Cross-cutting concepts to transform agricultural research

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Agriculture is an important link to many issues that challenge society today, including adaptation to and mitigation of climate change, food security, and communicable and non-communicable diseases in animals and humans. Transformation of agriculture and food systems has become a priority for a range of federal agencies and global organizations. It is imperative that food and agricultural researchers effectively harness the global convergence of priorities to overcome research "silos" through deep and sustained systemic change. Herein, we identify intersections in federal and global initiatives encompassing climate adaptation and mitigation; human health and nutrition; animal health and welfare; food safety and security; and equity and inclusion. Many agencies and organizations share these priorities, but efforts to address them remain uncoordinated and opportunities for collaboration untapped. Based on the interconnectedness of the identified priority areas, we present a research framework to catalyze agricultural transformation, beginning with the research enterprise. We propose that transformation in agricultural research should incorporate (1) innovation, (2) integration, (3) implementation, and (4) evaluation. This framework provides approaches for food and agricultural research to contribute to sustainable, flexible, and coordinated transformation in the agricultural sector.

KEYWORDS

agricultural transformation, climate change, convergence, health, food systems

1. Introduction

Agriculture has the potential to simultaneously influence numerous global challenges related to the health of people, animals, and the planet. In recent years, researchers, policymakers, non-profit organizations, farmers, and other stakeholders have advocated for transformation within the agricultural sector. Transformation is characterized by "deep and sustained, nonlinear systemic change, generally involving cultural, political, technological, economic, social and/or environmental processes (Linnér and Wibeck, 2020). In regard to agriculture, transformation is warranted for a number of reasons, including maximizing efficiency, feeding the growing population, mitigating ecological harm, adapting to a changing climate, and promoting human and animal health. Thus, agricultural transformation, be it local or global, should be catalyzed by diverse trans-disciplinary research approaches and implemented differently based on

practical, economic, and cultural considerations. To execute this, researchers must harness cross-cutting innovation to promote fruitful, long-term partnerships and scalable research outcomes. Proposed approaches to meet these societal needs often overlap, creating a challenge and an opportunity for researchers across disciplines to contribute to agricultural transformation.

We propose a framework of four approaches to agricultural research that, separately or in combination, can be employed across academia, government, and the private sector: (1) innovation of novel agricultural practices that favorably impact people and the environment; (2) integration of multiple research areas to solve complex agricultural and environmental problems; (3) implementation of novel practices within a wide range of agricultural systems; and (4) embedding evaluation and systematic analysis throughout the research process (Figure 1).

2. Intersections in federal and global priorities

Supplementary Table S1 summarizes several examples, within the United States and globally, of the role of agriculture in the following priority areas: (1) climate adaptation and mitigation, (2) human health and nutrition, (3) animal health and welfare, (4) food security, and (5) equity and inclusion. Agricultural transformation is most often deliberated in the context of climate and the environment. On the international scale, the 27th Conference of Parties (COP27) of the United Nations Framework Convention on Climate Change (UNFCCC) featured a Food Systems Pavilion for the first time, emphasizing the importance of food and agriculture systems in the global climate response (Food Systems Pavilion, 2022). At the prior COP26 meeting, the United States and United Arab Emirates announced the Agriculture Innovation Mission for Climate (AIM for Climate), a joint initiative between these nations and other partners

FIGURE 1
Dynamic relationships in the proposed transformative agricultural research framework. This illustration affirms that evaluation is embedded within innovation, integration, and implementation.

(Agriculture Innovation Mission for Climate, 2023). AIM for Climate seeks to organize a global response to climate change and food insecurity by promoting innovation in the agricultural sector. In 2023, the AIM for Climate Summit was convened in Washington, DC., to catalyze conversations and collaborations in food and agriculture prior to COP28 in Dubai. Also in the United States, several federal agencies have developed climate adaptation plans that include initiatives in the agriculture sector (Supplementary Table S1). Coinciding with the AIM for Climate Summit, the U.S. Department of Agriculture (USDA) announced its latest science and research plan, which prioritizes climate solutions in agriculture (USDA Science and Research Strategy, 2023–2026: Cultivating Scientific Innovation, 2023). In addition to climate, this plan connects agriculture to the ability of people, animals, cultures, and communities to survive and thrive. For example, equity and inclusion are embedded in priorities related to innovation, nutrition security, and workforce development. To sustain agricultural transformation in the long-term, all priority areas must be considered to support a healthy, safe, and equitable food system for human and animal populations (Figure 2).

The interconnectedness of these priorities has been displayed on the global scale at the, 2022 COP27 meeting, where overall conference initiatives included Food Systems for Sustainable Transformation (FAST) and the Initiative on Climate Action and Nutrition (I-CAN), connecting both the transformation of agriculture and human nutrition to climate action (FAST, 2022; I-CAN, 2022). For example, a key component of the FAST initiative is supporting food and economic security while simultaneously promoting climate adaptation and mitigation that limits global warming to 1.5°C (FAST, 2022). Similarly, the UN Sustainable Development Goals (SDG) provide a nearly comprehensive blueprint of 17 components required for long-term global prosperity (Sustainable Development, 2022). These goals span aspects of human, animal, and planetary health, many of which have direct connections to agriculture. The 2023 AIM for Climate Summit featured sessions highlighting and expanding upon the SDGs, indicating that a sustained climate response in agriculture must simultaneously prioritize health, nutrition, and equity (Agriculture Innovation Mission for Climate, 2023).

The significant overlap in U.S. and global initiatives related to food and agriculture affirms that the outlook for transformation is promising. The challenge is to harmonize work across the U.S. and internationally in public, private, and non-profit sectors to encourage coordination and collaboration. The framework outlined in the following section is specifically focused on research entities. Nevertheless, there are numerous key stakeholders beyond the research enterprise that should be involved in the global effort to transform agriculture.

3. Cross-cutting research framework

The global emphasis on agriculture as a solution to a range of societal challenges promises nearly unlimited opportunities for impactful, trans-disciplinary research initiatives. Therefore, we propose that research to transform agriculture should harness the following framework:

I. **Innovation**: Identification and creation of novel agricultural technologies to address critical societal needs.
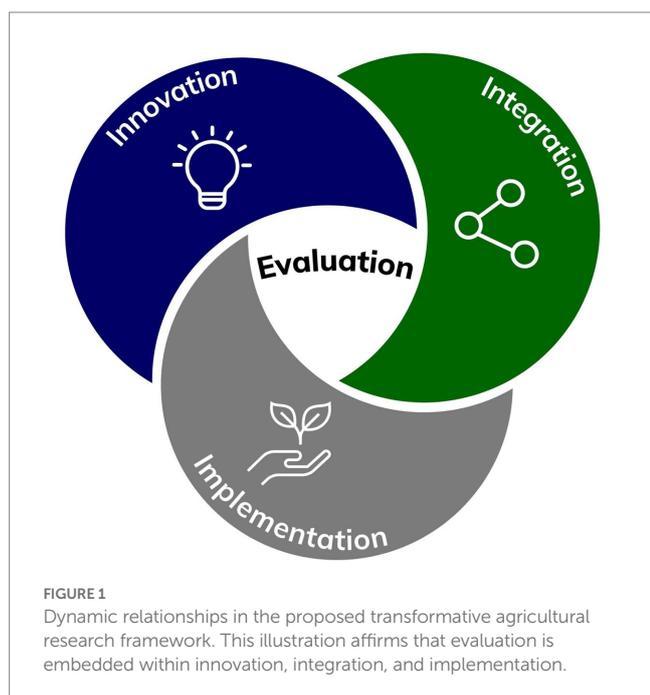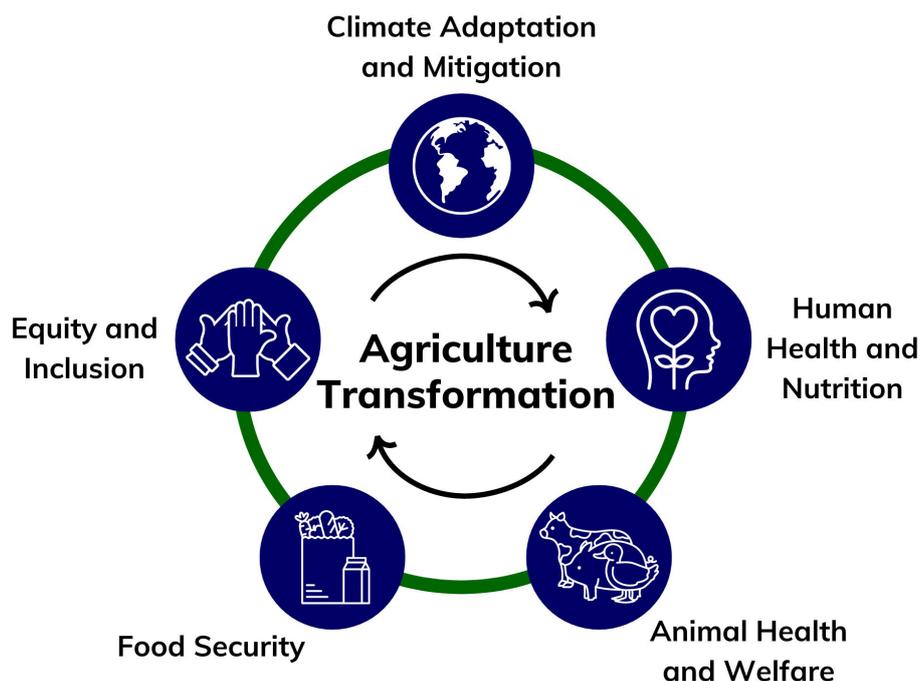
FIGURE 2
Interconnected key priority areas for agricultural transformation. Transformation in agriculture has the potential to influence aspects of each priority area and vice versa.

II. **Integration**: Development of new partnerships and research areas to prioritize cross-cutting projects across government, academia, and industry.

III. **Implementation**: Outreach, education, and adaptation to apply novel agricultural research in farms, ranches, and forests of all scales.

IV. **Evaluation**: Measurement of new and existing approaches to understand environmental, health, and societal impacts; needs and impact assessments performed prior to and following project completion, and knowledge management.

3.1. Innovation

Research to identify and execute novel approaches is essential for agricultural transformation. While comprehensive "quantum leap" transformations are often the center of discussions on innovation and progress, "convergent" transformations can be just as revolutionary. In convergent transformations, change is still rapid, but only parts of a system are transformed (Linnér and Wibeck, 2020). To encourage transformation in an area as complex and diverse as agriculture, incorporation of innovative pieces into established techniques is a useful approach. The COP27 Food Systems Pavilion mentioned above held conversations on innovation in food production, such as the application of digitization to existing climate-smart agricultural practices, and the development of novel "future foods" with reduced climate impact (Food Systems Pavilion, 2022). In a recent report titled, "Science Breakthroughs to Advance Food and Agricultural Research by 2030," by the National Academies of Sciences, Engineering, and Medicine (NASEM) it was noted that innovations and approaches

must be diversified in order for our food systems to be resilient (National Academies of Sciences, Engineering, and Medicine, 2019). Therefore, innovations in food and agricultural research should incorporate multiple conceptualizations of transformation across academia, government, and industry. Furthermore, present societal challenges will require disruptive solutions. To achieve this, researchers must be able to take risks and mirror the innovation initiatives of programs such as the Defense Advanced Research Projects Agency (DARPA). Likewise, the 2018 U.S. Farm Bill established a similar program in the Department of Agriculture, to be known as the Agriculture Advanced Research and Development Authority (AGARDA) (Research and Science, 2023). This authorization aims to promote high-risk, high-return research projects using an organizational structure modeled after DARPA and similar programs. This approach may be applied within research institutions in the public, private, and non-profit sectors to foster the scale of innovation required to meet society's most pressing challenges.

3.2. Integration

Transformation necessitates a wide range of expertise to be engaged in research and innovation. This integration is comprehensive and extends far beyond surface-level cooperation. NASEM recently released a report titled, "Enhancing Coordination and Collaboration Across the Land-Grant System," which is particularly relevant to advancing food and agricultural research (National Academies of Sciences, Engineering, and Medicine, 2022). Land-Grant institutions are embedded in the U.S. agricultural system and are the destination for a large portion of USDA National Institute

of Food and Agriculture (NIFA) research funds. The authors of the report argue that better integration within and across Land-Grant institutions will yield more impactful, far-reaching research. Beyond academic institutions, President Biden has encouraged cross-sector partnerships and engagement in multiple executive orders and strategic plans during his administration. For example, Biden's executive order on federal sustainability argues that progress in sustainability will be accelerated by cultivating better partnerships across public, private, and non-profit sectors (Biden, 2021). The White House strategy to end hunger by 2030 outlines numerous ambitious strategies that can only be achieved if a wide range of sectors and disciplines are a part of the solutions (Biden-Harris Administration National Strategy on Hunger, Nutrition, and Health, 2022; White House Conference on Hunger, Nutrition, and Health, 2022). In the non-profit sector, recent reports from the Food and Land Use Coalition (FOLU) advocate for similar cross-sector coalition building to achieve desired climate, health, and equity outcomes (Ewer et al., 2023; Resilient Food and Land Use Systems: from concept to practice, 2023).

The concept of multidisciplinary research is not new, especially in applied sciences. Over the past several years, NASEM and the National Science Foundation (NSF) have published multiple reports on the benefits of "convergence research," in which "knowledge, methods and expertise from across science and engineering" disciplines are integrated (National Research Council, 2009, 2014; National Science Foundation, 2022). Ideally, convergence research creates a "comprehensive synthetic framework for tackling scientific and societal challenges that exist at the interfaces of multiple fields" (National Research Council, 2014). Despite an increase in the use of the term, the potential for convergence in food and agricultural research remains untapped. It is argued that rapidly evolving agricultural challenges require solutions that exist at the convergence of multiple disciplines, from biology, to engineering, and to data science (National Academies of Sciences, Engineering, and Medicine, 2019). Integration requires a conceptual shift; moving from multiple disciplines simply cooperating with one another, to a more integrated and transdisciplinary approach.

This shift can and should occur at multiple organizational levels, from individual projects, to research institutions, to funding agencies and beyond. Strategies for improved integration at each of these levels may require investments in time, resources, and/or policy change for successful implementation. As outlined in the NRC report on convergence research, a "one-size-fits-all" approach to integration would ignore systemic or institutional barriers, including budgets, policies, or mission (National Research Council, 2014). Furthermore, ushering in such a shift toward integration must occur on different timelines and scales based on existing barriers.

Acknowledging these challenges, we propose examples of integration strategies on various scales. A team could shift toward convergence research by ensuring that several disciplines are included within a singular research project. In this case, collaborators would need to harness "team science" to optimize composition and function of the cross-disciplinary research team (National Academies of Sciences, Engineering, and Medicine, 2022). Alternatively, principal investigators might hire project managers who are skilled in working across multiple disciplines to ensure that each area of expertise is represented in the work. These decisions in project administration can be made in the short term, but researchers need to be incentivized to participate in convergence research, which has historically not been the case.

The onus of incentivizing integration lies with research institutions and funding agencies. At the institutional level, this could look like required trainings for researchers to hone science communication and "team science" skills or networking events for principal investigators in order to identify opportunities for cross-disciplinary engagement. Funding agencies could rework funding opportunities to require representation from numerous sectors and disciplines on a singular proposal. For example, USDA-NIFA's Agriculture and Food Research Initiative features crosscutting programs that require multiple disciplines to be represented (Agriculture and Food Research Initiative, 2023). Most recently, the U.S. Economic Development Administration's Regional Technology and Innovation Hubs (Tech Hubs) funding opportunity has taken this approach to promote simultaneous community investment and technological advancement (Regional Technology and Innovation Hubs, 2023). These examples serve as a starting point in reimagining how researchers, institutions, and funding agencies interact and collaborate across disciplines. Improved coordination, not just among research disciplines, but also among government agencies, academic institutions, and private companies, is crucial in transforming agricultural research.

3.3. Implementation

Food and agricultural systems are comprised of a range of producers, from small family farms to large, global corporations. For this reason, implementation of research findings must be optimized and scaled to achieve the maximum benefit to society. Adoption of new technologies and methodologies takes place constantly in research and development environments. In the context of agricultural transformation, this framework component may be realized in a number of ways. In developing a long term strategy for implementation, communication, policy, and financing are just as important as the innovations themselves (Govaerts et al., 2021). The NASEM report on improving collaboration among land-grant institutions recommended enhancing communication and extension to amplify research results (National Academies of Sciences, Engineering, and Medicine, 2022). This could require employing individuals who are not themselves researchers but are skilled in translating and communicating technical information to a lay audience. Such science communicators should carefully consider the language employed when describing agricultural transformation. Descriptors such as "regenerative," "sustainable," "resilient," "climate-smart," "precision," "nature-based" and other easily misunderstood terms should be clearly and appropriately defined in research communications to avoid confusion or "greenwashing" (Newton et al., 2020). This is especially important when communicating with stakeholders outside the field of research, such as policymakers or agricultural producers. Both require clear and concise communication that accurately reflects research findings. In some cases, researchers may serve as subject matter experts for legislative activities of policymakers who are not familiar with the research implications. Thus, all researchers would benefit from designated training in science communication beyond the research community. Appropriate communication allows legislators to make informed policy decisions and provides researchers with more credibility.

The USDA Climate Hubs represent another implementation model by bringing together several agencies and disciplines within the

department to better respond to the unique climate challenges faced in different regions of the United States (USDA Climate Hubs, 2022). This allows scientists, economists, and administrators to collaborate in delivering solutions that are appropriate for diverse environmental, social, and economic circumstances and present them in terms that resonate with producers' existing perception of financial gain and risk. This model is taken a step further in the Tech Hubs strategy discussed in the previous section, which requires industry stakeholders, local governments, and economic development organizations to be represented in the proposed research consortia (Regional Technology and Innovation Hubs, 2023).

In addition to effective communication from the research community to decision makers and stakeholders, funding is critical for implementation of transformative agricultural research findings. Funding mechanisms were at the root of many discussions at the 2023 AIM for Climate Summit (Agriculture Innovation Mission for Climate, 2023). Just as there is no "silver bullet" approach to the transformation of our food and agriculture systems, there is no sole financial strategy to fund innovation and implement solutions. Governments must work together with private and non-profit organizations to help scale transformative agriculture for sustained implementation (Govaerts et al., 2021). Agricultural researchers should consider these intricacies as they design, execute, and share their research to minimize barriers to implementation.

3.4. Evaluation

One critical aspect of research for agricultural transformation is our ability to measure and assess it. When conducted properly, evaluation helps build knowledge and inform decision-making and future directions. Evaluation should occur early and often throughout the entire research process and is essential in identifying societal challenges and solutions, building cross-disciplinary research teams, and measuring research impacts at all scales. This includes assessment of new and existing agricultural practices, as well as developing improved tools and techniques for data collection. It also includes the analyses and assessments that take place before the research begins and after it is completed. Thus, evaluation is the glue that holds transformative research together and the motor that allows it to propel forward. Figure 1 demonstrates the deeply embedded and integral role of evaluation within this research framework.

Consistent evaluation often results in complex, "big data" sets (e.g., from earth observations or bioinformatic data). Application of data science will be essential for the transformation of food and agriculture. The NASEM report on food and agriculture breakthroughs identified data science as a key component for agriculture transformation (National Academies of Sciences, Engineering, and Medicine, 2019). The emerging importance of data science across all areas of research indicates not only an opportunity, but a requirement, for research teams to incorporate data science expertise. Incorporating this expertise into research teams will improve their capacity for management and evaluation of large data sets and increase throughput and eventual transformative impact.

Beyond data collection, management, and analysis, the concept of knowledge management is integral to the evaluation component of this framework. USDA-ARS scientists recently reviewed the role of knowledge management in addressing modern agricultural challenges (Short et al., 2023). Knowledge management organizes and

communicates not only numeric data, but also best practices, research methods, and policy implications, to name a few. Embedding this concept into the evaluation process will promote successful execution of the remaining framework components. Effectively managing knowledge improves communication, which in turn improves integration of transdisciplinary research teams and implementation of their findings.

4. Conclusion

Adapting food and agriculture research to meet present and future challenges requires comprehensive and novel approaches. Our proposed framework aids in conceptualizing transformative research efforts amidst a convergence in food and agriculture-related priorities in the U.S. and abroad. Failure to take advantage of this convergence will result in slow, incremental change that will be unable to keep pace with current and future societal challenges. There are many promising pathways to transforming agriculture and building a more resilient, less vulnerable system that promotes human, animal, and environmental health. We encourage researchers across government, academia, and industry to adopt this framework to produce crosscutting, high impact project outcomes.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

WK initiated the idea for this manuscript. AB wrote the initial draft manuscript. AB, YL, and JL extensively reviewed and revised the manuscript. All authors discussed manuscript development, provided substantial review, and approved the final draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1242665/full#supplementary-material

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