produce through the application of animal manures or biosolids, irrigation with contaminated water, contamination of harvesting, transportation, and processing equipment, or cross-contamination with other foods (Chapman & Gunter, 2018; Fraser & Simmons, 2017; Gelting & Baloch, 2013). Common pathogens which lead to foodborne illness are *Salmonella*, norovirus, and *E. coli* (Chapman & Gunter, 2018; Rossi & Garner, 2014; Stuart & Worosz, 2012). It is also possible that foods could be contaminated with harmful chemicals along the food system (Fraser & Simmons, 2017; Maffini et al., 2017).

The next category, antimicrobial resistance, occurs when target organisms develop a resistance to an antimicrobial. This is a multifold concern in the food system. From a public health perspective, antimicrobials, particularly antibiotics, are an important line of defense. The high rate of antibiotic usage on livestock speeds the development of resistance and transmittance to humans while decreasing the effectiveness of antibiotics in other situations (Wallinga, 2009). This is also an ongoing process for fungicides and pesticides, and while the latter does not as directly impact human health, there are significant implications for agricultural yield.

Similar to previous categories, **occupational health outcomes** occur throughout the food system and is broken into the subcategories of occupational illness, work-related injuries and fatalities, and occupational pollution-related health effects. **Occupational illnesses** can result from exposure to pathogens or zoonotic diseases, and food system workers have a higher risk of exposure than the general public (Neff et al., 2015; Rossi & Garner, 2014). Workers in the livestock rearing, slaughter, and processing supply chain are also at higher risk of being exposed to antimicrobial resistant bacteria (Rossi & Garner, 2014). Agriculture and food manufacturing has a high rate of **work-related injuries and fatalities** from accidents than other industries (Neff et al., 2015; Newman et al., 2015). Work-related injuries include acute and chronic injuries, such as chronic back pain or musculoskeletal problems from repetitive motions or long hours of standing (Newman et al., 2015). **Pollution** in the workplace can also contribute to health outcomes like respiratory issues from irritation to serious conditions like respiratory diseases and asthma (Rossi & Garner, 2014; Shannon et al., 2015). Exposure to pesticides can result in a variety of health effects, including mortality from acute pesticide poisoning (Rossi & Garner, 2014; Wallinga, 2009). Occupational health effects can be worsened through lacking or improperly enforced health and safety practices.

The final category in human health outcomes is **risks to food safety.** Food safety is impacted by a **lack of knowledge on safe practices,** leading to mishandled food and increases in foodborne health outcomes, **lack of chemical safety information,** particularly the risks of multiple interacting chemicals, and a **lack of safety regulations and enforcement** (Chapman & Gunter, 2018; Maffini et al., 2017; Stuart & Worosz, 2012; Taylor & Hoffmann, 2001). Chemicals are notoriously understudied, as many have not been extensively tested and are still used as they are "generally recognized as safe" (GRAS) (Maffini et al., 2017). There are thousands of chemicals added to foods, which poses a challenge for responsible management by the FDA in isolation, much less when considering chronic low-level exposure, exposure for vulnerable populations like children, or multiple chemical interactions (Jaffe & Gertler, 2006; Maffini et al., 2017; Taylor & Hoffmann, 2001). Food safety and the safety of food system employees are further at risk due to lacking safety regulations, limited food and facility inspections, and a minimal response from firms to address safety concerns (Stuart & Worosz, 2012; Taylor & Hoffmann, 2001).

Appendix C. Raw Coding and Additive Coding

Outcome	Raw	Additive
Environmental Outcomes	11	41
Environmental Pollution	16	40
Air Pollution	5	26
Greenhouse Gas Emissions	23	23
Particulate Matter Air Pollution	2	2
Noxious Gases Air Pollution	3	3
Water Pollution	24	29
Water Nutrient Pollution	20	20
Water Pathogen Pollution	4	4
Water Chemical Pollution	9	9
Particulate Matter Water Pollution	8	8
Soil Pollution		7
Soil Chemical Pollution	5	5
Soil Pathogen Pollution	2	2
Soil Degradation	14	21
Soil Structure Degradation	2	2
Soil Composition Degradation	4	4
Erosion	14	14
Loss Of Biodiversity	13	18
Genetic Biodiversity	6	6
Community Biodiversity	5	5
Freshwater Depletion	24	24
Aquifer Depletion	7	7
Land-Use Changes	14	17
Deforestation	5	5
Desertification	2	2
Climate Change	17	17
Fishery Collapse	2	2
Waste Generation		18
Food Waste	15	15
Other Waste Generation	4	4
Resource Usage	9	21
Fossil Fuel Consumption	11	11
Input Resource	3	3
Other Energy Resource Usage	7	7

continued

Outcome	Raw	Additive
Socio-Economic Outcomes		37
Social Outcomes	5	31
Social Inequalities	3	14
Gender Inequalities	5	5
Racial And Ethnic Inequalities	3	3
Resource Inequalities	5	5
Food Access Inequalities	10	10
Food Insecurity	15	15
Human Rights Violations	5	10
Social And Cultural Rights	3	8
Right To Food	4	4
Right To Health	2	2
Right To Benefit From Scientific Advances	3	3
Loss Of Vibrant Rural Communities	5	11
Decreasing Standard Of Living	6	8
Population Shifts In Rural Areas	3	3
Social Outcomes Of Pollution	4	4
Corporate Interference	1	16
Influence On Educational Institutions	3	3
Influence On Media And Public Spaces	5	5
Influence On Governmental Processes	7	7
Control Over Production	8	8
Lack Of Transparency	4	4
Deskilling Of Consumers	10	10
Animal Welfare	5	5
Risks To Food Security	13	21
Vulnerability To Disruption	3	3
Reliance On Non-Renewables	9	9
Reliance On Transportation And Trade	2	2
Economic Outcomes		22
Corporate Consolidation	14	14
Economic Inequalities	5	18
Income Inequality	11	11
Unequal Healthcare Spending	4	4
Labor Issues	3	7
Lack Of Decent Living Wages	4	4
Labor Exploitation	6	6

continued

Outcome	Raw	Additive
Human Health Outcomes	5	43
Environmental Pollution Health Effects	4	11
Airborne Health Outcomes	7	7
Waterborne Health Outcomes	5	5
Diet-Related Health Effects	27	33
Consumption Pattern And Lifestyle Changes	14	26
Diabetes	11	11
Cardiovascular Disease	12	12
Obesity	17	17
Hypertension	4	4
Inadequate Nutrition	11	11
Antimicrobial Resistance	7	7
Foodborne Health Effects	1	18
Pathogen Contamination Of Food	12	12
Chemical Contamination Of Food	3	3
Occupational Health Effects	7	15
Occupational Illness	6	6
Work-Related Injuries	7	7
Work-Related Fatalities	6	6
Occupational Pollution-Related Health Effects	6	6
Risks To Food System Safety	14	14
Lack Of Safe Practices Knowledge	1	1
Lack Of Safety Regulations And Enforcement	2	2
Lack Of Chemical Safety Information	3	3
TOTAL	**728**	**1,074**

Appendix D. List of Reviewed Articles

Title	Citation
Improving Farm Animal Welfare: Is Evolution or Revolution Needed in Production Systems?	(Hoetzel, 2014)
Understanding Sustainable Diets: A Descriptive Analysis of the Determinants and Processes That Influence Diets and Their Impact on Health, Food Security, and Environmental Sustainability	(Johnston et al., 2014)
Soil Science and the Carbon Civilization	(Lal, 2007)
Roles of Rural Areas in Sustainable Food System Transformations	(Anderson, 2015)
Options for keeping the food system within environmental limits	(Springmann et al., 2018)
Leveraging foodways for health and justice	(Cachelin et al., 2019)
Food Sustainability in the Context of Human Behavior	(Morawicki & Díaz González, 2018)
Implications of leading crop production practices on environmental quality and human health	(Udeigwe et al., 2015)
Victual Vicissitudes: Consumer Deskilling and the (Gendered) Transformation of Food Systems	(Jaffe & Gertler, 2006)
The restructuring of food systems: Trends, research, and policy issues	(Koc & Dahlberg, 1999)
Luxus Consumption: Wasting Food Resources Through Overeating	(Blair & Sobal, 2006)
Racial, ethnic and gender inequities in farmland ownership and farming in the U.S.	(Horst & Marion, 2019)
Risk, anti-reflexivity, and ethical neutralization in industrial food processing	(Stuart & Worosz, 2012)
Industrial Farm Animal Production: A Comprehensive Moral Critique	(Rossi & Garner, 2014)
Relationship between food waste, diet quality, and environmental sustainability	(Conrad et al., 2018)
The Progressive Increase of Food Waste in America and Its Environmental Impact	(Hall, Guo, Dore, & Chow, 2009)
Rights-based food systems and the goals of food systems reform	(Anderson, 2008)
Characterizing Rural Food Access in Remote Areas	(Bardenhagen et al., 2017)
Local Food Systems Food Safety Concerns	(Chapman & Gunter, 2018)
Economic Inequality, Food Insecurity, and the Erosion of Equality of Capabilities in the United States	(Elmes, 2018)
The Evolution of the School Food and Farm to School Movement in the United States: Connecting Childhood Health, Farms, and Communities	(Feenstra & Ohmart, 2012)
Nutritional Sustainability: Aligning Priorities in Nutrition and public health with Agricultural Production	(Finley et al., 2017)
Food Safety Education: Training Farm Workers in the US Fresh Produce Sector	(Fraser & Simmons, 2017)
A systems analysis of irrigation water quality in environmental assessments related to foodborne outbreaks	(Gelting & Baloch, 2013)
US food safety under siege?	(Gilmore, 2004)
Sustainable Food and Agricultural Policies: A U.S. Perspective	(Hallam et al., 1993)
Assessing the sustainability of the US food system: a life cycle perspective	(Heller & Keoleian, 2003)
Food Waste in the United States: A contributing factor toward environmental instability	(Hickey & Ozbay, 2014)
The effects of the industrialization of US livestock agriculture on promoting sustainable production practices	(Hinrichs & Welsh, 2003)
Supporting Equitable Food Systems Through Food Assistance at Farmers' Markets	(Jones & Bhatia, 2011)

continued

Role of Veterinary Medicine in Public Health: Antibiotic Use in Food Animals and Humans and the Effect on Evolution of Antibacterial Resistance	(Lathers, 2001)
The Natural Resource Limits of US Agriculture	(Libby, 1993)
The Good Food Purchasing Policy: A tool to intertwine worker justice with a sustainable food system	(Lo & Delwiche, 2015)
We are what we eat: Regulatory gaps in the United States that put out health at risk	(Maffini et al., 2017)
Designing a sustainable diet	(Merrigan et al., 2015)
Cities' Role in Mitigating United States Food System Greenhouse Gas Emissions	(Mohareb et al., 2018)
A Food Systems Approach to Healthy Food and Agriculture Policy	(Neff et al., 2015)
Alignment of Healthy Dietary Patterns and Environmental Sustainability: A Systematic Review	(Nelson et al., 2016b)
Estimating Occupational Illness, Injury, and Mortality in Food Production in the United States: A Farm-to-Table Analysis	(Newman et al., 2015)
Energy Intensity of Agriculture and Food Systems	(Pelletier et al., 2011)
"The Only Thing That Isn't Sustainable...Is the Farmer": Social Sustainability and the Politics of Class among Pacific Northwest Farmers Engaged in Sustainable Farming	(Pilgeram, 2011)
Position of the Society for Nutrition Education and Behavior: The Importance of Including Environmental Sustainability in Dietary Guidance	(Rose et al., 2019)
Food system policy, public health, and human rights in the United States	(Shannon et al., 2015)
Redesigning Food Safety: Using Risk Analysis to Build a Better Food Safety System	(Taylor & Hoffmann, 2001)
Drivers of food waste and their implications for sustainable policy development	(Thyberg & Tonjes, 2016)
Sustainability of the US dairy industry	(von Keyserlingk et al., 2013)
Today's Food System: How Healthy Is It?	(Wallinga, 2009)
Beyond Eating Right: The Emergence of Civic Dietetics to Foster Health and Sustainability Through Food System Change	(Wilkins et al., 2010)
Changes in environmental impacts of major crops in the US	(Yang & Suh, 2015)