FFAR's Research Strategy 2024-2028

FOUNDATION FOR FOOD & AGRICULTURE RESEARCH

Bold science for big challenges

Contents

Message from FFAR's Executive Director

Since the Foundation for Food & Agriculture Research's (FFAR) creation in 2014, the world has changed dramatically. We have experienced a global pandemic that disrupted food supply operations, an avian flu epidemic that sent egg prices soaring, an onslaught of various pests and pathogens plaguing crops and livestock each year, a changing climate that continues to threaten farmers' crops and livelihoods as well as consumer demands for more sustainable and nutritious foods. These changes have had a direct effect on the food and agriculture industry and created new challenges—and new opportunities.

I joined FFAR as executive director in fall 2022. I am continuously impressed by the scope and scale of FFAR's research. Our unique model fosters collaboration with our more than 550 partners to fund bold food and agriculture research.

FFAR initially established Challenge Areas in 2016, which were updated with stakeholder input in 2018 to the following six: Sustainable Water Management, Soil Health, Next Generation Crops, Advanced Animal Systems, Health-Agriculture Nexus and Urban Food Systems. While FFAR has updated our research focus over the years, we never developed a comprehensive Research Strategy.

Considering the dynamic nature of the food and agriculture sector, I wanted to hear from our stakeholders to ensure the research we fund is meeting their evolving and future needs. These challenges require a level of intersectionality that was missing from our individual Challenge Areas. I saw an opportunity to develop a Research Strategy that creates more coordination between research areas, aligns our work around intended impacts, creates opportunities to involve new partners and ensures that funded research is meeting stakeholders' needs.

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The timing of this endeavor also coincided with the development of U.S. Department of Agriculture Research's (USDA) Science and Research Strategy, 2023-2026, which outlines USDA's priorities through 2026. We worked closely with USDA to ensure our Research Strategy complements their priorities.

We began developing our Research Strategy by connecting with numerous stakeholders. We were humbled to hear that our public-private partnership model and the research we fund are successfully reflecting stakeholder needs. Yet, we continue to drive towards greater impact. The following report outlines how we will transition from Challenge Areas to focus on four overarching Research Priorities to foster greater collaboration across disciplines, strengthen the scientific workforce and provide the impacts stakeholders need.

Developing this Research Strategy has been a truly collaborative effort. We could not have developed the resulting strategy without the valuable input provided by our stakeholders. Thank you to everyone who took the time to talk with us on the phone, meet in person, pull us aside at a conference or submit thoughts online.

We are proud of this strategy, but our work is just beginning. I look forward to working with you to tackle current and emerging food and agriculture challenges together through FFAR's new Research Strategy.

Sincerely,

Saharah Moon Chapotin, Ph.D.
Executive Director

FFAR

Who We Are & What We Do

At the Foundation for Food & Agriculture Research (FFAR), we envision a world in which pioneering, collaborative science provides every person access to affordable, nutritious food grown on thriving farms and ranches.

Since 2014, FFAR has been working to realize this ambitious vision by building partnerships that support bold, actionable science informed by stakeholder engagement. We fund research to fill critical knowledge gaps, develop solutions previously deemed impossible and prepare today's scientific workforce to address the food and agriculture challenges of tomorrow. Our work requires significant collaboration across the food and agriculture system to foster multidisciplinary expertise, input from stakeholders and support from a range of funding partners.

Our agile approach leverages public funds by building public-private partnerships. Congress created FFAR in the 2014 Farm Bill and provided $200 million with the requirement that we match each federal dollar with at least $1 from a non-federal source. The 2018 Farm Bill provided the Foundation with $185 million and the same matching requirement. FFAR's model greatly exceeds this matching requirement, bringing in more than $1.40 from non-federal partners for every federal dollar allocated to research.

In addition to our successful funding model, FFAR catalyzes dynamic science by bringing multiple stakeholders together throughout the research process. Our convening capabilities and the depth of our relationships with wide-ranging stakeholders foster collaboration that is unique within the food and agriculture community. It is not every day that competitors join forces to address common challenges, yet our mission helps unusual partners work together for the common good.

Focusing on What We Do Best: Partnerships & Research

FFAR and the Innovation Center for U.S. Dairy (DMI) established the Greener Cattle Initiative in 2021 to unite partners across the public and private sectors to support pioneering research to reduce enteric methane emissions. Since then, the Consortium has awarded three grants totaling $7.2 million to address the following knowledge gaps in enteric methane mitigation:

- Testing enteric methane inhibitors and delivery methods and optimizing dietary conditions that maximize reductions in enteric methane emissions;
- Studying how diets and different methane inhibitors alter enteric fermentation and how they affect the amount of enteric methane produced; and
- Developing genomic evaluations for methane traits to selectively breed low methane emitting cows.

The Greener Cattle Initiative, through its collaborative public-private partnership approach, is significantly changing the research landscape around enteric methane:

1. This is the first consortium to leverage investments and accelerate research to develop scalable and commercially feasible solutions that specifically reduce enteric methane emissions.
2. The Consortium brings together a unique combination of industry expertise, including producers and animal health, genetic, feed and nutrition research organizations and companies.
3. Lastly, with an initial investment of $2,352,628, and additional contributions from the Consortium's 11 partners and co-funders, the Consortium will invest at least $14 million into cutting-edge research.

"The Greener Cattle Initiative consortium exemplifies how FFAR's public-private partnership model propels innovation and creates effective options to complex, urgent challenges. FFAR partnered with the Innovation Center for U.S. Dairy to convene a wide range of stakeholders through the Greener Cattle Initiative to develop enteric methane mitigation options for the beef and dairy industries."

Dr. Juan Tricarico, Senior Vice President, Environmental Research at the Innovation Center for U.S. Dairy

FFAR's Collaborative Approach
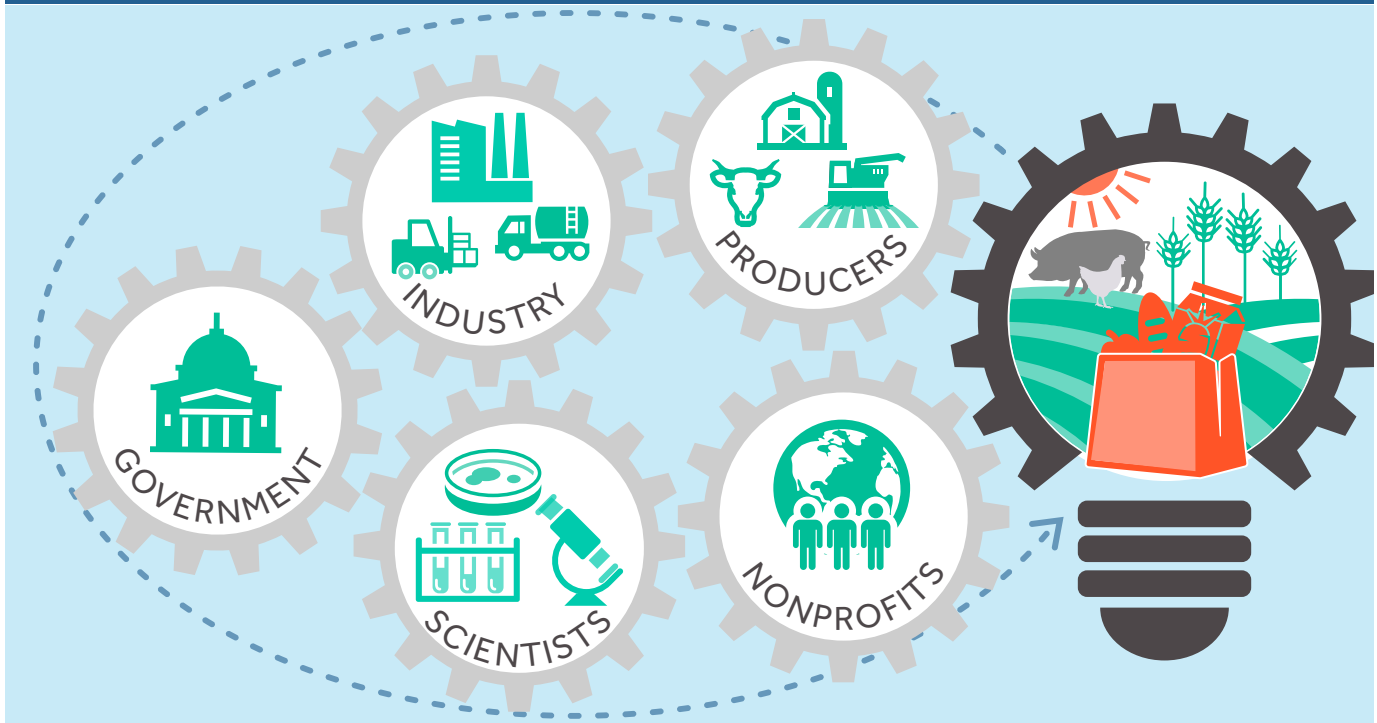
As we approach our 10-year anniversary, FFAR is redoubling our efforts to deliver solutions to a U.S. food and agriculture system facing some of the world's greatest challenges. We are strengthening existing partnerships while identifying new partners in the scientific community, philanthropic organizations, the private sector and throughout the food and agriculture system, and we will collaborate with these partners to work toward our vision, building on the notable results we have achieved thus far.

In 2019, FFAR issued a Strategic Plan that described the Foundation's value proposition as our ability to leverage public dollars to mobilize private investment, form partnerships between public-private entities, identify and address important gaps in food and agriculture science and facilitate the translation of research into impact. It further noted that FFAR's public funding from Congress is essential to bringing partners to the table and allows FFAR to serve as an independent, neutral third party. The Strategic Plan advanced FFAR's previously established Challenge Areas, which were created with stakeholder input to address urgent food and agricultural concerns, as our primary research focus areas; however, the Strategic Plan did not include an overarching Research Strategy.

The Research Strategy documented herein builds upon the Strategic Plan by outlining a research goal and redefining our research priorities. This Research Strategy seeks to refine what we do and how we work to ultimately make FFAR more impactful.

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Providing Returns on Public & Private Investments

Together with our 550-plus funding partners, FFAR has awarded more than 350 grants. The Foundation has invested over $730 million into pioneering food and agriculture research, including more than $300 million in federal funds and $430 million from matching partners as of October 2023. FFAR first awarded grants in 2016.

Food and agriculture research takes time. While some projects yield results in a few years, most agricultural research investments take a decade or longer to accrue full benefits. These investments are worth the wait, as results can secure the global and U.S. food supply, increase farmer profits, lower consumer costs, address market challenges, improve animal health and wellbeing, deliver more nutritious crops, build

resilience and provide significant environmental benefits. The full impact of FFAR's investments is still being realized, and some have already yielded impactful results. Many of these investments and their results are detailed in our annual Impact Reports, further highlighting FFAR's proven value for the food and agriculture sectors.

Additionally, public agriculture research offers significant returns on investment. USDA Economic Research Service found public agricultural research spending generated, on average, $20 in benefits to the U.S. economy for every dollar spent. We expect our investments will similarly add to economic growth.

FFAR Funding Amplifies Actionable Food & Agriculture Research

1X FFAR Funding + **1.4X Matching Funds** (non-federal) = **2.4X the IMPACT**

Future Challenges for the U.S. Food & Agriculture System

The U.S. food and agriculture system is a great American success story and has not only provided consumers safe, affordable and convenient food, its exports have also played a pivotal role in the world's food security.

Nevertheless, consumers' expectations of the food and agriculture system are changing. They want to know the history of their foods from farm to table. They want to ensure that farm workers and ranchers thrive and that farm animals are

treated well. They want safe, nutritious food made with few, familiar ingredients, and they want to know that their food was produced, processed and delivered sustainably.

Consumer expectations, manifested in their purchases from food retailers, permeate the value chain through branded food manufacturers who, in turn, expect their ingredient suppliers, farmers and ranchers to help in meeting these consumer wishes.

FFAR

FFAR Works Across the Food & Agriculture Value Chain

Resources & Inputs → **Production** → **Processing** → **Retail/ Food Service** → **Consumers**

Resources & Inputs
- Land & water-based solutions
- Improved animal breeds & crop varieties
- Approaches & tools to ensure animal welfare
- Tools for managing crop pests & diseases

Production
- Providing farmers data, tools & technologies to curb agriculture's impact on the environment.

Processing
- Sustainable food packaging
- Improved ingredients
- Food traceability & transparency data

Retail/Food Service
- Alternative proteins
- Nutritional quality metrics

Consumers
- Understanding consumer behavior & demands
- Approaches & tools to improve food safety

Resource & Waste Recovery

FFAR's research priorities span the whole value chain. We partner with a range of stakeholders, including input suppliers, farmers, ranchers, processors, food companies, retailers and many more to identify and address whole-of-value-chain challenges to sustainably deliver safe, nutritious food to consumers.

Global concerns about environmental impacts and a changing climate are increasingly leading industries to improve their environmental footprint. Increased sustainability across industries requires companies to work across the whole supply chain to address direct and indirect environmental impacts.

Achieving this level of sustainability further requires significant new research and technology, which FFAR is leading in many areas, and the need for increased sustainability is often a catalyst that drives the private sector to partner with us.

Meeting these challenges demands that all food system players engage in developing, testing and deploying research and technology. As highlighted in FFAR's 2019 Strategic Plan, we are uniquely positioned to bring relevant players together. FFAR's mandate, neutral status, agility and congressional funding allow us to form consortia and partnerships with the relevant parties needed to tackle industry-wide and value chain-wide problems.

Poised for the Future

In early 2023, FFAR launched a process to document our Research Strategy and ensure we continue prioritizing research that addresses new challenges and leverages new opportunities while also partnering with new stakeholders. We began by soliciting input from numerous stakeholders, which involved a public webinar with 76 written comments; mixed panel discussions with 24 representatives from industry, nonprofits, academia and international actors; and interviews with 74 stakeholder organizations from across the value chain, including 23 companies, 13 commodity groups, 10 producer trade associations, six foundations, seven nonprofits, five federal agencies, the National Association of State Departments of Agriculture, six research universities, four scientific societies and the Association of Public and Land-grant Universities. The Acknowledgement Section at the end of this document includes a full list of organizations that contributed to our strategy.

Through this engagement, the following themes emerged (further elaborated in the Appendix):

When asked about the current state of U.S. food and agriculture, stakeholders recognized the urgency to address climate change and broader ecosystem health. Stakeholders foresee solutions to these challenges through value chain connections supporting producer actions and fulfilling strong environmental and social commitments. We further heard calls for broadly accepted metrics and standards to empower producers and provide predictability for business decisions across value chains. Stakeholders identified specific emerging concerns and promising new technologies across production and post-harvest, emphasizing supply chain, automation, artificial intelligence and bioeconomy opportunities along with more traditional areas of research investment.

Based on the input we heard, FFAR is exploring research across the following interrelated areas:

- Improvements in crop and animal production systems for multiple productivity, environmental, welfare, health and bioeconomy traits;
- Agriculture-specific data science and artificial intelligence/ machine learning for automation, modeling, genetic analysis and decision tools;
- Systems approaches for ecosystem and human health;
- Circular bioeconomy;
- Nutrition, food quality and food safety;
- Tools and metrics for environmental and social impact; and
- Tools for understanding decision-making and adoption.

The Research Strategy outlined below was informed by stakeholder input as well as an internal review of scientific literature.

Stakeholders confirmed that we are investing in areas of critical importance, and overall, ourpreviously established Challenge Areas reflect stakeholders' research priorities. FFAR will continue our meaningful work — ensuring our research achieves defined impacts and delivers on the overarching goal outlined below.

However, we heard from stakeholders that more intersectionality is needed to better address critical research. To foster greater collaboration across disciplines, FFAR's Research Strategy will be organized around the four Research Priorities, outlined below, rather than specific Challenge Areas.

FFAR's Research Strategy
Setting an Ambitious Goal

The U.S. food and agricultural enterprise, like that of the rest of the world, is facing new and accelerating challenges, including greater competition for limited resources, water scarcity, increased weather variability, rising input costs, the constant threat of pests and pathogens and the imperative to have a positive or neutral impact on the environment. Meanwhile, demands on the food system necessitate increased efficiency and improvements in food safety and nutrition. Continued investment in innovative research and a diverse, creative scientific workforce is critical to address these unprecedented global challenges urgently.

Recognizing this, and considering the input FFAR received from stakeholders, our research will seek to support this ambitious goal:

> A U.S. food and agriculture system that supports producers and their communities, sustains the environment and enables processors and retailers to deliver foods that equitably nourish our population.

FFAR's Research Strategy works toward this goal by focusing our research around four central priorities that together aim to provide the specific impacts stakeholders need to improve and advance the food and agriculture system. Our strategy also accounts for external drivers that allow us to better align FFAR's research with that conducted by others.

FFAR

Research Priorities

Beginning in 2024, FFAR will focus on four interrelated, strategic research priorities as we strive toward our goal. These priorities reflect a systems approach — recognizing the complex relationships between primary production systems, agroecosystems and the food system as a whole. Collectively, these priorities drive transformational systemic change by taking a broad view of U.S. agriculture, considering its social, environmental and economic benefits and impacts.

Cultivating Thriving Production Systems

Production systems thrive when input providers and producers have the information and technologies (novel germplasm, digital tools, pest and disease solutions, etc.) necessary to manage their enterprises efficiently and profitably — which includes selecting animals, crops and management practices that support site-specific environmental, social and business goals.

Approach

FFAR will support animal and crop systems research to develop knowledge and tools that increase productivity, combat pest and disease threats, support animal welfare and safeguard producers' return on investment. We will do this in ways that advance economic, social and environmental benefits and producers' ability to make tradeoffs informed by biophysical conditions and market demands and opportunities.

Sustaining Vibrant Agroecosystems

Tools, technologies and integrative models designed at scales needed for site-specific decision making allow producers to create, build and maintain healthy, productive agroecosystems that meet consumer expectations under changing climate conditions. Such solutions must provide flexibility to deal with future uncertainty and clarify trends and trade-offs in environmental regeneration, productivity and resilience.

Approach

FFAR will support research to deepen our understanding of agricultural system interactions with surrounding ecosystems. This research will focus on how changes in environmental conditions, production systems and practices affect biodiversity, water systems and climate change to support efficiency, regeneration and resilience.

Bolstering Healthy Food Systems

In a healthy food system, food processors, distributors and retailers have the information and technologies needed to produce nutritious, environmentally sustainable and culturally appropriate food for consumers. Likewise, consumers require convenient access to safe, nutritious, desirable foods with a balance of macronutrients, micronutrients and protective phytochemicals — chemicals plants produce for their protection that also benefit human health.

Approach

FFAR will support research that promotes the availability of nutritious, quality foods to diverse populations; promotes human health and nutrition outcomes; improves food safety; reduces loss and waste; develops novel food processes and products; increases understanding of social and cultural dimensions of food security and nutrition; and advances the overall functionality of the food system.

Strengthening the Scientific Workforce

Addressing the accelerating and unprecedented global challenges faced by the U.S. food and agricultural enterprise will require a dynamic and highly skilled scientific workforce. Moreover, developing a diverse and inclusive workforce is critical to drive innovation, foster creative solutions and lead pioneering science.

Approach

Since its inception, FFAR has prioritized and will continue to support scientific workforce programs that center on working with public and private stakeholders to understand, evaluate and address current needs in research and scientific workforce training. Based on those needs, FFAR is co-creating unique training opportunities for future food and agriculture leaders.

The Impacts We Seek

In alignment with funding research necessary to meet the goal outlined in this Research Strategy, FFAR also aims to design research that will deliver one or more of the following impacts.

Sustainably Intensified Productivity

Agricultural productivity has long been understood as a powerful driver of economic growth. Indeed, the USDA reports that the U.S. agriculture and food industry contributes $1.1 trillion to the country's economy and represents nearly 11% of total U.S. employment. To meet the needs of our dynamic food and agriculture system, research investments must provide adaptive and responsive solutions. FFAR will invest in research and scientific workforce development that enables more efficient animal and crop production systems, sustainably increasing profits and benefiting producers and processors of all sizes and their communities while delivering the products that underpin our food system.

Increased Environmental Sustainability

While agriculture is responsible for 13% of greenhouse gas emissions, the sector can also be a powerful climate change solution. Research is the linchpin to developing practices and tools that reduce emissions and minimize negative environmental impacts. Furthermore, increasing adoption of these practices and tools can bolster the ability of sustainable food and agricultural systems to produce a sufficient quantity and diversity of food in ways that protect the environment. Through the creation of innovative partnerships with all parts of the food and agriculture system, we will support research and scientific workforce development programs that produce evidence-based guidance and tools to enhance productivity and enable sustainable water and nutrient management, improve soil health, mitigate climate change and deliver other ecosystem benefits.

Improved Human Health

The World Health Organization defines health as "a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity." To equitably nourish our population, more research is needed to understand the inefficiencies in current systems and opportunities to develop crops and foods with improved nutrition, as well as how the food system impacts human health more broadly. To improve human health, FFAR will invest in food and agriculture system research and scientific workforce development opportunities that provide proven approaches and tools to deliver positive health and wellness outcomes for people.

Key Drivers

To ensure we are well positioned to deliver the impacts we seek, FFAR will use the key drivers below to prioritize research investments.

Diversity, Equity & Inclusion

Bringing individuals with diverse perspectives, experiences and backgrounds historically underrepresented in science to food and agriculture research results in more innovative and actionable outputs. FFAR is committed, both internally and externally, to supporting diversity, equity and inclusion. We will continue embedding greater diversity, equity and inclusion into our work, including in the design of research and training programs as well as in consideration of how results are used and communicated.

Sources of Matching Funds

FFAR seeks every opportunity to proactively collaborate with funding partners to identify matching funds or secure a match commitment prior to issuing research opportunities or calls for proposals, rather than relying on applicants to identify matching funds. FFAR recognizes that requiring applicants to identify matching funds prior to submitting a proposal may prevent some researchers from engaging with us, especially when their institutions are not well resourced or do not have strong industry connections. FFAR has successfully reduced reliance on applicant-match over time and we aim to continue this trend to further broaden our potential pool of research partners.

In addition to industry, foundations are important partners for FFAR and are often a source of match commitment that allows researchers to bring their best science to a challenge regardless of their ability to identify matching funds. There is strong alignment between FFAR's commitment to diversity, equity and inclusion, societal impact and environmental sustainability and the missions of many foundations. We will increasingly seek to partner with foundations, as well as with industry players, nonprofits and non-U.S. government entities to proactively secure matching funds.

Some FFAR funding opportunities may still require applicants to secure matching funds. For example, applications to our rapid-response research program, Rapid Outcomes from Agricultural Research, will still require applicants to secure matching funds, as FFAR cannot anticipate the need for this research in advance.

Complementarity With Federal Agencies

FFAR's research agenda seeks to complement USDA's research investments as well as those of other federal agencies investing in food, nutrition and agriculture research. We will continue to maintain this complementarity and avoid duplicating efforts by:

1. Filling knowledge gaps by investing in areas that federal research agencies do not prioritize or are unable to fund;
2. Employing different funding models to address shared priorities; for example, utilizing public-private partnerships, prizes or other approaches to incentivize development and adoption of research outcomes; and/or
3. Providing funds in a manner that federal agencies cannot typically support or on an expedited timeline; for example, rapid response grants to urgent or emerging challenges.

Industry Collaborations

FFAR provides a unique opportunity for food and agriculture companies to collaborate and advance outcomes of shared interest, both by bringing competitors together and by connecting players along the value chain. FFAR establishes consortia to support research on common challenges recognized across the sector, where working in the precompetitive space provides solutions beneficial to all members and society. Consortia participants jointly determine research priorities, provide necessary funding, pool resources and knowledge and share research results. We will leverage our proven success in establishing impactful consortia to help meet consumer demand for sustainably grown, safe, nutritious and convenient food products. By bringing industry together to support actionable, user-driven research, FFAR's consortia deliver the solutions that producers, processors and others need to meet market demands.

Global Science, U.S. Benefits

FFAR recognizes that challenges faced in the U.S. food and agriculture system are often shared globally. To ensure that we are tapping into the best of global science, our opportunities are open to researchers across the world, and we routinely create international partnerships. The Farm Bill instructs us to address food and agriculture challenges of national and international significance. In recognition of FFAR's funding model and our efforts to provide U.S. taxpayers a strong return on investment, the Foundation's investments will always benefit U.S. food and agriculture systems, even when addressing global challenges.
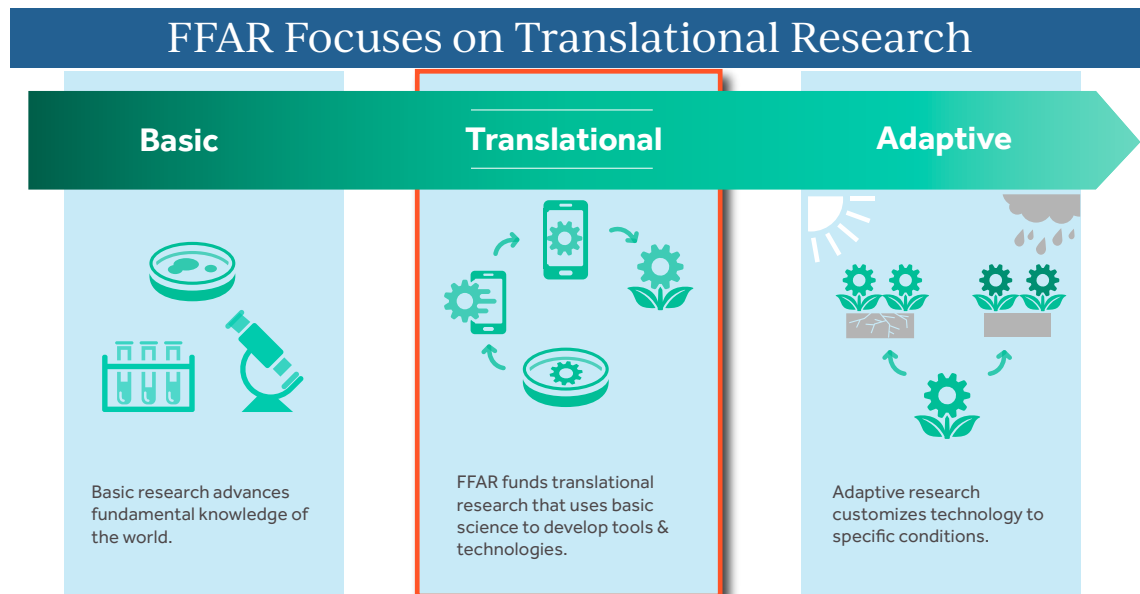
Excellence Through Competition

When possible, FFAR will prioritize competitive grant opportunities to identify and support diverse ideas, approaches and researchers. However, to remain agile and support innovative approaches, we also employ other funding mechanisms such as prizes, direct fund awards and consortia, and we accept unsolicited proposals. The Foundation employs a peer review process for all research proposals as part of our commitment to funding rigorous science.

Actionable Science, Translational Research

FFAR strives to balance research activities designed to deliver near-term outputs and research that is perceived as longer term or higher risk. Additional food and agriculture research is necessary along the entire continuum — from basic to translational to adaptive — and FFAR will emphasize translational research in its research portfolio. Moreover, our research will seek to build upon and translate the research outputs from federal science agencies where there is a greater focus on basic research. In addition, the Foundation will continue to quickly fund certain unanticipated research activities when situations require a rapid response.

FFAR Focuses on Translational Research

Basic — Basic research advances fundamental knowledge of the world.

Translational — FFAR funds translational research that uses basic science to develop tools & technologies.

Adaptive — Adaptive research customizes technology to specific conditions.

While FFAR-supported research activities span the research continuum, the majority are characterized as translational. Informed by our stakeholders and funding partners, we will focus on research that translates outputs and knowledge from basic science to tools and technologies our stakeholders will adopt.

A Convergence Approach

Recognizing that diverse areas of expertise are necessary to solve complex problems, we will bring a convergence approach to our work. As defined by the National Science Foundation, convergence research "entails integrating knowledge, methods and expertise from different disciplines and forming novel frameworks to catalyze scientific discovery and innovation." Our convergence approach will bring scientists from a range of disciplines together to engage in new and creative partnerships to address food and agriculture challenges.

Next Steps

As we begin to implement our Research Strategy, our work will be organized around our four overarching Research Priorities and incorporate our previously established Challenge Areas portfolios as follows:

- Work previously included in our Advanced Animal Systems and Next Generation Crops Challenge Area portfolios will merge and be complemented by new research that cultivates thriving production systems.
- Research to sustain vibrant agroecosystems will encompass activities that were previously grouped within the Soil Health and Sustainable Water Management Systems Challenge Areas and AgMission™, as well as new programming.
- The Health-Agriculture Nexus and the Urban Food Systems Challenge Areas will merge to develop research that bolsters healthy food systems.
- Our ongoing and future scientific workforce development efforts will be elevated and serve to strengthen the scientific workforce.

We will use an interdisciplinary approach as we focus on these four priorities and work toward our research goal. Through robust internal collaboration and new and enduring external partnerships, FFAR will continue to tackle current and emerging food and agriculture challenges.

Acknowledgements

Appendix:
Synthesis of Stakeholder Engagement

Stakeholder Engagement Process

FFAR began its Research Strategy process by developing a Theory of Change, a practice that challenges an organization to work backwards from high-level goals to identify causal relationships and dependencies required for program actions to the envisioned impact. We combined a literature review with a collaborative internal process to develop a draft Theory of Change, which was tested and improved through peer review by external experts from academia, civil society and industry. This draft was presented at a public webinar to invite public comments and to structure conversations with a broad range of stakeholders. The process was designed to ensure that FFAR heard from a diversity of known and potential partners from along the research-to-development pipeline and across the value chain, including commodity promotion groups, input supply industry, production industry, food and beverage industry, civil society, federal and state agencies, researchers, scientific societies and research administration.

The stakeholder engagement invited input around the following questions:

- What is the current state of the food and agriculture landscape?
- What are the current and future challenges and what do you need research to deliver?
- How can FFAR have the greatest impact?

Synthesis of Stakeholder Input

Current State of the Food & Agriculture Landscape: What Has Changed

The most consistent theme we heard from stakeholders is the urgency of coping with climate change impacts on production systems. Stakeholders recognized the need to address climate adaptation and advance mitigation while investing in productivity.

Commenters from across the value chain also noted the importance of broader ecosystem health. This recognition was expressed in strong and specific commitments towards environmental, social and governance goals, placing a high priority on climate, water, biodiversity, animal welfare and social issues. Some of these commitments can be met by companies directly, but stakeholders identified an important gap for food and beverage companies whose commitments rely on changes in production practices by other businesses. Scientifically validated metrics and standards are not adequate to demonstrate the impacts that are required to provide financial support and economic benefits to producers for meeting value-chain demands. The uncertainty in metrics and standards also denies predictability to producers to plan and invest their plotting a profitable path forward.

Stakeholders reported uncertainty for producers and processors from emerging concerns about soil and water contamination with PFAS (per- and polyfluoroalkyl substances), the "forever chemicals" that have very useful properties as ingredients and coatings but also pose serious health risks still under research. The regulatory landscape is evolving as more is learned about contamination and mitigation. Other areas of regulatory uncertainty include biostimulants, plant protection, nanotechnology, animal welfare and water quality.

Stakeholders see opportunities in emerging areas such as the increasing diversity of cultivated products, and bioeconomy opportunities, including the potential for upcycling of byproducts previously considered to be waste. Many also expressed great interest and excitement about the digitization of agriculture, increasing data availability, improving data stewardship and expanding advanced artificial intelligence (AI) and machine learning (ML) tools in the domain of agriculture. These technologies hold promise for better understanding the present, predicting the future, adapting to the impacts of climate change, managing risks and creating efficiencies across food and agriculture.

The COVID-19 pandemic brought heightened attention to supply chains, international trade across food and agriculture and labor issues. Labor shortages and worker welfare issues were highlighted by stakeholders, driving increased interest in automation. Stakeholders expressed the need not only for new technologies but for attention to their practicality for smaller farms, specialty crops and post-harvest enterprises. In addition to solving acute labor shortages, automation is seen as one way to attract the next generation of farmers, but stakeholders are aware of the shortages in the skilled workforce such technologies require, including skills in the agriculture-specific AI/ML tools that often drive their application.

As the complexity of challenges increases, stakeholders see the need for systems approaches and greater integration across sectors and disciplines. Commenters called for greater involvement of the social sciences in general, particularly calling attention to their value to understand preferences and choices of consumers and rates of adoption of improved technologies and practices by producers.

Stakeholders appreciate the work we do to develop the scientific workforce in food and agriculture and expressed a desire to reach beyond the traditional agricultural disciplines. Stakeholders also encouraged FFAR to further enhance leadership from minority-serving research institutions and to support researchers whose work benefits smaller farmers. Research administrators expressed concern about the challenges of attracting and supporting graduate students and early career scientists doing work to advance food and agriculture research, highlighting the need for domain-specific AI/ML expertise.

Research to Deliver Solutions to Familiar & Emerging Problems

Production Systems

Food and agriculture stakeholders are eager to see the sector contribute to multiple aspects of sustainability, asking researchers to work towards crop and animal production systems that can meet productivity, environmental and social goals.

- Maintaining or increasing production under climate change requires resilience to temperature and moisture extremes and management of current and invading weeds, pests and diseases. This requires new varieties, new crops and new breeds, along with co-development of management practices appropriate to variable environmental and biological pressures.
- The research envisioned by stakeholders also supports agriculture's relationship with the surrounding landscape by attending to water-use efficiency, energy input, impacts on biodiversity and interactions with biogeochemical cycles for nitrogen and carbon.
- For animal agriculture, stakeholders highlight the complexities of meeting new expectations for animal welfare and antimicrobial stewardship while achieving environmental goals — all at an affordable cost for consumers.
- The food system is also raising expectations for nutrition profiles for macro- and micronutrients and other food properties while maintaining excellent food safety.
- A parallel set of demands is placed on production, processing and delivery for the bio-based economy.

Stakeholders understand that the complexity of these demands requires increasingly integrated approaches to research and management, bringing together domains of expertise from multiple fields of research and the sectors that will take up the research. For example, animal disease and welfare are increasingly thought of in the context of integrative biosecurity, and manure management includes the potential for energy generation and attention to the food safety of fresh produce. Stakeholders also commented on the need to expand precision sensing, mechanization and automation for irrigation, fertilization and harvest. Making this practical and affordable for small farms and specialty crops requires not just agronomy, engineering and computer science but also social science research. Stakeholders urged FFAR to expand learning from Indigenous foodways and highlighted potential contributions from new crops, specialty crops and perennials to meet productivity, nutrition and environmental goals.

Data science tools hold incredible promise for agriculture, supporting increasingly useful models to predict climate change impacts, revolutionary genetic analysis, customized sensing and automation, supply chain analytics and site-specific decision tools across production inputs and management. Stakeholders commented that unlocking this potential requires resolving data access and compatibility issues and generating food and agriculture domain-specific AI and machine learning tools.

Agroecosystems

Stakeholders across the food and agriculture landscape urged FFAR to continue pursuing systems approaches for ecosystem and human health. They require additional research to deepen understanding of connections between soil health, carbon, water, crop health and fertility, biodiversity, food and nutrition properties, and animal and human health across production systems. Stakeholders highlighted the need for increased work in livestock and grassland systems, greater attention to perennial species and incorporation of forest systems.

Envisioning vibrant systems of the future also requires research at larger scales over time and space, challenging researchers to work from plot and farm to landscape scales — and in the case of integrative biosecurity, even across borders. Systems models need to connect agricultural production; microbiomes of plants, animals and soil; carbon and nitrogen cycles; water quality and quantity; biodiversity; society; trade; and localized impacts of climate changes. This is not a theoretical exercise; the understanding gained from

such modeling will be needed by food and agricultural enterprises across the value chain to craft viable adaptation pathways for their businesses over time.

Stakeholders recognized a need for deeper understanding of biogeochemical mechanisms and systems models with further support for a more circular bioeconomy, placing food production within the broader context of agricultural production for natural fibers, biofuels and biochemicals. Many stakeholders see practical and efficient solutions to the many demands on the food and agricultural system through biomass reutilization, bioenergy production, bio-based agricultural inputs for fertility and pest and disease management, and the production of bio-based chemicals for industry and medicine. Potential research in these areas ranges from the molecular scale to life-cycle analyses for entire industries.

Food Systems

Stakeholders see a continuing role for FFAR in post-production aspects of the food system to deliver nutritious, high-quality, appealing and safe foods while delivering on sustainability targets concerning how food is grown. Processing, packaging, transportation and retail activities contribute to reliable supply chains that can deliver the information needed for food traceability and transparency. Stakeholders recognize research needs in precision mechanization and sustainable packaging, along with an integrative understanding of their interactions with ripening control, microbiota and pathogens. A systems approach to food includes linkages back along the value chain to production decisions and forward to integrated food science research on fermentation, metrics for sensory and nutrient profiles, and even the personalization of nutrition to individuals and their microbiomes. Stakeholders support the need for social science work and the integration of perspectives from Indigenous foodways to improve understanding of current and possible food systems.

Delivering on sustainability commitments for food and beverage products requires greater cross-sector communication and collaboration. Stakeholders noted a need for increased research to fill gaps in measurement and reporting on multiple facets of the food value chain, including ecosystem impacts, economics and labor, animal welfare and nutrition information. Filling these gaps with scientifically validated measurements and data standards would support decision-making and enable market pathways to provide economic benefits to producers and support the rigor of claims made to consumers. Tools generated for this purpose need to be practical for use by small farmers as well as large and on specialty crops as well as commodities. In general, all users across the value chain need measurement and reporting tools to be cost effective, time efficient and widely accepted.

FFAR's stakeholders see multiple roles for the social sciences to improve understanding of critical issues in food systems, particularly in decision making and behavior change. Understanding consumer demands and behavior involves research in economics, culture and social systems. Social sciences can also deepen understanding of how to increase adoption of new technologies and practices by producers. Possible avenues of research range from characteristics of trusted site-specific decision tools to understanding unique barriers for small-scale enterprises and underrepresented groups. Stakeholders further see a need to leverage extension mechanisms and increase the synthesis and translation of science.

Scientific Workforce

Stakeholders expressed appreciation for FFAR's unique support of the scientific workforce and urged FFAR to continue supporting early-career scientists and early-stage research. Commenters particularly value supporting scientists in interdisciplinary work and elevating the participation and leadership of social scientists throughout food and agricultural research.

Achieving Impact: FFAR's Value Proposition

Stakeholders see FFAR as uniquely responsive to stakeholders and open to new ideas. FFAR has relationships with multiple sectors and facilitates valuable partnerships between researchers and the private sector, leading to new knowledge, technologies and practices that are practical, efficient and relevant to evolving needs. Stakeholders also value FFAR's ability to rapidly respond to emerging issues.

FFAR is known for our convening abilities; we bring together diverse stakeholders including nontraditional voices. By convening entities that would not normally work together, FFAR can workshop problems and facilitate research avenues that would not otherwise have been envisioned.

Stakeholders derive significant value from FFAR's pre-competitive, public-private consortia. This funding mechanism connects competitors and companies across highly segmented industries to solve common problems that are too big or too risky for any one organization to solve, moving the food and agriculture system towards a more sustainable and vibrant future.

Bold Science for Big Challenges

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