

Pursuing a Unifying Message

*Elevating Food, Agricultural and
Natural Resources Research as a National Priority*



Charles Valentine Riley
Memorial Foundation

IOWA STATE UNIVERSITY



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*Elevating Food, Agricultural and
Natural Resources Research as a National Priority*

Charles Valentine Riley Memorial Foundation

and

Iowa State University

in a partnership with

Mississippi State University, Soil and Water Conservation Society,
Texas Tech University and Colorado State University

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Foreword

Something is wrong when agriculture is left out of invitations to set the course for future national science programs that benefit society. Something is wrong when agriculture does not have a seat at the table in discussing federal investments to spur innovation.

Distressingly, those situations are becoming more common. Those of us who care deeply about the science of food, agriculture and natural resources need to change this situation. That's why this report, *Pursuing a Unifying Message: Elevating Food, Agricultural and Natural Resources Research as a National Priority*, is so important. It is a stepping stone for serious consideration on how to move food, agricultural and natural resources research higher on the priority list for government-supported research. We need a clear strategy and a common message to ensure agricultural research is a much higher priority for the nation.

It presents a case for why we should be pursuing a unifying message on the importance of investing more in agricultural research. The report should be raised up as a call to action to bring together a broad coalition to think carefully and decisively about developing the message and the blueprint.

Pursuing a Unifying Message is the launching pad to inspire a diverse set of groups to come together and realize how important this goal is not only for the future of American society, but for the global village. The report makes it clear that we need a loud, clear and common message that investments in broadly defined food, agricultural and natural resources research must increase. Each segment of agriculture must come out of its silo and think less about business-as-usual winners and losers. Each must think more about the advantages of working together with a broader set of society's stakeholders on a common agenda and a common end — an end that results in a compelling message on the relevance of broad, diverse agricultural research that captures attention on the national stage.

There is very little we cannot accomplish if we agree on taking a shared approach. *Pursuing a Unifying Message* is an excellent rallying point to making the case. This report is the planted seed that now must be germinated and nurtured to full stature. It is time to make U.S. agricultural research the priority it deserves to be and it absolutely must be for our common future.



Daniel Glickman
Former U.S. Secretary of Agriculture,
Vice President of the Aspen Institute and
Executive Director, Aspen Institute Congressional Program

Preface and Acknowledgements

The journey that we are now on — to pursue a unifying message to elevate agricultural research as a national priority — may be traced back to the latter part the 19th century. In 1872, Charles Valentine Riley stated: *“None but the well-informed are successful...for success in agriculture...today, implies knowledge — scientific knowledge.”* Riley made many scientific contributions, but perhaps his greatest legacy was his ability to see the “whole picture” of the role of agriculture and forestry in the productive, sustainable use of the landscape, as an artistry upon which all society depends.

The Riley legacy was kept alive during much of the 20th century primarily through the extensive insect collection he contributed to the Smithsonian Institute, a number of writings about his contributions and student awards in his name granted by the Entomological Society of America or its affiliates. When his youngest daughter, Catherine Vidalia Riley, died in 1972, a trust was established to honor her father. The trustee, Victor John Yannacone, Jr., donated many of C.V. Riley’s papers and artifacts to establish the Charles Valentine Riley Collection at USDA’s National Agriculture Library. Thus, both Catherine Riley and Victor Yannacone are to be recognized for their efforts to preserve the Riley legacy. In 1982, Yannacone reached out to USDA to implement a program to honor Riley. With the invaluable assistance of USDA’s Assistant Secretary for Research and Education Orville Bentley, a key outcome was the founding of the Charles Valentine Riley Memorial Foundation (RMF) in 1985, with John C. Gordon, then Dean of Forestry and Environmental Studies at Yale University, as its first president.

RMF seeks to promote a broader and more complete understanding of agriculture as the most basic human endeavor and to enhance agriculture through increased scientific knowledge. Much of what RMF has accomplished over the years can be found at www.rileymemorial.org, but it is important to acknowledge those who played key leadership roles for the foundation. Those include Gilbert A Leveille, past president of the Institute of Food Technologists and former research administrator in the private sector; Ralph Grossi, then president of the American Farmland Trust; and Edward Hiler, vice chancellor and dean emeritus, agriculture and life sciences, at Texas A&M University. The Riley legacy also has been well-represented over the years by his granddaughter, Emilie Brash of Hampshire, England, an original RMF board member and concurrently director emeritus. I have had the pleasure of working with all those aforementioned dignitaries in one role or another since Yannacone contacted U.S. Secretary of Agriculture John Block in 1982.

RMF accomplished many good works over the years by bringing together diverse groups to work more effectively on issues such as soil and water conservation, food safety and invasive species. However, efforts to build unified support for research that increases knowledge for broadly defined agriculture found limited success. Taking advantage of its past experiences, RMF began to look for opportunities to reach out more broadly. In 2008, RMF selected the American Association for the Advancement of Science (AAAS) to receive an endowment to further the goals of RMF and build on Riley’s legacy, primarily through an annual lecture. Charles Valentine Riley’s involvement with AAAS, which included his service as vice president of the biology section in 1888, was a contributing factor in the decision to place the endowment with AAAS.

At the first event organized by RMF in 1986 at the National Academy of Sciences, a featured speaker was Nobel laureate Norman Borlaug, who announced plans to establish the World Food Prize. That event and a continuing relationship between RMF and the World Food Prize Foundation (WFPF) led to a formal arrangement.

With the establishment of the Riley endowment in 2008, RMF, AAAS and WFPF signed an agreement to implement the intent of the endowment. Alan Leshner, CEO for AAAS and executive publisher of *Science*, and Ambassador Kenneth Quinn, president of WFPF, were instrumental in consummating the agreement.

In addition, CaseIH, DuPont, Mars Inc. and the USDA joined the effort as sponsors of the annual lectures. Collaboration between AAAS, RMF and WFPF has provided a unique opportunity to build upon Riley's legacy.

Along with the first AAAS Riley lecture in 2010, RMF organized the first networking breakfast for leaders concerned with food, agriculture and natural resources research. In 2012, AAAS joined RMF in organizing this annual event. At the breakfast held on June 5, 2013, Catherine Woteki, USDA Undersecretary for Research, Education and Economics, and Alan Leshner, CEO of AAAS, made informal remarks. Dr. Woteki reported that China was now investing more in agricultural research than the United States; also, China had increased its investment as much as 10 percent annually. Dr. Woteki said the rate of increase in related productivity was on the rise in countries such as China and Brazil — at rates substantially greater than in the United States. Later, in discussions with the RMF leadership, Dr. Leshner shared his concern regarding investments in research. On July 26, 2013, RMF released a brief on international investments in agricultural research and productivity, with data provided by Keith Fuglie of USDA's Economic Research Service. Dr. Leshner published an editorial in *Science* entitled "Maintaining Science Eminence" on August 23, 2013, in which he stated: "*Agriculture R&D provides a dramatic example of how neglect can undermine a scientific domain.*"

With Dr. Leshner's encouragement, RMF organized a focus group session with 17 participants that was held at AAAS on November 12, 2013, to discuss the topic of "Advancing Food, Agricultural and Natural Resources Research: Developing a Common Message." The vast majority of those present indicated that they desired to be a part of an effort on a common message. In response, RMF, Iowa State University, Mississippi State University, the Soil and Water Conservation Society and Texas Tech University formed a partnership, that later included Colorado State University, to develop a report on pursuing a unifying message in support of elevating agricultural research as a national priority. That partnership established two committees to help coordinate the effort and engaged 20 contributors to assist in providing input and materials for the report. Selected references are included to provide a general perspective on the sources used, many of which were provided by the contributors; although in some cases there may not be enough information included to locate a reference.

A very special thanks goes out to those who served on the Editorial and Communications Committees, which are recognized on the following pages, and to the sponsors of RMF. Lead sponsors as of November 7, 2014, are: Bayer CropScience, Colorado State University, Iowa State University, Mississippi State University, Texas Tech University and the National Pork Producers Council. Supporting sponsors are: American Society of Agronomy, CropLife America, Crop Science Society of America, Institute of Food Technologists, Soil Science Society of America, Soil and Water Conservation Society and Southwest Council for Agribusiness.

The unifying message partnership is most appreciative to those who reviewed a draft of this report, including: Anonymous; Ellen Bergfeld, American Society of Agronomy, Crop Science Society of America, Soil Science Society of America; Carolyn B. Brooks, Association of Research Directors of 1890 Land-Grant Universities; Ronald A. Brown, Association of Southern Region Extension Directors; Tim L. Cross, University of Tennessee; Neil Dierks, National Pork Producers Council; Caron Gala, Council on Food, Agricultural and Resource Economics; Mike Gaylean, Texas Tech University; Ferd Hoefner, National Sustainable Agriculture Coalition; Jeff Jacobsen, Michigan State University; Greg Lardy, North Dakota State University; Brian A. Larkins, University of Nebraska, Lincoln; Ian Maw, Association of Public and Land-Grant Universities; Ron Lacewell, Texas A&M University; Caird Rexroad, Agricultural Research (retired); Patrick Schnable, Iowa State University; Jane Schuchardt, Cooperative Extension, Extension Committee on Organization and Policy; and Eric Young, North Carolina State University.

Much expression is extended to the College of Agriculture and Life Sciences at Iowa State University for providing editorial services and assuming the cost for publication. However, RMF as the publisher, assumes full responsibility for the contents of this report.



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Executive Summary

A Pivotal Moment. A pivotal moment exists for pursuing a unifying message that elevates food, agricultural and natural resources research as a national priority. The opportunity comes at a time when the United States' prominence in agricultural research is endangered.

Broadly Defined Agriculture, Everyday Impact. Because agricultural research has the power to touch the lives of every person, a unifying message needs to take a broad definition of agriculture that encompasses essential elements of everyday life: food, fiber, nutrition, energy, natural resources, environment quality and more. Research also underpins agriculture as a key engine driving the national economy. Nearly a tenth of American jobs are within agriculture and food-related industries. In 2011, the value added to the gross domestic product from agriculture and related industries was \$743 billion — nearly 5 percent of total U.S. economic output. U.S. agricultural exports accounted for more than \$140 billion in 2012.

Global Concerns. The nation's leadership and competitiveness on the global stage are at stake. China and India are dramatically increasing investments in agricultural research compared to waning support in the United States; China has outspent the United States in agricultural research since 2009. Federal funding of research through USDA declined 16 percent from 2005 to 2012 and lags woefully behind other government-supported research. Agricultural productivity rates in China and Brazil are increasingly rapidly while the same rates are slowing in the United States. Meanwhile, the pressures of world population continue to mount, with an estimated 2 billion more people by 2050.

Rising Call to Invest More. Awareness is growing that U.S. agricultural research is unprepared to meet looming challenges facing the nation and the world. A rising call to reverse waning support has been expressed by entities across agriculture, science and society. In recent years many organizations have issued reports calling for increased federal investment in agricultural research. One of the strongest statements on the essential nature of agricultural research to the nation was contained in the 2012 report by the President's Council of Advisors on Science and Technology (PCAST), which called for a \$700 million annual increase in federal funding to prepare U.S. agriculture to meet the challenges of the 21st century. To gain maximum support for such an increase, more stakeholder input would be needed.

Great Opportunities. The great challenges come at a time of great opportunities: Expanding scientific frontiers, especially in increasingly data-rich areas of food, agriculture and natural resources; dramatic increases in enrollment at many agricultural institutions; the establishment of new nonprofit institutions committed to partnering to the cause of agricultural research and development; and strong national leaders willing to engage on the value of agriculture and agricultural research.

Benefits to Society. Meeting the challenges and taking advantage of the new opportunities require more investment in agricultural science and technology. The benefits to society of investing in agricultural research have been significant. Studies of estimated real rates of return to society show from 20 to 60 percent annual return. The outcomes impact the lives of everyone on a daily basis, including safe and nutritious food, healthy families, quality natural resources, renewable energy and a growing economy.

Public Good. Agricultural research must be recognized as a force in the forefront of providing for the public good. It must continue to be an integral part of problem-solving across society and a positive influence on quality of life. It must take its inspiration and direction from societal needs. Those who champion greater advances for the public good must recognize the common ground found in ensuring vital, dependable resources for agricultural research.

Unifying Message: A Lofty Goal. Connect the dots of every major societal challenge ahead and the picture that emerges is the critical importance of agricultural research. A unifying message to elevate food, agricultural and natural resources research is a lofty goal, but one worth pursuing. It is a goal worthy of the time and attention of many organizations, sectors and individuals in agriculture, science and society. The self interest that often fragments the effectiveness of the agricultural research message must be set aside. The best chance for improving the research landscape is to work together. A coalition must be formed around the commitment to develop the compelling case for enhanced investment. Additional input from a wide range of stakeholders will be needed. A unifying message would support expanding the overall funding portfolio of food, agricultural and natural resources research. The story and strategy must capture the public’s imagination and position agricultural research as having a place among the nation’s highest priorities for the public good.

Unifying Message: Next Steps. A unifying message effort will take visionary leaders who command a broad view of the complex nature of agriculture, and a deep knowledge of how a broad portfolio of food, agricultural and natural resources research benefits society. They must be exemplars of communication capable of developing and delivering a unifying message on agricultural research’s critical role in addressing global challenges. Suggestions for transitioning from “pursuing” to “developing” a unified message include: a call to action to leaders of diverse stakeholder groups to form a coalition; frame the opportunity for input from a wide range of stakeholders to shape the future of the national agricultural research enterprise; take a consensus approach to crafting a timely, unifying message that will be heart of future efforts; consider the lessons learned from current or past efforts that may serve as models for prioritizing research; focus a consensus message on a succinct, compelling story; and review the PCAST funding recommendation as a starting place for discussion and input on achievable goals for priority needs.

Sectors and Partners. Many sectors and partners play significant roles in food, agricultural and natural resources research, including USDA and other federal agencies, universities, scientific societies, nonprofit organizations and coalitions, agricultural organizations, trade associations and industry. Public-private partnerships that leverage the strengths of diverse players are an increasingly important mechanism to develop and deliver science-based results.

Major Research Areas. Foundational advances in major research areas will depend on increased funding. *Agricultural production* will require unprecedented levels of innovation and cooperation to ensure adequate food for billions more people worldwide — and in turn, redefining the importance of *rural communities*. Sustaining *natural resources* is essential to achieve long-term goals for food security, economic viability and quality of life. *Food science and human nutrition* promote healthy growth, development and well-being, and ensure a safe food supply. *Forestry* is a cornerstone for economic and environmental benefits for all Americans. Common threads running through many research priorities are *sustainability, resiliency and innovation* — all central to the public good and future quality of life as scientists tackle the immense challenges of our time, including climate change, alternative energy sources (bioenergy), water quality and quantity, public health, hunger and job creation.

The Opportunity

Introduction. This may be a pivotal moment for pursuing a unifying message on how food, agricultural and natural resources research benefits society as a whole.

This opportunity emerges as the United States is in danger of losing its prominence in food, agricultural and natural resources research. In the most recent decades, public investment in agricultural research has eroded. The factors leading to this situation, including fierce pressures faced by federal and state budgets, are well known. There is a growing awareness that, without a significant recommitment of resources, U.S. agricultural research is unprepared to meet this century's formidable and looming challenges. That awareness has led to a growing number of urgent calls to reverse faltering support by entities across the scientific and agricultural spectrum.

A common commitment to greater advances in agriculture, food and nutrition, forestry, natural resources, bioenergy and environmental sciences is required to improve productivity, spur the economy and meet future demands for:

- Ensuring a sufficient and quality food supply
- Ensuring research application to improve agricultural productivity and human health and wellness
- Reducing the number of malnourished people globally
- Addressing obesity as a public health challenge
- Lessening the dependence on petroleum fuels and products through renewable pathways
- Mitigating the expected effects of climate change and adapting to increased weather variability and extremes
- Increasing jobs, wages and wealth creation opportunities, including opportunities to farm and opportunities that stem the tide of rural outmigration
- Protecting and enhancing ecosystem services — the natural resource assets vital for life and livelihood

Why A Unifying Message

This report is envisioned as the formal beginning of a process to develop a unifying message. The intent is not to present a structure or strategy, but to present information, make a case for why this is a pivotal moment and to suggest a way forward. Why now? Here are some factors contributing to this opportunity:

Global R&D Leadership at Stake. China, India and other nations have made significant financial investments in food and agricultural research and development. While the rapid rate of investment and productivity build in these countries, the United States struggles. Agricultural productivity rates are increasing rapidly in countries such as China and Brazil, while some studies note a slowing in U.S. agricultural productivity — the opposite direction for what the global situation demands. This threatens future U.S. productivity and food security, and it is beginning to jeopardize the nation's competitive position in the international agriculture arena. A strong, unifying response is needed as other nations step up in a major way. Sufficient resources are needed to support the best scientists and innovators to keep U.S. agriculture competitive and close the gap between current productivity and that needed to meet the needs in 2050.

National Reports. Recently, many different groups have articulated the need for increased funding for food, agriculture and natural resources research. Many organizations' reports argue the necessity of preparing the nation for a future built on a strong agriculture. For example, the 2013 report from the Chicago Council of Global Affairs, *Advancing Global Food Security: The Power of Science, Trade, and Business*, called on the nation to make agricultural innovation a priority both domestically and internationally, and to double the annual funding for agricultural research. Another example is the President's Council of Advisors on Science and Technology (PCAST) 2012 report, *Agricultural Preparedness & the United States Agricultural Research Enterprise*. The PCAST report represents one of the strongest statements yet on the imperative to increase public funding of agricultural research. The report's analysis and recommendations ring true, including increased competitive grant funding for USDA, establishment of regional innovation centers, emphasis on the importance of public-private partnerships and training the next generation of agricultural workforce. Most importantly, the PCAST report initiated critical discussions on how the nation can best prepare itself to meet the huge challenges facing agriculture and society, including increased investment and a focus on research for the public good. The current rate of public and private funding for agriculture research is 1.9 percent of agricultural GDP, well below the 3 percent that PCAST argues is necessary. The PCAST recommendation to increase federal funding for agricultural research by \$700 million is clearly justified and a move in the right direction. To gain maximum support for such an increase, more stakeholder input would be needed on how funds would be used.

Expanding Scientific Frontiers. The frontiers of agricultural science are rapidly expanding. For example, scientific research that optimizes microbial communities of plants offers a new approach to enhancing productivity. In the realm of genetics, the list of sequenced genomes surpasses 180 organisms and continues to grow. The impact of the quantitative geneticists working on one animal or plant genome will be much bigger than that one species. Knowledge feeds efforts across genomes, a great example of the transformative nature of agricultural research made possible by long-term investments in genome sequencing and genotyping technologies. With sufficient funding, exploration of this vast trove of data will generate novel insights and opportunities for the future of food, energy, environmental rejuvenation and climate resiliency — breakthroughs of importance to society.

New Institutions. The establishment of the new USDA Foundation for Food and Agriculture Research in the Agricultural Act of 2014, better known as the Farm Bill, promises a new emphasis on public-private partnerships in support of research. The nonprofit foundation, modeled after similar organizations that benefit the National Institutes of Health (NIH) and the Centers for Disease Control and Prevention, would advance research through financial support provided by public and private entities. It would foster collaborations of agricultural scientists in government, academia, industry and nonprofit organizations. The foundation will foster innovation, translational research and expand public understanding of agriculture and its scientific underpinnings. In 2011, the Agricultural Technology Innovation Partnership (ATIP) Foundation was formed to strategically develop collaborative partnerships around USDA research discoveries and integrate industry, academia and government research with venture capital and technology-based business knowledge. ATIP is viewed as one the most significant events in the history of USDA technology transfer because of its potential impact on the economic growth and viability of the U.S. agricultural sector. Finally, it is worth noting the USDA National Institute for Food and Agriculture (NIFA) is itself only five years old. NIFA was designed as a step forward in national agricultural research funding programs that generate real results for all Americans.

The Specter of 2050. The opportunity and the urgency of a unifying message is perhaps most clearly seen in view of the impending world population surge that is expected to add an estimated 2 billion people in less than 40 years. Agriculture has been called "the optimistic science." A unifying message that fosters support for research and training in agriculture can be the harbinger of a promising future and help dispel 2050 as a symbol of an imperiled world.

Strong Voices. A remarkable set of men and women currently in top leadership positions are giving voice to the importance of agricultural research in addressing global challenges. If the importance of food, agriculture and natural resources are better communicated, and if the level of discourse has been raised, it is to their credit. More state and national leaders in the USDA, the land-grant university system, colleges and universities, the private sector, stakeholder organizations, professional societies and associations are willingly to engage in public discussions on the value of — and at times, in defense of — agriculture and agricultural research.

Reflection and Renewal. In recent years, a series of anniversaries and commemorations provided an opportunity to reflect, recommit to fundamental values and take stock in what agricultural research, education and extension can do for the nation. These included:

- In 2012, the 125th anniversary of the Hatch Act of 1887 that established the state agriculture experiment stations
- In 2012, the 150th anniversary of the Morrill Act that established the nation's land-grant institutions
- In 2012, the 150th anniversary of the establishment of the U.S. Department of Agriculture
- In 2014, the 100th anniversary of the Smith-Lever Act that created Cooperative Extension Service, the state-by-state national network of educators who extend university-based research and knowledge to the people
- In 2014, the 20th anniversary of the land-grant tribal colleges and universities
- In 2014, the observance of the 100th year since the birth of Nobel Prize-winning agricultural scientist Norman Borlaug
- In 2015, the historically black land-grant colleges (the 1890 institutions) will celebrate 125 years

These institutions and individuals signify what agricultural research can accomplish for society and, with increased investment, can continue to provide into the future.

Rising Enrollments. In many states, enrollments in agricultural majors at universities and colleges are increasing, and in some cases to record levels. A major reason is that students recognize the promise of essential, stimulating and challenging careers — truly careers with a future and a global impact. A growing number of studies show a significant demand, well in excess of the predicted supply, for highly trained students to enter the agricultural and food-related workforce. Education and training in scientific fields must be adequate to prepare them to meet the future needs, here and abroad. The Coalition for a Sustainable Agricultural Workforce is an example of one organization working to bring the best, brightest young students into these careers and garnering increased support for training programs. Outside the classroom, more young people are studying abroad and gaining a sense of diverse cultures and an understanding of the global economy that agriculture impacts. The classes graduating in coming years will be on the front lines of 21st century innovation; each year is an opportunity to mentor the next great minds. Robust research and education funding raises the likelihood of the next Norman Borlaug emerging from the ranks of today's students in agricultural sciences. Producing the next generation of scientists may be one of the most important outcomes, if not the most important one, from U.S. agricultural labs.

The Need Is Great. Agricultural research must address formidable global challenges of food and nutrition security, energy, health and environment. The challenges require more, not less, investment in agricultural science and technology. For over 150 years, the benefits of investing in agricultural research have rippled throughout U.S. society, even during the recent decades of gross underfunding. Agriculture's embrace of innovation always has been key to its significant role in U.S. economic growth and its enormous productivity. Ripples of benefits can become waves, but this starts with a consensus that there is a great need for a unifying message on making food, agricultural and natural resources research a higher national priority.

A Focus on the Public Good

It is enlightening to view the public good through the prism of agricultural research. The benefits derived from agricultural science and the agriculture sector have a multiplier effect that ripples across all of society. The inherent impact that a vigorous agricultural and food system, environment and economy has on quality of life, health and well-being is nearly immeasurable. Scientific innovation, a hallmark of American agriculture, has had — and continues to have — valuable impacts on the public good that are interwoven into the fabric of everyday life: safe, abundant and nutritious food; healthy families; life-sustaining and aesthetically pleasing natural resources, including clean water and healthy, productive soils; renewable energy and products; and a sound and growing economy. Among the benefits of U.S. agricultural research to the public is the world's

lowest percentage of disposable income spent on food. Agricultural research must continue to be an integral part of problem-solving and evolution across society. The essentials for good life, health and economy — and for new challenges that threaten those essentials — depend on a strong science base in the broadly defined landscape of agriculture. That is why a vigorous research underpinning for food, agriculture and natural resources systems is in the best interest of all Americans. Agricultural research is, in itself, an essential. It should be recognized as a force in the forefront of providing for the public good.

Rich Dividends. Through the decades, public investments in agricultural research by federal and state governments have paid great dividends to the public good and the American economy. Some estimated real rates of returns to society show a 20 percent annual return. Others show a 40 to 60 percent annual return. Dividends are realized through improved consumer welfare and quality standard of living and enhanced worldwide competitiveness of American products. What these figures do not account for are the nonmarket goods, like increased water quality, safer food, fertile soils, enhanced wildlife habitat and more, that dramatically broaden the impact of agricultural research across society. Results are delivered by the public sector, private industry and through public-private partnerships. Private industry always will have a critical role in partnership with the public sector in maintaining a strong economy, particularly in scaling up and commercializing new developments. However, some essentials of the public good cannot be readily monetized. Public research in agriculture must lead in addressing challenges unlikely to be taken on by the private sector or that may require the long view and sustained focus and effort to achieve future success.

Recent Progress and Innovation. New scientific discoveries and innovations are continually needed to enhance consumer benefits and meet emerging consumer expectations, whether it's foods, clothing, fuels, vaccines or more. Research constantly seeks to improve the efficient production of food and fiber, making America's food supply safe, secure, economical, plentiful and the envy of the world. Recent results from publicly funded agricultural research, conducted by university and USDA scientists around the country, include:

- Development of a dairy cow genetic test that reduces selection time for the best animals from five years to one week, plus increased prediction accuracy for many important traits by more than 30 percent
- Development of new climate, soil and water friendly cover crop systems and livestock grazing methods (including management-intensive rotational grazing and mob grazing)
- Discovery of methods to dramatically reduce *Escherichia coli* (E. coli) bacteria on leafy vegetables
- Identified genetic traits in poultry that have led to more effective treatments for poultry diseases and more efficient feeding, improving both animal welfare and performance
- Reducing hazardous air pollutants through a process to make environmentally friendly wood adhesives from soybean components
- A better understanding of the genetic secrets of photosynthesis that can significantly increase yields of crops
- Developed approaches to increase beneficial — and decrease adverse — effects of bioactive food chemicals and microbial contaminants. Beneficial bioactive chemicals can protect against human diseases such as cancer, inflammation, birth defects and microbial infections
- Identified genetic markers that may help select beef cattle that are resistant to fescue toxicosis, a disease that costs producers more than \$600 million annually

Researchers' studies and evaluations of gene function and expression in poultry have improved poultry welfare and performance; made production more efficient less costly, and more sustainable; and ensured that affordable, safe, nutritious poultry product are available to consumers.

Extension Delivers. A significant part of the public good derived from agricultural research is the delivery of unbiased research-based information and education to the public. The nationwide Cooperative Extension System network, for example, is integral to the core mission of federal and state land-grant institutions. The role of extension in transformational education for the U.S. population may be the model best suited for use in other countries to meet global challenges that begin with enhancing food and agricultural production.

Public-Private Partnerships. Addressing today’s global agricultural challenges will require diverse partners who are capable of making new connections and formulating new ideas. The magnitude of the challenges, especially rising world food demand in the approaching decades, can be daunting. For agricultural research and development to achieve its fullest potential, enhanced collaboration, cooperation and partnerships will be required. Maximum results and benefits to society will require research partnerships that leverage the strengths of many diverse players. Public-private partnerships in agricultural research must be a key mechanism to develop and deliver a reliable stream of science-based results and technology. Collaborative partnerships — grounded in respect, collaborative planning and goal setting, participatory approaches and open communication — can effectively bridge the gap between public and private sectors’ distinctive competencies and achieve common goals that meet society’s needs. Key benefits of public-private partnerships include:

- Coordination of activities at all levels
- Synergy gained from sharing knowledge and expertise
- Exposure to differing perspectives
- Leverage of scarce resources
- Building on long-term investments in research
- Developing a shared vision for the future

The promise of expanded public-private partnerships is expedited research and maximized benefits. Partnerships enable each entity, public or private, to pool resources and expertise around a promising, novel idea. The result may dramatically improve chances for success. Public-sector researchers often do not have the ability or experience to turn great ideas and innovations into products or services. The private sector, with the infrastructure and navigation skills to bring ideas forward to be used by farmers or consumers, has a great deal to contribute. Well-trained graduates from the research programs of public institutions are invaluable for filling industry’s future workforce demands — another benefit of the public-private partnership.

A lesson on the potential for agricultural research partnerships may be drawn from the announcement that the National Institutes of Health, large drug companies and nonprofit organizations will join forces in a partnership to speed development of drugs to treat Alzheimer’s disease, Type 2 diabetes, rheumatoid arthritis and lupus. The \$230 million, five-year effort calls for shared data, regular communications and making data and findings public. The plans include bringing together scientists from different perspectives and “leaving their egos [and] their affiliations at the door.”

Greater Leaps. Signs point to the problem-solving capacity of agricultural science to take even greater leaps on behalf of the public good. One example is the enormous power to capture and analyze vast stores of genetic data. This advance is rapidly transforming the biological sciences, which undergird many agricultural areas, from a descriptive science to a much more prescriptive one — one capable of producing public-good solutions to the grand challenges facing humanity. Agricultural science also has the potential to address unintentional consequences that have accompanied industrialization and agricultural development. For example, the development of cost-effective, science-based methods to reduce the use and flow of agricultural nutrients and retain them on the landscape holds enormous potential for improved ecosystems and human health — in both the developed and developing worlds.

Vision Based on Societal Needs. Agricultural science must continue to take its inspiration and direction from societal needs. Agricultural research — both goal-oriented and discovery-oriented — needs an integrated, collaborative strategic vision for the future. A good example is the vision clearly outlined by USDA’s Research, Education and Economics. The vision extends to the value of educating the next generation of agricultural scientists — another enormous public benefit — and society-ready graduates in many disciplines who keep the nation’s economic engine running at top performance.

Needed: A Vast Team. Norman Borlaug, one of history’s most respected and honored agricultural scientists, said: “I am but one member of a vast team made up of many organizations, officials, thousands of scientists and millions of farmers . . .” In today’s context, public and private scientists might expand his quote to include

“and millions of consumers” or “and millions of community leaders” or “and millions of urban and rural residents.” A vast and diverse team made up of public and private partners is needed to confront global challenges through agricultural sciences and secure a better, shared future.

Past Is Prologue. The achievements of agricultural research in service to the public good are landmarks in this country’s history. What’s past is prologue. Agricultural science must continue to deliver on meeting challenges and positively influencing quality of life in the future. Though they may not realize it, everyone has an intimate connection to agricultural research. Everyone may not understand or appreciate agricultural research for what it is, but everyone can appreciate agricultural research for what it’s *for*. Those who champion greater advances for the public good must recognize the common ground in ensuring vital, dependable resources for agricultural research.

The Definition of Agriculture (It’s More) and Its Importance

The full spectrum of agricultural research has the power to touch the lives of every person. If a key concept for renewed commitment and investment in agricultural research is benefits for the public good, then a simple definition of agriculture will not suffice. A modern definition — that includes vast subject areas of food, fiber, nutrition, forestry, natural resources, energy, economics, the environment and more — dispels the perception that agriculture means solely production agriculture. Naturally, agriculture includes the high-quality food, fiber, fiber and fuel produced on farms; it puts food on the table at affordable prices and provides a myriad of raw materials for a myriad of purposes. But it’s more.

Agriculture Is Dynamic. U.S. agriculture is a dynamic, enormously complex biological system, social-ecological system and economics system. It is a vast, interconnected system encompassing ecosystems and watersheds, organisms and microorganisms, genetics and genomes, individuals and communities, and tools, technology and management. As a social-ecological system, it consists of ecological components and processes and human components and social processes that overlap in multiple areas. The agriculture system interacts with the global climate system, large-scale biogeochemical conditions and global political and economic conditions.

Agriculture’s breadth extends to critical needs and issues not immediately associated with traditional agricultural production, including stewardship of natural resources; strong, viable rural communities; safe, nutritious food; and renewable energy.

Agriculture Is the Forefront of Science. Because agriculture deals with life, sustains life and is key to quality of life, the definition of agriculture must include the sciences of life as a central theme. Agricultural research is at the forefront of scientific frontiers, including: plant and animal breeding, genomics, biorenewables, human health and wellness, environmental stewardship, carbon sequestration, food safety and security, and the profitability and competitiveness of agricultural producers and businesses. Additionally, agricultural and applied economics research serves as a critical underpinning for many areas of innovation within a market-based, behavior-based and decision-based framework.

Agriculture Is an Economic Engine. A definition of U.S. agriculture is incomplete without an understanding of its role as a key engine of economic growth. Agriculture is a key economic development driver in many communities, both rural and urban. The economic contributions of agriculture include gross domestic product (GDP), exports, jobs, and productivity.

Gross Domestic Product. Output from American farms contributed \$139 billion to the U.S. gross domestic product in 2011. But under a broadened definition, which includes sectors related to agriculture such as forestry, fishing, food and beverages, textiles and apparel, food services and more, the GDP contribution soars to \$743 billion (**Figure 1**). That’s nearly 5 percent of total U.S. economic output.

Exports. A definition of agriculture without the American export story is incomplete. More than \$140 billion in current U.S. agricultural exports (2012) is a highlight for the U.S. economy (Figure 2). Since 1960, the United States has exported more agricultural products than it imports, translating into a positive continuing chapter in U.S. agricultural trade. The strength of agricultural exports has benefited U.S. farm incomes, sustaining prices and revenues, and in turn, strong incomes have benefited rural communities.

FIGURE 1. Value Added to GDP by Agriculture and Related Industries

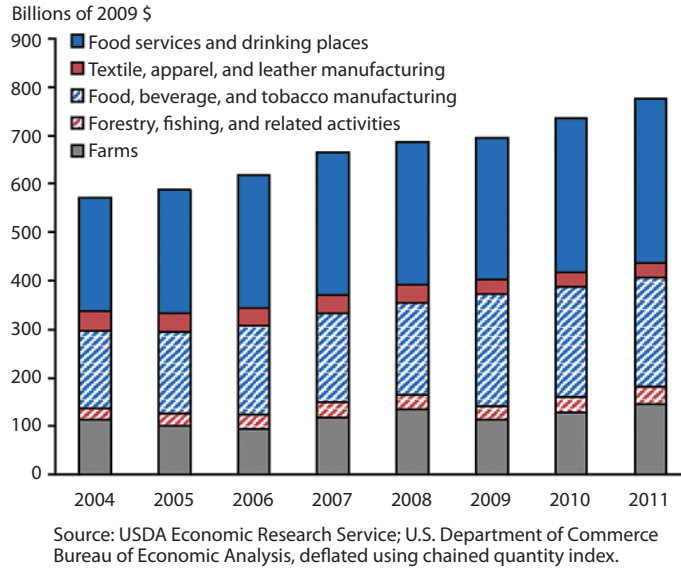


FIGURE 2. U.S. Agricultural Exports, 1980-2012

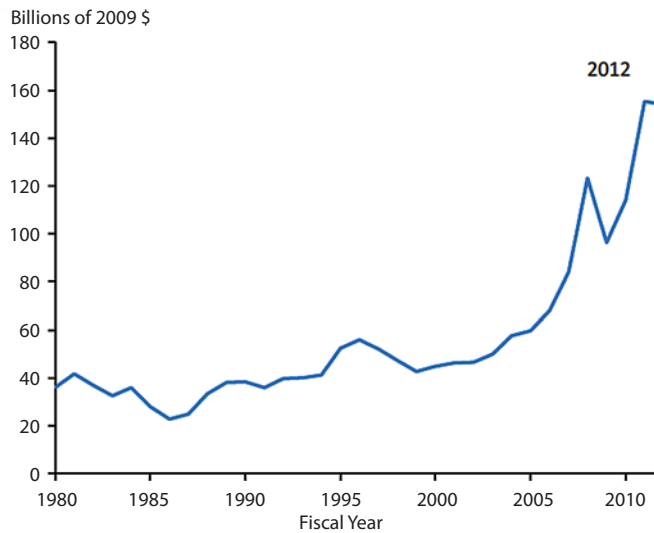
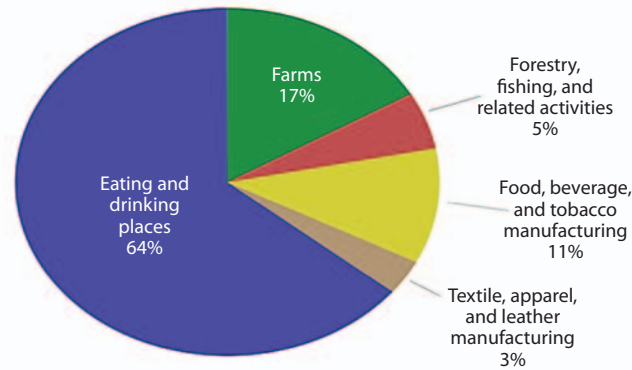


FIGURE 3. American Jobs in Agriculture and Food-Related Industries



*Full- and part-time jobs.

Source: USDA, Economic Research Service using data from U.S. Department of Commerce, Bureau of Economic Analysis.

Jobs. Nearly a tenth of American jobs are in agriculture and food-related industries (**Figure 3**). In 2012, over 16 million full-time and part-time jobs were related to agriculture, about 9.1 percent of total U.S. employment, and 2.6 million of the jobs provided direct on-farm employment. It's important to note that U.S. farm exports support about one million jobs.

Productivity. Over the past 60 years, yields per acre of major crops — such as corn, soybean, wheat and cotton — have doubled, tripled and, in some cases, even quadrupled. At the same time, livestock production and specialty crop production have become far more efficient. According to USDA's Economic Research Service, total farm production more than doubled between 1948 and 2011, and U.S. total agricultural output grew at an average annual rate of 1.49 percent over this period. Almost all of this growth in U.S. agricultural output was due to increased productivity. Today, continued gains in productivity are endangered by lack of agricultural research funding.

Global Perspective to Agricultural Research Investments. U.S. federal research investments related to agriculture need to be placed in a global perspective. In 2009, China overtook the U.S. to become the global leader in public spending on agricultural research. In inflation-adjusted dollars, China tripled its spending on agricultural research between 2000 and 2010. India and Brazil also increased their spending on agricultural research over the past decade by 102 percent and 31 percent, respectively (**Figure 4**).

The Risk to Productivity. The issue of productivity is a key part of agriculture's definition today and in the future, especially related to agricultural research. Stagnant funding for public agricultural research may be causing agricultural total factor productivity growth to slow down. It may be another risk factor for future productivity growth in addition to climate change, water scarcity, competition for arable land and population preferences for meat over plant-based diets. This is critical for the country because agriculture is a national security issue, both in ensuring a safe, abundant food supply and an accessible, nutritionally sound and affordable diet for all U.S. citizens. Also at risk is the nation's competitive position in the international arena. Agricultural productivity is increasing considerably more rapidly in China and Brazil than it is in the United States (**Figure 5**). These countries, as well as India, are rapidly increasing their public investment in research.

Agriculture Grows with Its Future Leaders. Agriculture is attracting a new and growing generation of bright young minds into education and careers in agriculture and related fields. Between 1972 and 2007, about one-third of all college freshmen planned to study science and engineering. This proportion gradually rose to 38 percent by 2010. Increases in freshmen planning to major in biological and agricultural sciences accounted for most of this growth. Nationally, undergraduate enrollment in agriculture and related sciences programs grew by 28 percent from 2005 to 2012. In the same period, undergraduate enrollment in natural resource and conservation programs grew by 41 percent. Young people realize that agriculture is where they

FIGURE 4. Global Public Agricultural R&D Spending, 1981-2011, in Constant 2005 Dollars (millions)

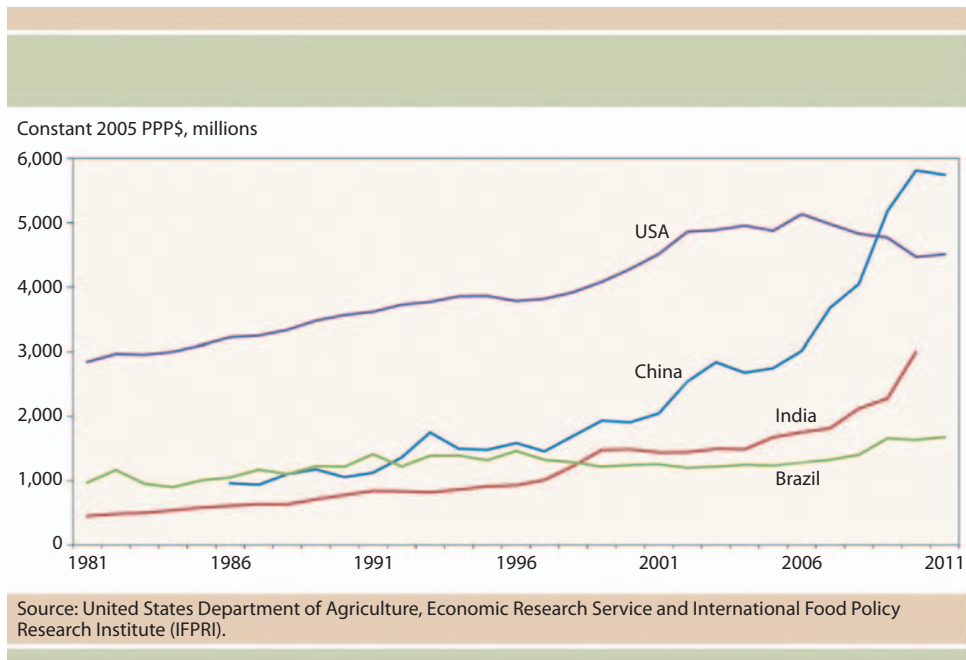
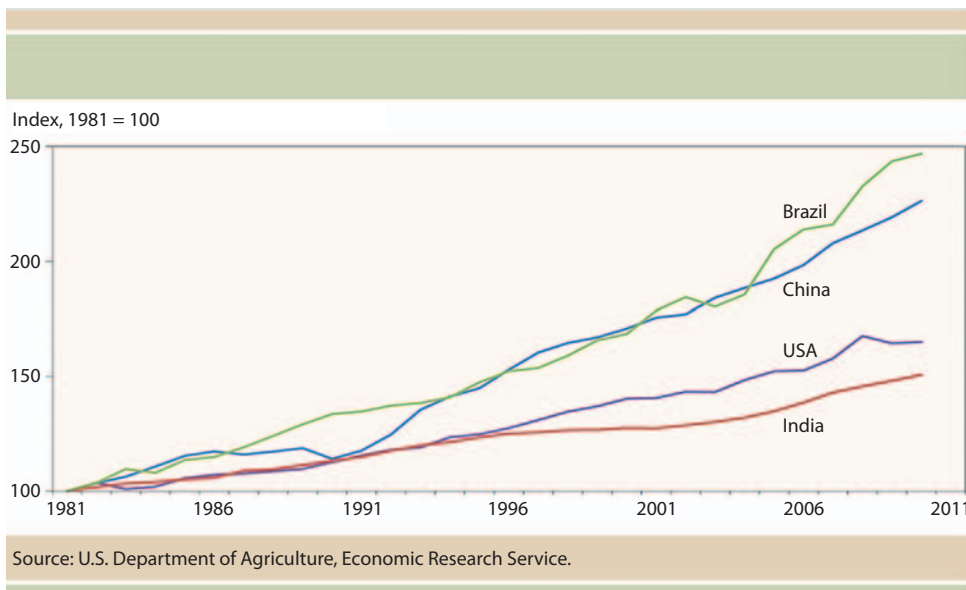


FIGURE 5. Agricultural Total Factor Productivity



need to be if they seek careers in which they are engaged in addressing the most serious global challenges. The future national and global leaders who will advance food and nutrition security, food safety, environmental stewardship, renewable energy and human health and nutrition will come from diverse agricultural and related disciplines. The United States should be self-sufficient for leadership in food, agricultural and natural resources.

The Way Forward

Pursuing a Unifying Message: Elevating Food, Agricultural and Natural Resources Research as a National Priority is a first step in outlining the opportunity that exists now. The way forward envisions a convergence of efforts. The way forward invites voices from every sector to work together in articulating a unifying message.

A Lofty Goal Worth Pursuing. A unifying message may sound like a lofty goal. But it is one worth pursuing to close the distance, and worthy of the time and attention of many organizations, sectors and individuals in agriculture, science and society. As a result of continued neglect, there may come a time when the essential contributions from food, agricultural and natural resources research may begin to diminish. Part of a goal of a unifying message is to reverse the trend of investment. There may come a time when the United States may truly struggle to re-establish its leadership and capacity in agricultural research. Part of a goal of a unifying message is to prevent that from happening.

An Interdependent System. The success of American agriculture was no accident or product of chance. It was a dividend of historic investments in research. Renewed investment will help society continue to reap the rewards of future discovery and help the U.S. gain back the competitive edge it has long enjoyed around the globe. U.S. agricultural research is conducted by a system of interdependent entities: government, federal laboratories, universities, industry, societies and associations, NGOs and more. If lack of investment results in part of the interdependent system to be unable to make its full contribution, then the number of successes will be reduced.

Stop the Fragmentation. The work of defining and articulating the “unifying message” is an important and, hopefully, a near-future step. It is a step that will require diverse partners working together as a team toward a common goal. The self-interest that often fragments the effectiveness of the agricultural research message must be set aside. Based on the evidence of current trends in federal investments, there must be a shared understanding that, something must change dramatically. There must be a paradigm shift away from many voices advocating for narrow slices of federal resources and toward a convergence of voices with a unifying message on expanding total agricultural research funding. It is a movement away from the zero-sum game where funding decisions that favor one request often are realized at the expense of another. That is the prevailing environment that makes a Babel of agriculture’s voices in the halls of Congress. Agricultural and food research interests are viewed as the one of the least effective groups in Washington, D.C., because there are so many voices, often squabbling amongst themselves.

Effectiveness of a Uniform Message. The best chance for improving the research landscape in agriculture is to work together to present a uniform message. A unified position among many diverse organizations supportive of agricultural research will be the most effective. It will be more effective than smaller campaigns that advocate for specific or narrower interests. A unifying message will not argue that smaller campaigns are unimportant. But the overall priority and campaign must become growing resources as a whole, not subdividing them.

A New Coalition. The time has come to form a coalition around the commitment to develop the compelling case for enhanced investment in agricultural research. Representatives may include those from general agricultural or farm organizations; consumer groups; agricultural commodity groups; agribusinesses; food industry; nonprofit organizations, including foundations, universities and governments; scientific societies; and trade associations. Each offers a unique, strong voice. Each may view the value and benefits of research differently. Each may have opinions on the funding goals and mechanisms best suited to achieve the desired results.

Leaders with Vision. A unifying message effort will take visionary leaders who command a broad view of the complex nature of agriculture, and a deep knowledge of how a broad portfolio of food, agricultural and natural resources research benefits society. They must be exemplars of communication capable of developing and delivering a unifying message on agricultural research’s critical role in addressing global challenges. The story and the strategy must capture the public’s imagination and position agricultural research as having a place among the nation’s highest priorities for the public good.

Common Purpose. This truly is the way forward. It will take great coordination to present a common front working toward a common end, but the commonalities outweigh the differences. The goal of a unifying message is to seize the opportunity to move food, agricultural and natural resources research funding to a whole new level — to broaden and deepen the investment. A unifying message will provide the framework for broad support of many stakeholders that contribute to advances in agricultural science and innovation. A unifying message will support diverse and plentiful funding opportunities; the overall portfolio must expand. A unifying message will, as a fundamental concept, support all stakeholders involved in achieving societal goals. The prevailing perception should be one of common purpose, instead of one that views a particular sector, group, agenda or funding mechanism being favored over another.

Collaborations and Partnerships. Increased emphasis on public-private partnerships must be part of the dynamic and a unifying message. Because the challenges are so great, it will be increasingly important to make maximum use of expertise wherever it occurs. Agricultural research has long benefited from research from many fields, and vice versa; the outcomes today from the biological and environmental sciences are astounding. Now is the time to invest to take better advantage of these opportunities and make possible more collaborations and more public-private partnerships.

Suggested Next Steps. Here are suggested next steps or guiding principles for the way forward, to transition from “pursuing” a unifying message to “developing” a unifying message:

- Put out a challenge or call to action to leaders of diverse stakeholder organizations, inviting them to come together to form a timely coalition committed to making food, agricultural and natural resources research a high national priority.
- Frame the opportunity to participate as one that will:
 - o require input from a wide range of stakeholders
 - o help shape the future of the national agricultural research enterprise as an essential force for the public good
 - o require a shared understanding that on the evidence of current federal investments, if there is broad-based support for increasing scientific knowledge, that support is not resulting in the kind of investments that are desired.
 - o provide a vision for what agricultural research as a high national priority will look like and the actions required to achieve that goal
 - o take a consensus approach to crafting a timely and unifying message that will be the heart of future efforts and actions
 - o require strong leadership to rally many diverse organizations, agencies and entities and their memberships to the overall value of a unifying message
- Acknowledge all the important work that has been accomplished by many sectors and voices on behalf of agricultural research in its many forms, and that now leads to the need to speak together to deliver a positive message on growing the funding portfolio to serve society.
- Consider researching the lessons learned from existing or past efforts and organizations that may serve as models for uniform messaging and actions on prioritizing research. Perhaps taking a page or two from the playbooks of similar organizations is worthy of close analysis. One example may be Research!America for the biomedical research community. With a tagline of “Making research to improve health a higher national priority,” Research!America is “the nation’s largest nonprofit public education and advocacy alliance working to make research to improve health a higher national priority.” The alliance advocates to increase funding for several federal agencies “at levels that keep pace with scientific opportunity.” Research!America also advocates for federal funding for global health research and for a legislative and regulatory climate that stimulates growth in industry R&D. The alliance claims its members and supporters, which include many diverse entities from the public and private sectors, “represent the voices of 125 million Americans.”
- Focus a consensus message on the succinct and compelling story — how food, agricultural and natural resources research improves the lives of everyone — and the risks facing the nation without adequate funding of research. An additional consensus-led part of the message and the case for increased investment

may be outlining the promise of anticipated innovations and the key research questions for addressing major challenges.

- Review the PCAST recommendation for increasing federal funding for agricultural research by \$700 million as one starting place for discussion and additional input from stakeholders on achievable goals to meet priority needs.

An Uncommon Enterprise. Forging a common message will be an uncommon enterprise. But the times call for an inspiring vision, bold action and a heightened sense of purpose. It will take time, but a positive beginning for the uncommon enterprise can be a group of leaders making a firm commitment to the objective of developing a unifying message and beginning to identify the components needed to define the vision.

Connect the dots of every major societal challenge ahead. The picture that emerges is the critical importance of making research in food, agriculture and natural resources a higher national priority.

Overview of USDA and Its Collaborators

Introduction. This chapter examines federal contributors to agricultural research, including a description of the U.S. Department of Agriculture (USDA) agencies, the collaboration of Agricultural Research Service with other federal agencies, investments by USDA in food, agricultural and natural resources research when placed in an international context and closely related program activities in other federal agencies.

USDA Agencies and Collaborators

The USDA is the primary federal department responsible for food, agriculture and natural resources research. It fulfills that responsibility primarily through agencies within the Research, Education, and Economics mission area; a unit within the Forest Service; and key collaborations with other federal agencies, universities and the private sector that depict a highly leveraged and diverse local-to-global research effort.

Research, Education and Economics (REE). USDA's REE mission area provides federal leadership for the discovery, application and dissemination of information and technologies spanning the biological, physical and social sciences. It fulfills its mission through agricultural research, education and extension activities and economic research and statistics. Through its intramural and competitive grant programs and by strengthening the capacity of institutions of higher education, REE supports all of USDA's strategic goals. The 2015 REE budget serves to ensure a safe, sustainable and competitive U.S. food, fuel and fiber system and healthy individuals and communities.

REE works with other USDA agencies, other federal agencies, international organizations and the private sector to protect, secure and improve U.S. food, agricultural and natural resources systems. REE's responsibilities are carried out by four agencies: the Agricultural Research Service, which conducts intramural research in agricultural, natural and biological sciences; the National Institute of Food and Agriculture, which partners with land-grant and non-land-grant colleges and universities, nongovernmental organizations and government and private labs to carry out extramural research, higher education and extension activities; the Economic Research Service, which performs economic, social science and policy research; and the National Agricultural Statistics Service, which conducts the Census of Agriculture and provides official, current statistics on agricultural production and indicators of the economic and environmental welfare of the farm sector.

Agricultural Research Service (ARS). ARS is the USDA's chief in-house research agency. It is one of the four component agencies of the REE mission area. In 1862, Congress first authorized federally supported agricultural research in the Department of Agriculture Organic Act, which established what is now USDA. That statute directed the Commissioner of Agriculture "to acquire and preserve in his department all information he can obtain by means of books and correspondence, and by practical and scientific experiments . . ." The scope of USDA's agricultural research programs has been expanded and extended many times since the department was created. Today ARS has a workforce of approximately 6,000 employees, including 2,100 scientists and postdoctoral researchers representing a wide range of disciplines. ARS has 800 research projects working at more than 90 locations, including overseas. The National Agricultural Library and National Arboretum also are part of ARS.

The ARS Office of National Programs has organized the agency's research into 17 national programs that are managed by approximately 24 national program leaders drawn from different scientific disciplines. ARS conducts research to develop and transfer solutions to agricultural problems of high national priority and

provide information access and dissemination to sustain a competitive agricultural economy; ensure high-quality, safe food and other agricultural products; assess the nutritional needs of Americans; enhance the natural resource base and the environment; and provide economic opportunities for rural citizens, communities and society.

To achieve these objectives, the Office of National Programs identifies critical problems affecting American agriculture, then plans and executes the strategies needed to address these problems. The office mobilizes human and financial resources; fosters multidisciplinary research; links research to program and policy objectives; and communicates and interacts with customers, stakeholders, partners and beneficiaries to ensure program relevancy and timely transfer of new knowledge and technologies to potential users. The Office of National Programs seeks to broaden public understanding of the value of agriculture and agricultural research to ensure the continued primacy of the U.S. agriculture in the 21st century.

ARS research certainly contribute to the common good and serve a wide range of stakeholders. Research is both complementary and unique.

Complementary Research. Many ARS units are located on or near university campuses, where ARS scientists conduct research jointly with faculty and where ARS often supports graduate students and postdoctoral positions.

ARS research on commodities is designed to complement research by universities, the private sector and others. A primary objective of ARS research is for the public good, whereas profit is the primary objective in the private sector. In addition, the private sector may have more of an international focus, which may or may not provide technology that has the maximum positive impact on the U.S. economy. Also, some research on major commodities is desirable to provide some checks and balances necessary to provide competition in the marketplace.

Six national nutritional research laboratories, the majority located on university campuses, is a specific example of a national complementary effort. This research is another example where the private sector has limited incentive.

Research by ARS on natural resources is complementary, with results critical to the goal of sustainable natural resources and minimizing impact on the environment. Since management of natural resources needs to be approached on a regional basis, ARS research and leadership is an essential part of a national effort.

Unique Capabilities. ARS plays a unique role in some research situations where the infrastructure provides stability in perpetuity for some critically important and expensive to maintain facilities. Here are two examples:

- The National Center for Genetic Resources Preservation (NCGRP) acquires, evaluates, preserves and provides a national collection of genetic resources to secure the biological diversity that underpins a sustainable U.S. agricultural economy through diligent stewardship, research and communication. NCGRP is an important part of the USDA-ARS Germplasm Resources Information Network, which provides germplasm information about plants, animals, microbes and invertebrates.
- The National Animal Disease Center (NADC) conducts basic and applied research to produce knowledge and technology to reduce economic losses from infectious, genetic and metabolic diseases to the livestock and poultry industries and the associated rural agricultural community. NADC works to reduce or eliminate preharvest contamination or infection of livestock and poultry with foodborne human pathogens and to prevent suffering and death caused by diseases in agriculturally important livestock and poultry. NADC maintains unique, highly specialized containment facilities that are critical in studying dangerous organisms associated with its research.

Support of Action Agencies. In addition to maintaining collections and managing specialized facilities, ARS has a unique role in providing research support to USDA action agencies. The importance of a substantial part

of ARS intramural research is reflected in these brief descriptions of the action agencies.

- Food Safety and Inspection Service (FSIS). FSIS is the public health agency responsible for ensuring that the nation's commercial supply of meat, poultry and egg products is safe, wholesome and correctly labeled and packaged.
- Animal and Plant Health Inspection Service (APHIS). APHIS is a multifaceted agency with a broad mission area that includes protecting and promoting U.S. agricultural health, regulating genetically engineered organisms, administering the Animal Welfare Act and carrying out wildlife damage management activities.
- Natural Resources Conservation Service (NRCS). NRCS helps America's farmers, ranchers and forest landowners conserve the nation's soil, water, air and other natural resources. Its programs are voluntary and offer science-based solutions that benefit both the landowner and the environment.

Other Federal Collaborations. ARS collaborates with other federal agencies to a greater extent than any other organization. The collaborations include: Food and Drug Administration (FDA), National Institutes of Health (NIH), Environmental Protection Agency (EPA), Department of Defense (DOD), Department of Energy (DOE), National Science Foundation (NSF), U.S. Geological Survey (USGS), Department of Homeland and Security (DHS) and National Aeronautics and Space Administration (NASA). The missions of these federal agencies can be found in **Appendix A**.

Its research in support of action agencies and its collaborations with other federal agencies clearly demonstrate that ARS has impacts on many aspects of society, and those impacts are much broader than many realize.

National Institute of Food and Agriculture (NIFA). NIFA is USDA's primary extramural research funding agency. As outlined in its newly published 2014-2018 strategic plan, NIFA's vision is to "catalyze transformative discoveries, education and engagement to address agricultural challenges."

NIFA integrates research, education and extension to ensure that groundbreaking discoveries in the food, agricultural, natural resource and human sciences go beyond the laboratory. Research enables discovery of knowledge to provide answers to complex problems of national and global importance. New science-based information makes its way into the classroom and, through extension leadership, to people who put the knowledge into practice to improve their lives. Schools and universities educate and train the next generation of scientists, educators, producers and citizens, and prepare the workforce for a thriving economy. Extension translates the knowledge gained through research and education into innovations that provide solutions to problems people face.

The agency provides extramural funding and works with other government agencies, industry and academia to lead research, education and extension activities towards pursuit of the following goals:

- Advance the nation's ability to achieve global food security and fight hunger
- Advance the development and delivery of science for agricultural, forest and range systems adapted to climate variability and to mitigate climate impacts
- Improve and increase the production of goods and services from working lands while protecting the nation's natural resource base and environment
- Contribute to the nation's energy independence and enhance other agricultural systems through the development of regional systems for the sustainable production of optimal biomass (forests and crops) for the production of bioenergy and value-added biobased industrial products
- Combat childhood obesity by ensuring the availability of affordable, nutritious and safe food and providing families with science-based nutritional guidance
- Ensure the development of human capital, communities and a diverse workforce through research, education, extension and engagement programs in food and agricultural sciences to support a sustainable agricultural system

NIFA's key partners are the institutions of higher learning making up the land-grant university system, which includes the original 1862 institutions, the historically black colleges, the tribal colleges and the Hispanic-serving institutions. Working with these institutions, NIFA funding supports exemplary research, education and Cooperative Extension efforts in communities, carried out by more than one hundred institutions. The agency also partners with other federal agencies; nonprofit associations; professional societies; commodity groups and grower associations; multistate research committees; private industry; citizen groups; foundations; regional centers; the military; task forces; and other groups.

The NIFA "capacity funding" programs, which are matched and in many cases exceeded by states' funds, strengthen the land-grant university system and help ensure that research and extension programs are conducted efficiently and collaboratively across states and regions. Capacity funding is essential for research and extension to operate as a national system, making local, state and regional work more proactive and effective. University leaders decide the projects in a broad framework that its capacity-building funds will support. The decisions are informed, in part, by stakeholders who support and use agricultural research and extension. Capacity funds are used to support regional, state and local extension education, including agricultural and natural resource programming, 4-H (America's premier agriculture youth organization) and nutrition education programs.

NIFA awards competitive grants for fundamental and applied research, extension and higher education activities, and for integrated research, education and extension projects. Competitive programs attract a large pool of applicants to work on agricultural issues of national, regional and multistate importance. NIFA's Agriculture and Food Research Initiative (AFRI) is the agency's largest competitive grants program (\$325 million in Fiscal Year 2014). AFRI projects are aligned with the 2014 Farm Bill priorities and address six priorities:

- Animal health and production and animal products
- Plant health and production and plant products
- Food safety, nutrition and health
- Bioenergy, natural resources and environment
- Agriculture systems and technology
- Agriculture economics and rural communities

Other NIFA competitive grants programs include Sustainable Agriculture Research and Education, Organic Agriculture Research and Extension, Specialty Crop Research, Integrated Pest Management and Beginning Farmers and Ranchers Development. For these programs, Fiscal Year 2014 funding totaled more than \$200 million or about 40 percent of total competitive grant funding, according to the Office of Management and Budget.

When making grants, the agency takes into consideration, when available, the determinations made by the National Agricultural Research, Extension, Education and Economics Advisory Board. The authority to carry out this program has been delegated to NIFA through the Undersecretary for REE.

The program authorizes grants of which the Secretary may retain no more than 4 percent for administrative costs. Funds are available for obligation for a two-year period beginning in the fiscal year for which funds are first made available. Grants are awarded on the basis of merit, quality and relevance and may have terms of up to 10 years.

Subject to the availability of appropriations to carry out the AFRI program, the Secretary may award grants to state agricultural experiment stations; colleges and universities; university research foundations; other research institutions and organizations; federal agencies; national laboratories; private organizations or corporations; individuals; or any group consisting of two or more of the aforementioned entities. There may be restrictions on who is eligible to apply for grants and, in some cases, matching funds may be required. Details are outlined in Request for Applications (RFAs) as they become available and cost-sharing requirements are available

online (http://nifa.usda.gov/business/awards/matching_require.html). As of October 2014, examples of RFAs for FY2015 funds include: Agricultural and Natural Resources Science for Climate Variability and Change; Food Security; Food Safety; Childhood Obesity Prevention; and Water for Agriculture. For AFRI's integrated research, extension and education programs, eligibility includes colleges and universities, 1994 land-grant institutions and Hispanic-serving agricultural colleges and universities.

Economic Research Service (ERS). ERS is USDA's primary source of economic information and economic and social science research. The ERS informs and enhances public and private decision-making on economic and policy issues related to agriculture, food, the environment and rural development. With more than 300 employees, ERS fulfills its responsibilities through:

- Agency-published research reports, market analysis and outlook reports, economic briefs and data products
- An award-winning magazine, *Amber Waves*, covering the entire range of ERS work
- The website, which provides access to all ERS products and links users directly with ERS analysts
- Oral briefings, written staff analyses and congressionally mandated studies delivered directly to executive and legislative branch policy-makers and program administrators
- Articles in professional journals and papers presented to academic colleagues at conferences and meetings

National Agricultural Statistics Service (NASS). NASS is committed to providing timely, accurate and useful statistics in service to U.S. agriculture. Its reports cover virtually every aspect of U.S. agriculture, including production and supplies of food and fiber, prices paid and received by farmers, farm labor and wages, farm finances, chemical use and changes in the demographics of U.S. producers. Although the work of NASS is not classified as R&D by the Office of Management and Budget, it provides valuable information used by REE and many others for making decisions.

Forest Service (FS). The FS research and development arm, a component of USDA, works at the forefront of science to improve the health and use of the nation's forests and grasslands. Research has been part of the FS mission since the agency's inception in 1905. Programmatically, FS functions as if it were part of REE. FS research has programs in all 50 states plus U.S. territories and commonwealths. The organization consists of seven research stations and 80 experimental forests and ranges. FS R&D interacts with national forests in nine regions and with the agency's State and Private Forestry Deputy Area throughout the United States. R&D also is allied with REE agencies, including the Agricultural Research Service, National Institute of Food and Agriculture, National Agricultural Statistics Service and ARS National Agricultural Library. FS R&D also partners with other federal agencies, nongovernmental organizations, universities and the private sector.

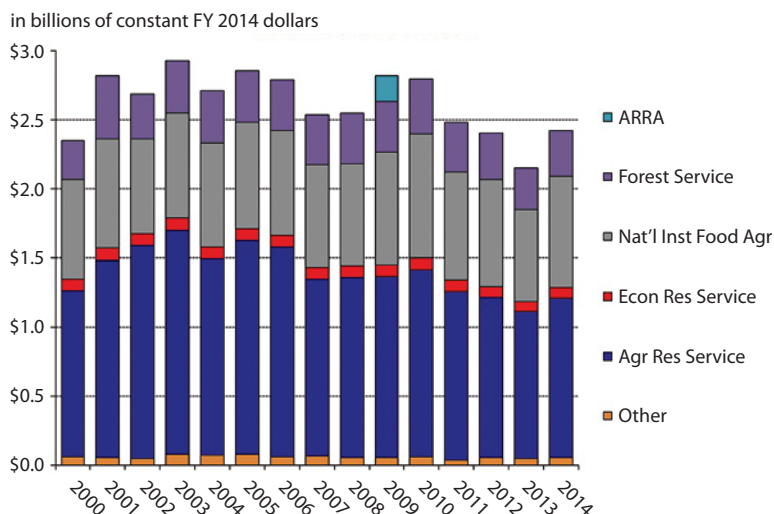
Today, more than 500 Forest Service researchers work in biological, physical and social science fields to promote sustainable management of the nation's diverse forests and rangelands. The work informs policy and land-management decisions on issues such as invasive insects, degraded river ecosystems and sustainable ways to harvest forest products. The researchers work independently and with a range of partners, including other agencies, universities, nonprofit groups and industry. FS makes information and technology produced through basic and applied science available to the public for its benefit.

Federal Investments

While this part of the unifying message focuses on U.S. federal research investments related to agriculture, those investments need to be placed in a global perspective. As stated earlier, China has overtaken the U.S. to become the global leader in public spending on agricultural research. In inflation-adjusted dollars, China tripled its spending on agricultural research between 2000 and 2010. India and Brazil also increased their spending on agricultural research over the past decade by 102 percent and 31 percent, respectively.

USDA Budgets. A review USDA's ARS, NIFA, ERS and FS funding since 2001 indicate that there has been a decline in the investment in these combined agencies in recent years (**Figure 6**). For instance, if the distortions

FIGURE 6. Total Federal R&D by USDA Agency, FY2000-FY2014



Source: AAAS R&D reports, agency budget documents, and appropriations reports. FY 2014 figures are current estimates. © 2014 AAAS.

associated with stimulus and sequestration are not included in the annual investment in R&D through USDA, investments were slightly over \$2.5 billion from 2001 to 2010 and investments were less than \$2.5 billion from 2011 to 2014. Increases in competitive grants through Agriculture and Food Research Initiative appear to be getting special attention. This increase is important, but it is not having a significant impact on the total USDA R&D budget, which contains many other important programs.

Comparing R&D funding for USDA with other agencies also is instructive. Between 1990 and 2012, USDA had a relatively small increase of 21 percent; increases for NSF and NIH were 109 percent and 135 percent, respectively. But perhaps more important is that from 2005 and 2012, investments for R&D in USDA declined by 16 percent (**Table 1**). Thus, the numbers clearly demonstrate that the U.S. is not giving food and agriculture R&D a priority when compared with other countries in the world and with other federally funded research areas.

Although the lack of federal investments in agricultural research are the focus here, it is noteworthy to mention the decline in state governments' funding of agricultural experiment stations — another issue of considerable concern. The state government share of total state agricultural experiment stations support fell dramatically from 69.3 percent in 1970 to 38.3 percent in 2009.

TABLE 1. Federal R&D Funding by Agency, FY1990 – FY2012, Budget Authority in Constant 2014 Dollars (billions)

Agency	Billions of dollars by year					% change by years	
	1990	2000	2005	2009	2012	1990–2012	2005–2012
NIH	13.2	22.8	32.9	32.1	30.9	135%	-6%
NSF	2.8	3.9	4.8	5.1	5.9	109%	21%
USDA	2.0	2.4	2.9	2.6	2.4	21%	-16%

Source: AAAS

In FY2014, USDA agencies are expected to expend about \$2.4 billion in discretionary funds for research (**Table 2**). NIFA also is projected to spend \$140 million for mandatory programs in FY2014; \$150 million has been requested for mandatory programs in FY2015, accordingly to the FY2015 USDA budget summary.

The Administration's proposed FY2015 budget reflects a continuing decline of 0.4 percent in USDA's R&D budget when adjusted for inflation. In addition, the Administration has suggested that Congress consider an Opportunity, Growth and Security Initiative that would add \$197 million to the ARS budget and \$80 million to the NIFA budget. This would be a 17 percent increase in the budgets for ARS programs and facilities and a 10 percent increase for NIFA programs.

TABLE 2. USDA Federal R&D Funding by Agency, FY2014-FY2015 (Budget Authority in Millions of Nominal Dollars)

	FY 2014 Estimate	FY 2015 Budget	FY 2015 House*	FY 2015 Senate*
Research and Development Estimates				
Agricultural Research Service (ARS)				
Salaries and Expenses	1,122	1,104	1,120	1,139
Trust Funds	32	32	32	32
Buildings and Facilities	0	0	155	0
Total ARS R&D	1,154	1,136	1,307	1,171
National Institute of Food and Agriculture (NIFA)				
Biomass R&D 1/ Res and Edu Activities	3	3	3	3
<i>Agri Food Res Init (AFRI)</i>	723	802	741	754
<i>Integrated Activities</i>	316	325	325	325
Integrated Activities	81	71	79	79
Total NIFA R&D	807	876	823	836
Economic Research Service	78	83	85	85
Foreign Agricultural Service	1	1	1	1
Nat Agricultural Stats Service	7	10	9	10
Animal & Plant Inspection Srv	44	40	42	42
Total USDA R&D	2,091	2,146	2,267	2,145
Forest Service 2/ Total USDA R&D w/ Forest Service	327	301	324	319
	2,418	2,447	2,592	2,464
Select Agency Discretionary Budgets (includes non-R&D components)				
Forest Service 2/				
Forest and Rangeland Research	293	275	298	293
Wildland Fire R&D	20	20	20	20
Research, Education, and Economics				
Agri Research Service (ARS)	1,122	1,104	1,275	1,140
Nat Inst Food Agri (NIFA)	1,277	1,336	1,274	1,292
<i>Research and Ed Act</i>	773	838	774	788
<i>Extension Activities</i>	469	469	467	473
<i>Integrated Activities</i>	35	29	32	32
Economic Research Service	78	83	86	85
Nat Agriculture Stats Serv	161	179	169	178

*Appropriations Committees. The Senate Committee reported its bill on May 22, the House Committee on May 29.

1/ Mandatory program authorized in Farm Bill.

2/ The Forest Service is funded in the Interior appropriations bill. The Senate committee has not yet acted on its bill; the House committee approved its bill July 15.

Source: OMB R&D data, agency budget documents, and appropriations bills and reports.

All figures rounded to the nearest million. Changes calculated from unrounded figures.

Source: AAAS

Other Federal Budgets and Programs. In reviewing federal investments related to broadly defined agriculture, it is important to look beyond USDA to closely related R&D program activities in other federal agencies.

Estimated FY2014 funding for FDA food safety research was \$1.218 billion; for NIH food safety research was \$235 million; for NIH nutrition and obesity research was \$2.395 billion; for DOE bioenergy research was \$232 million; for DOE biological and environmental research was \$610 million; and USGS water resources research was \$207 million. Related food, agricultural and natural resources funding in the National Science Foundation (NSF) also is important, but the amounts are not reflected in the classification used by the Office of Management and Budget.

The Riley Memorial Foundation (RMF), recognizing the importance of collaborative agricultural R&D programs throughout the federal government, organized a discussion on December 9, 2009, led by then RMF Director Catherine Woteki. The discussion, which included representatives from AAAS, USDA, RMF and six scientific societies, explored increasing the involvement of societies in the annual AAAS R&D report. As a result, AAAS agreed to establish a new chapter (chapter 27) entitled “Food, Nutrition, Agriculture and Natural Resource Science” in the annual *AAAS Report: Research and Development*. The chapter would include budget information from USDA, Food and Drug Administration (FDA), National Institutes of Health (NIH), U.S. Geological Survey (USGS) and the Department of Energy (DOE). In 2010, RMF recruited representatives of scientific societies to form a writing team for the new chapter. Represented on the team were the Institute for Food Technology; the Agronomy, Crop and Soil Science Societies; the American Society of Nutrition; the Federation of Animal Science Societies; the National Association of University Forest Resource Programs; and the Soil and Water Conservation Society. Each year since 2010, Chapter 27 has been prepared and included in the AAAS report.

To further recognize the importance of food, agricultural and natural resources, in 2011 RMF organized the *Agriculture, Food, Nutrition, and Natural Resources R&D Round Table: Partnerships Yield Greater Societal Benefits*. The objectives of the round table were to raise the profile of agricultural, food and natural resources-related R&D throughout the federal government and beyond, and to highlight the characteristics of highly productive collaborations to enhance future collaborations. Sixty-one projects or programs, financially supported by more than 20 federal agencies, were nominated as examples of collaboration and partnership. From that number, eight were selected as exemplary cases for presentation at the round table and six were selected for special recognition. The round table clearly demonstrated the importance of the research conducted in several federal agencies as well as value of collaborations between USDA, federal agencies and state institutions.

This review of federal investments in research on the many components of the food and agriculture system indicates there much important federally supported R&D underway. USDA is the only federal agency that conducts research on all aspects of agriculture, but it is important to make the maximum use of expertise wherever it occurs.

But the levels of funding indicate there is a need for the development of broad-based support for increased funding if the United States is going to ensure its own food security and national security, be competitive in the global marketplace and continue to be a world leader in science and technology associated with all aspects of agriculture.

Overview of Universities

Introduction. A review of the roles of universities — land-grant, non-land grant public and private, as well as key university associations — provides a perspective needed in considering the pursuit of a unifying message. Especially important is an understanding of the leadership role that universities historically have played in research, education and extension and also in collaboration, partnership and engagement. An important part of a unifying message would emphasize all these interconnected areas and extending and expanding them into the future.

Land-Grant Universities

Publicly funded research and extension efforts at land-grant universities have produced tremendous benefits not only for agricultural producers and industry, but for consumers and communities throughout society. Science has been the backbone of American agriculture's remarkable gains in productivity while lowering input costs. Since 1950, the U.S. agricultural sector increased output by more than 260 percent while using 2 percent fewer inputs such as labor, seed, feed, fertilizer and water. Many of these successes are the result of significant investments in land-grant universities. Consumers have benefited from lower food and fiber prices, improved food quality and safety, healthier human nutrition and behaviors, improved environmental conditions and enhanced standards of living. As the result, Americans spent only 5.5 percent of their disposable income on food consumed at home — far less than any other nation.

150 Years of Innovation. The roots of the land-grant universities reach back more than 150 years to landmark pieces of federal legislation, beginning with the Morrill Acts of 1862 and 1890. Organized structures for agricultural research through state experiment stations (Hatch Act, 1887) and for the Cooperative Extension System (Smith-Lever Act, 1914) arose to distinguish the American land-grant institutions as a scientific and information delivery system unique to the world — with investments not only by the federal government, but by states and counties. The state experiment stations created a structure for federated yet independent research to address location-specific problems and build a nationwide core of basic scientific knowledge on agricultural issues. Cooperative Extension filled the need to transfer research findings and newly developed technologies to users and stakeholders and to communicate science-based, practical information to the public.

The Value of Land-Grant R&D. During the past 50 years, nearly 300 published economic reports have attempted to measure the value of research and development on agricultural productivity and innovation. The findings mostly pertain to the value derived from land-grant universities, where the majority of agricultural R&D is conducted. The focus of these economic studies was to measure the social payoffs of R&D investments using tools like internal rate of return and benefit-cost ratios. A review of 292 studies that reported a total of 1,852 estimates of rates of return to agricultural R&D found an overall mean internal rate of return, after eliminating outliers, of 64.6 percent per year. These computed internal rates of return are consistent with the benefit-cost ratio estimates for state-level, land-grant research and extension funding (using a 3 percent real discount rate). The benefit-cost ratio findings indicate agricultural R&D generated tremendous amounts of net benefits that were 21 to 32 times greater than the cost. The bottom line is that public investments have yielded remarkable payoffs to all segments of society.

Job Creation. Another benefit of agricultural R&D is jobs. Land-grant R&D has spurred economic growth and new employment opportunities, including many in processing industries that transform raw agricultural goods into finished consumer products. Many more jobs lie in transportation, farm equipment manufacturing,

farm and ranch input supply and other firms that support producers and agribusinesses. Twenty-two million people in the United States work in agriculture or agriculture-related fields. Recently, job creation has been a benefit of R&D in renewable energy and, in particular, biofuels which utilize agricultural crops and residues as feedstock.

Impact Beyond Productivity. Public funding of land-grant university R&D not only finances traditional research and extension efforts devoted to increasing agricultural productivity, but also touches upon public-good issues for all of society. The USDA reported about 60 percent of public agricultural R&D is committed to improving farm and ranch production while the remaining 40 percent is put to work to advance areas such as community development, food safety and nutrition, natural resources, youth development, family and consumer science and economics. Public investments in land-grant universities are necessary to address not only immediate, short-term producer and consumer needs, but also to investigate basic research questions that could have long-term, significant benefits to society.

Today's Land-Grant System. Today there are nearly 110 land-grant institutions located in 50 states, six territories and the District of Columbia. They include the 1862 land-grants; the historically black land-grants (1890 institutions); and American Indian land-grants (1994 institutions). The Association of Public and Land-grant Universities (APLU) represents the land-grant universities and other public institutions conducting food, agriculture, and natural resources research. APLU maintains numerous commissions, councils, boards and committees that help support and manage key functions of the nation's land-grant system. Two key committees within the Board on Agriculture Assembly are the Experiment Station Committee on Organization and Policy (ESCOP) and the Extension Committee on Organization and Policy (ECOP), which work to establish goals and priorities of the nation's system of state agriculture experiment stations and Cooperative Extension services.

The Primacy of Collaboration. One of the defining characteristics of land-grant agricultural research is its collaborative nature. Throughout their history, the land-grants have partnered with the USDA, state, regional and local agricultural agencies, the private sector and nonprofit groups to provide the scientific knowledge that led to incredible payoffs for the nation and world. A shining historical example that continues to pay huge dividends today is the dramatic improvement in corn yields over nearly a century, the result of a commitment to progress by land-grants, USDA, state agencies and private companies. In the 1920s a national research effort of state experiment stations and the USDA, notably in Iowa, began to increase corn yields through inbreds and hybrid technology. Steady progress began as new plant genetic materials were made available. In the 1930s, corn yields averaged 23 bushels per acre. By 1978, yields averaged over 100 bushels per acre for the first time. In 2013, average yields reached 159 bushels per acre and the value of the crop was \$63 billion — 38 percent of the total value of all crops produced in the country.

Land-grant research and extension programs today continue the collaborative legacy to achieve the goals of providing a safe, secure, and cost-effective supply of food and fiber; preserving the environment and conserving natural resources; cultivating an engine for economic growth and job creation; and improving the health and life-styles of both youth and adults.

Funding Support: Capacity. Federal investments, matched and often exceeded by state and local investments, in research and extension are made annually to provide capacity for each state and territory to establish and operate land-grant agricultural research and extension programs. Every corner of the nation has depended upon the ability of land-grant universities to rapidly deploy adequate expertise and appropriate resources to developing challenges. Two recent examples are soybean rust and porcine epidemic diarrhea (PED). Capacity funds enable land-grant universities to respond quickly to emergency or rapidly developing problems such as disease outbreaks, natural disasters, pest infestations, food safety concerns, international conflicts and more. Besides these rapid-response projects, capacity funds are used to support activities in such areas as long-term research projects (like animal and plant breeding, water quality studies and sustainable best management practices); place-based geographically specific projects (such as adaptive breeding and production practices); high-value specialty crops and livestock (such as goats and muscadine grapes); and multistate research efforts (like sustainable livestock and poultry production, microirrigation and water conservation). Capacity funds

also make possible the critical research and education infrastructure needed for effective response, including faculty, staff, graduate students, equipment, research farms and other land resources, and facilities.

Funding Support: Competitive. Scientists at land-grant universities leverage capacity funds by taking advantage of many opportunities for extramural funding. They successfully compete for grant and contract funds that support research and extension programs. Key national competitive grant programs are available through agencies such as USDA National Institute of Food and Agriculture, National Science Foundation, National Institutes of Health, Department of Energy, National Aeronautics and Space Administration and National Oceanic and Atmospheric Association. Federal, regional, state and international organizations provide more opportunities. Funding is available from private companies and foundations seeking research and extension assistance extending their own R&D efforts. These grants and contracts provide significant financial resources that enable faculty to address both applied and basic questions.

Educating the Next Generation. Many land-grant universities are experiencing a resurgence of interest among young people in exploring the breadth of opportunities in agricultural sciences. Many report tremendous enrollment growth in their agricultural colleges, including increases from 50 to 75 percent over the past decade. Students are taught and mentored by faculty scientists conducting research in critical areas. That's why students are becoming keenly aware of the challenges and opportunities that lie ahead, including continued development of new, sustainable production methods to feed the rapidly expanding world's population while conserving and preserving water, land and air quality. Students understand the expertise that is needed to guide the impressive and diverse technologies employed in modern agriculture. Students are responding to the rising demand for highly trained technicians and scientists to meet these needs. High-paying jobs with national and multinational firms are attracting top graduates.

Questions on Sustaining Momentum. The successes of American agriculture over the past century can largely be attributed to land-grant universities' hand-in-hand missions in education, research and extension. Sustaining these successes is daunting in the face of major global challenges like dramatically increasing food production and adapting to climate change. Because the United States is one of the world's largest producers of agricultural commodities, sustained growth of agricultural productivity is critical to both domestic and global food security. Failure of agricultural productivity to keep pace with the nation's and the world's needs is a troubling development. Increasing global food demand could lead to rising food prices, which would increase pressure on low-income households as they are compelled to spend a greater share of their income on food.

Addressing these formidable problems along with meeting new or unknown challenges will require enhanced efforts and additional agricultural R&D investment at land-grant universities in the years ahead. "Capacity" is a critical term. As the world becomes more vulnerable to crises resulting from climate change, population growth, political unrest and other far-reaching hazards, the land-grants' ability to effectively address concerns will require more public investment beyond maintaining capacity. They must grow their capacity.

Non-Land-Grant Public Universities

Approximately 60 public universities that are not land-grant universities are an integral part of the nation's educational, outreach and research efforts in agriculture, food, natural resources and related fields. The non-land-grant universities (NLGU) prepare highly skilled, workforce-ready graduates. Experiential learning programs provide real-world, practical experiences in research laboratories, at university-owned farms and with industry and state and federal government. Didactic, research and hands-on training is designed to instill problem-solving, entrepreneurial, teamwork and communication skills in NLGU graduates. For FY2011, fall enrollment inclusive of graduate and undergraduate students in colleges of agriculture and natural resources at NLGU ranged from 34 (University of Louisiana at Monroe) to 3,945 (California Polytechnic State University, San Luis Obispo), and averaged 636 students per college. Of total enrollments across all NLGU, nearly 93 percent were undergraduate students and 7 percent were graduate students.

The extent of research activities at NLGU is not easily quantified, although sources of information such as the National Science Foundation Higher Education Research and Development Survey (HERD) provide useful information. Because categorization of research expenditures by the type of research — agricultural sciences compared to biological sciences, for example — is not always consistent, direct comparisons among universities is not always possible. Therefore, to provide a perspective on the contributions made by NLGU, the following four universities were selected as examples, based on geographical location and potential educational and research impact.

California Polytechnic State University. Cal Poly, founded in 1903, is located in San Luis Obispo. At the heart of Cal Poly's education is its renowned "Learn by Doing" methodology. The College of Agriculture, Food and Environmental Sciences (CAFES) has an enrollment of approximately 3,800 undergraduate students and 90 graduate students. CAFES facilities include 10,000 acres for hands-on learning and applied research, a state-of-the-art beef center and dairy production facilities. Cal Poly reported approximately \$4.1 million in research expenditures in agricultural sciences in FY2012. Areas of research include sustainability, specialty crops, coastal resource management, urban forestry and dairy product development. As a member institution of the California State University System, CAFES participates in the state-funded Agricultural Research Institute, in which awards, matched 1:1, provide for research in high-priority areas.

Southern Illinois University (SIU). Founded in 1869, SIU is located in Carbondale and ranks among Illinois' most comprehensive public universities. In 2013, SIU was designated a Carnegie High Research Activity University. SIU is dedicated to quality academic endeavors in teaching and research, supportive programming for student needs and development and effective social and community, regional and statewide economic initiatives. The College of Agricultural Sciences, with a strong reputation for teaching, research and service, has facilities that include 2,000 acres of university farms for crop and animal production, an equine center and greenhouses. Enrollment in the college is approximately 900 undergraduate students and 100 graduate students. In addition to traditional areas of food, feed and fiber production, research programs include nutrition and health, specialty crop production, food safety and security, tourism and protection and enhancement of the environment.

SUNY College of Environmental Science and Forestry (ESF). ESF, founded in 1911 in Syracuse, is a member institution of the State University of New York (SUNY) system. The ESF campus occupies 12 acres in Syracuse and 25,000 acres on its regional campuses throughout central New York and the Adirondack Park. It is the nation's oldest college dedicated solely to the study of the environment, developing renewable technologies and building a sustainable future. ESF enrolls more than 1,700 undergraduate students and 550 graduate students. Research expenditures in fiscal year FY2012 were \$14.3 million, with an average research expenditure of \$107,000 per faculty member. Nationally recognized research programs include aquatic ecosystems, bioenergy, biotechnology, biodiversity, ecology, genetic engineering, nanotechnology, remote sensing and wildlife disease prevention.

Texas Tech University. Founded in 1923, Texas Tech, a comprehensive higher education institution with more than 33,000 students, is located in Lubbock. The College of Agricultural Sciences and Natural Resources (CASNR) is the largest NLGU agricultural and natural resources research program in the nation. CASNR has several research farms for agronomic, horticultural and animal science programs. CASNR achieved an all-time high enrollment of 1,928 students in the fall of 2013. Approximately 18 percent are pursuing graduate degrees. Twelve faculty members have linkages to the land-grant system through joint appointments with Texas A&M AgriLife Research and Extension. Research expenditures in 2013 totaled \$25.5 million; of this amount, \$3.2 million was from federally sponsored programs. Nationally recognized programs include food safety, cotton production and fiber evaluation, sustainable agriculture, natural resources management, farm economics policy issues and risk management, and agricultural communication and education.

Private Universities

A central national database is not readily available that provides information on research related to food, agriculture and natural resources at private universities. The Association of American Universities (AAU) includes 26 private university members, although some might not consider their research contributions to be associated with broadly defined agriculture. The kinds of research conducted by private universities that directly or indirectly impact on agriculture include molecular biology, genomics, nutrition, climate change, natural resource conservation and bioenergy. Examples of private universities with this kind of research include Yale University, Harvard University, Stanford University and Washington University. For these four universities, the research expenditures reported in HERD for biological sciences is between \$154 and \$312 million — an indication of expenditures in areas likely to impact food, agricultural productivity and management of natural resources. To provide additional perspective, the following three programs at private universities were selected as specific examples of similar likely impact.

Earth Institute at Columbia University. The Earth Institute at Columbia University in New York City brings together the people and tools needed to address some of the world's most difficult problems, including climate change and environmental degradation, poverty, disease and the sustainable use of resources. By blending scientific research, education and practical solutions, the Earth Institute is working to help guide the world onto a path toward sustainability. Its work reflects the fundamental belief that the world possesses the tools needed to effectively mitigate climate change, poverty and other critical issues. The institute comprises more than 30 research centers and 850 scientists, postdoctoral fellows, staff and students. Working across many disciplines, scientists study and create solutions for problems in public health, poverty, energy, ecosystems, climate, natural hazards and urbanization. In the institute's largest research unit, the Lamont-Doherty Earth Observatory, some of the world's leading scientists study geology, oceans, freshwater systems, climate and atmosphere. Earth Institute experts work hand-in-hand with universities, corporations, government agencies, nonprofits and individuals. They advise national governments and the United Nations on issues related to sustainable development and the Millennium Development Goals. They are educating the next generation of leaders in basic sciences and sustainable development.

Jean Mayer USDA Human Nutrition Research Center on Aging (HNRCA) at Tufts University. Located in Boston, HNRCA is one of the largest research centers in the world studying nutrition and physical activity in healthy and active aging and the prevention of age-related disease. The goal of HNRCA is to explore the relationship between nutrition, physical activity and healthy and active aging. HNRCA is an excellent example of a strong partnership between a private university and a federal agency. It is run by cooperative agreement between Tufts University and USDA's Agricultural Research Service. The center has made significant contributions to U.S. and international nutritional and physical activity recommendations, public policy and clinical healthcare. The contributions include: advancements in the knowledge of the role of dietary calcium and vitamin D in promoting nutrition and bone health; the role of nutrients in maintaining the optimal immune response and prevention of infectious diseases; the role of diet in prevention of cancer; obesity research; modifications to the Food Guide Pyramid; contributions to the USDA nutrient data bank; advances in the study of sarcopenia, heart disease, vision, brain and cognitive function; opinions on food labeling initiatives; and research on how genetic factors impact predisposition to weight gain and various health indicators.

The Genome Institute (TGI) at Washington University. As one of only three NIH-funded, large-scale sequencing centers in the United States, TGI at Washington University in St. Louis is helping to lead the way in high-speed, comprehensive genomics. TGI creates, tests and implements new approaches to the study of biology with the goal of understanding human health and disease, as well as evolution and the biology of other organisms like plants. Its mission is to help improve the human condition by producing, studying and interpreting high-quality, genome-based data that drives biological discoveries that range from the bench to the hospital bedside. Since 1993, the institute has played a vital role in genome sequencing, receiving over \$800 million in funding. It began as a key player in the Human Genome Project, ultimately contributing 25 percent of the finished sequence. TGI works in concert with other genome-sequencing centers around the world, including the National Human Genome Research Institute; Baylor College of Medicine Human Genome Sequencing Center; Broad Institute; NIH Intramural Sequencing Center; Wellcome Trust Sanger Institute; Michael Smith Genome Sciences Centre; and International Sequencing Consortium.

University Associations

Universities must play a key role in developing the unifying message. University associations that represent the majority of institutions with strong food, agriculture and natural resources programs could benefit from involvement in developing a unified message and a strategy to communicate it to federal decision-makers.

Association of Public and Land-grant Universities (APLU). APLU is a research, policy and advocacy organization representing 237 public research universities, land-grant institutions, state university systems and affiliated organizations. Founded in 1887, APLU is North America's oldest higher education association, with member institutions in all 50 states, the District of Columbia, four U.S. territories, Canada and Mexico. Its membership includes many public institutions conducting food, agricultural and natural resources research. The association's membership comprises 206 campuses and 25 university systems, including 75 U.S. land-grant institutions; and 23 historically black colleges and universities, of which 21 are land-grant institutions. APLU also represents six related higher education organizations, including the American Indian Higher Education Consortium, which serves the interests of the nation's 33 American Indian land-grant colleges.

Non-Land-Grant Agricultural and Renewable Resources Universities (NARRU). NARRU is a forum and unifying force for faculty, students, staff and administrators of agriculture, food and renewable resource programs at NARRU state-funded public colleges and universities. Through its 60 members, NARRU values and promotes excellence in science-based teaching with hands-on experience, in conducting responsive and issue-based research and in communicating findings to stakeholders and the general public.

Association of American Universities (AAU). AAU is an important nonprofit organization of 62 leading public and private research universities. The association is unique in that membership is by invitation only. Its members include outstanding land-grant, non-land-grant public and private universities that are on the leading edge of innovation, scholarship and solutions that contribute to the nation's economy, security and well-being. AAU focuses on issues that are important to research-intensive universities, such as research funding, research policy issues and graduate and undergraduate education. Thus, AAU members are in a position to make important research contributions to agriculture when it is broadly defined, as it should be. Research on genomics, natural resources and nutrition are examples.

Overview of Supporting Societies and Organizations

Introduction. Over the past five years, as the Charles Valentine Riley Memorial Foundation has partnered with the American Association for the Advancement of Science and the World Food Prize Foundation “to promote a broader and more complete understanding of agriculture as the most basic human endeavor and... to enhance agriculture through increased scientific knowledge,” the annual AAAS Riley Memorial Lecture and related events have provided strong evidence of the broad interest in increasing the scientific knowledge associated with the many diverse aspects of agriculture.

Still, as evidenced in the review of federal investments, if broad-based support for increasing scientific knowledge exists, it is not resulting in the kind of investments that are desired.

As stated in earlier chapters, a complete understanding of agriculture must be built around a broad definition that encompasses agricultural production in both livestock and poultry and crops, rural communities, forestry, natural resources, food and nutrition, sustainability, climate, bioenergy, economics and environment.

Within this definition, many different entities are working to increase scientific knowledge. Scientific societies, most of which are organized around disciplines, and a number of supporting organizations play an important role in generating new knowledge. Support organizations include nonprofit organizations and coalitions with multidisciplinary research interests. In addition, a number of nonprofits are concerned with agriculture with research as a significant priority. Then there are others such as general farm organizations, agricultural commodity organizations, trade associations and foundations that have interests in research, but in general, are perceived as not giving research a high organizational priority. The grouping of organizations that follows is arbitrary in that there are likely to be exceptions on how those within each group deal with research. The listings are provided as examples only and are not intended to be comprehensive.

A unifying message needs to be a common thread through the wide range of interests of these varied societies and organizations. The common purpose represented by a unifying message would help deal with the real or perceived view that the related interests are not able to work together toward a single goal.

Scientific Societies

For more than 100 years, professional scientific societies in plant, animal and agricultural sciences have taken leadership roles in defining best practices in the scientific endeavor and in helping the U.S. prioritize the nation’s agricultural research agenda. They have played pivotal roles in formulating the concept of peer review in the scientific literature, as well as the importance of peer review in deciding funding priorities within public agencies and private philanthropies. The journals they publish, either alone or in conjunction with other publishers, are a primary source of definitive information on fundamental and applied findings — driving discovery and advancing research and development of novel agricultural products and practices. Members of these societies are frequently called upon to provide scientific expertise and input as Congress determines priorities for federal spending in support of research.

Given their central role as representatives of the major scientific disciplines, the societies help define both visionary and narrow priorities for U.S. agricultural research. Whether responding to a sudden threat to agriculture, food or renewable resources, or promoting basic research to provide foundational knowledge for responding to future threats, these societies and their members have been advocating for agricultural research

since their inception. Because of the broad reach of their memberships and their presence in Washington, D.C., scientific societies are essential players in helping to develop a unifying message in support of agricultural research.

Although these societies have banded together to form a number of advocacy coalitions and educational organizations, these have tended to focus their messaging on specific areas of research. Despite the obvious importance and potential impact of such bodies, it has yet to be proven possible to create a “grand coalition” that effectively unifies the messages propagated by the entire breadth of these societies. While it will remain essential for each society to promote the health and vitality of their respective constituents, they also should share a responsibility for furthering the broader needs of the agricultural research community per se. As efforts begin to move forward in crafting a unifying message in support of agricultural research as a whole, the professional societies should play a critical role in getting that message out both to their members and to the end users or consumers of their respective research results. And the societies’ experience in organizing and participating in coalitions should be leveraged to help establish broader organizational support for a unifying message.

For the most part, the scientific societies whose members make major contributions to food, agricultural and natural resources research are organized around a discipline or a group of closely related disciplines. However, there are two more general science organizations of note: The American Association for the Advancement of Science (AAAS) and the American Institute of Biological Sciences (AIBS).

AAAS seeks to “advance science, engineering and innovation throughout the world for the benefit of all people” by pursuing the following broad goals: enhance communication among scientists, engineers and the public; promote and defend the integrity of science and its use; strengthen support for the science and technology enterprise and provide a voice for science on societal issues; promote the responsible use of science in public policy; strengthen and diversify the science and technology workforce; foster education in science and technology for everyone; increase public engagement with science and technology; and advance international cooperation in science. Since AAAS is a general science organization with more than 200 affiliated societies, it may provide a useful framework for examining the role of scientific organizations. The vast majority of scientific societies contributing to agricultural research are AAAS affiliates. A similar number of affiliates that increase scientific knowledge beneficial to broadly defined agriculture can be considered significant contributors (**Appendix B**).

AIBS is dedicated to advancing biological research and education for the welfare of society. AIBS works to ensure that the public, legislators, funders and the community of biologists have access to and use information that will guide them in making informed decisions about matters that require biological knowledge. The organization catalyzes action to build the capacity and leadership of the biology community to address matters of common concern.

An important consideration is that in order to meet the challenges related to food, agriculture and natural resources, a robust system is needed that includes not only those scientific societies traditionally associated with those fields, but many others as well. For example, it is worthy of note that significant contributors of scientific knowledge on natural resources include groups such as the American Meteorological Society, American Water Resources Association, Association of American Geographers, American Geophysical Union, Ecological Society of America and National Ground Water Association.

Nonprofit Organizations and Coalitions with Research Interests

The summary of organizations and coalitions presented below is not intended to be all inclusive, but to provide an indication of the variety of organizations concerned with food, agriculture and natural resources, exclusive of research granting foundations. Those included are ones that are most familiar to the contributors to this report and the descriptions derive primarily from the organizations themselves. The organizations and coalitions all have some interest in research, but their roles are quite different, ranging from those that focus

primarily on information sharing, those that focus on policy and those that focus on influencing appropriations. For a unifying message to have significant impact, a common goal needs to be defined that brings these and other organizations and coalitions closer together.

AFRI Coalition. The AFRI Coalition is a group of scientific societies and science advocacy organizations with diverse research interests that support a full appropriation of the USDA's Agriculture and Food Research Initiative (AFRI). The coalition believes that robust funding of AFRI shows strong commitment to America's farmers, consumers, researchers and food and rural entrepreneurs, bringing them the tools necessary to maintain the country's competitiveness. At the same time, work performed under AFRI helps to protect the natural resource base and environment, enhance human nutrition and promote health, improve fundamental understanding of plants and animals and foster vibrant rural communities.

AGree. Since 2008, this group of nine U.S.-based foundations has been exploring how they can work together to support efforts that better enable U.S. policies related to food and agriculture to meet needs for food, nutrition, environmental quality and rural development in America and abroad. The Meridian Institute facilitates the effort.

Association of American Universities (AAU). AAU is a nonprofit association of 60 U.S. and two Canadian pre-eminent public and private research universities. Founded in 1900, AAU focuses on national and institutional issues that are important to research universities, including funding for research, research and education policy and graduate and undergraduate education.

Association of Public and Land-grant Universities (APLU). Agricultural research is primarily supported through APLU's Commission on Food, Environment and Renewable Resources and its boards on Agriculture Assembly; Natural Resources; Human Sciences; Oceans, Atmosphere and Climate; and Veterinary Medicine. The Council for Agricultural Research, Education and Teaching (CARET), a unit within the Board on Agriculture Assembly, is a national grassroots organization with a mission to advocate for greater national support and understanding of the land-grant university system's food and agricultural research, extension and teaching programs.

Chicago Council of Global Affairs. The Chicago Council is one of the nation's oldest and most prominent international affairs organizations. The independent, nonpartisan council is committed to influencing the discourse on global issues through contributions to opinion and policy formation, leadership dialogue and public learning.

Council for Agricultural Science and Technology (CAST). CAST is a nonprofit organization composed of scientific societies and many individual, student, company, nonprofit and associate society members. Its board of directors includes representatives of scientific societies, industry and nonprofit and trade organizations.

Council on Food, Agricultural and Resource Economics (C-FARE). C-FARE is a nonprofit organization that promotes the work of applied economists and serves as a catalyst for incorporating economic thinking into the analysis of food, agricultural and resource decisions. It serves as a conduit between the academic research and extension communities and Washington, D.C., policymakers and agency personnel, matching expertise to public needs.

Farm Foundation. The Farm Foundation is a non-advocacy public charity that promotes objective analysis, constructive dialogue and innovative ideas to build a deeper understanding of issues critical to the future of agriculture, food systems and rural communities. Its 80-year reputation for objectivity allows it to bring together diverse stakeholders for discussions on economic issues and public policies.

Global Harvest Initiative (GHI). GHI is a private-sector voice for productivity growth throughout the agricultural value chain to sustainably meet the demands of a growing world. The initiative believes the right policies can improve global food and nutrition security by accelerating agricultural productivity gains while conserving natural resources.

National Coalition for Food and Agriculture Research (NC-FAR). National C-FAR is a nonprofit, non-partisan, consensus-based and customer-led coalition. It brings food, agriculture, nutrition, conservation and natural resource stakeholders together with the food and agriculture research community, serving as a forum and a unified voice in support of sustaining and increasing public investment at the national level in food and agricultural research, extension and education.

National Sustainable Agriculture Coalition (NSAC). NSAC is an alliance of grassroots organizations that advocates for federal policy reform to advance the sustainability of agriculture, food systems, natural resources and rural communities. In its vision, a safe, nutritious, ample and affordable food supply is produced by a legion of family farmers who make a decent living pursuing their trade, while protecting the environment and contributing to the strength and stability of their communities.

Non-land-grant Agricultural and Renewable Resources Universities (NARRU). NARRU is a forum and unifying force for faculty, students, staff, and administrators of agriculture, food and renewable resource programs at state-funded public colleges and universities. Through its 60 members, NARRU values and promotes excellence in science-based teaching with hands-on experience, conducting responsive, issue-based research and communicating findings to stakeholders and the public.

Organic Farming Research Foundation (OFRF). OFRF fosters and improves the widespread adoption of organic farming systems. The foundation cultivates organic research, education and federal policy that brings more U.S. farmers and acreage into organic production. Since 1992, OFRF has conducted four National Organic Farmers' Surveys, collecting information about organic farmers' research and information needs, their experiences in the organic marketplace, effects of genetically modified organisms on organic production and markets, organic farmer demographics and much more.

Supporters of Agriculture Research (SoAR). SoAR is a nonpartisan, science-based coalition seeking sound research policies that focus more of the best minds on feeding America and the world. SoAR is working with major research institutions, farmer groups, scientific organizations and private-sector partners who believe a strong competitive grants program will encourage top scientists from multiple disciplines to address the many agriculture-related challenges facing the country.

Union of Concerned Scientists (UCS). For nearly half a century, the Union of Concerned Scientists has combined the knowledge and influence of the scientific community with the passion of concerned citizens to build a healthy planet and a safer world. Food and agriculture is one of six major program areas for UCS.

General Farm Organizations, Agricultural Commodity Organizations, Trade Associations and Selected Foundations

There are some 70 general farm organizations, agricultural commodity organizations, trade associations and selected foundations that have a primary interest in food and agriculture (**Appendix C**). Most have state-based organizations as well as national offices. Although most agribusiness firms are members of a trade association, individual companies need to be considered as well.

The number and diversity among these organizations offers a unique challenge on how to best engage their interests. However, it should be possible to select leaders that are sensitive to the diverse interests who would be willing to participate in efforts to develop a unifying message. As stated above, a unifying message can serve as a common thread and a common purpose.

Overview of Major Research Thrusts

Introduction. Less than a hundred years ago, a U.S. farmer fed fewer than 10 people from the farm's output. Tremendous gains in productivity have allowed a single U.S. farmer today to feed 155 people and provide other nonfood benefits such as biofuels and fibers. With forests and natural resources, the economic, environmental and social impacts over time also have been profound. Gains are a result of research, funded by both private and public sectors, for better seeds, fertilizer, animals and other inputs as well as improved methods and innovative systems for producing food, feed, fuel and fiber. Despite continuous improvement, the rate of change in agricultural innovation is slowing. The time from discovery to application can be long in agricultural research. Advances in productivity have slowed because of shrinking funding in the past two decades. This lack of funding obstructs success in meeting future needs.

The sections that follow describe major research thrusts in key areas of agricultural productivity and rural communities, forestry, natural resources and food science and human nutrition. Foundational advances in these research areas will depend on increased funding.

Agricultural Production and Rural Communities

Production of food is critical to basic survival. In parts of the world where food is scarce, turmoil erupts, as evidenced by the civil unrest and government disruption in many nations due to price spikes for food in 2008 and 2010. Because of this, agricultural production is highly valued by governments worldwide as a source of income and stability. In the United States, a strong case can be made for agriculture's role in both economic security and national security; agriculture provides a national security edge. Unfortunately, changing weather patterns and environmental pressures of pests, drought, weeds, diseases, and soil degradation hamper agricultural outputs and require continual improvements to agriculture practices. These improvements come from research designed to sustainably increase the efficiency of food production.

To support a growing population, more food needs to be produced each decade and to do so in a way that improves outcomes for the environment, rural communities and urban communities; increases employment and farming opportunities; enhances health and nutrition; accounts for adequate food distribution; and reduces food waste. This is an enormous undertaking. Higher production targets must be met with increased adoption of existing food production technologies and farming systems and discovery of improved technologies. To speed adoption of new innovations and technologies, it will be increasingly important to reach more farmers through extension and education. Farmers' input also is critical in defining the needs and in research design and implementation.

Research plays a major role in defining the farm and food system and its evolution, including the structure of agriculture and economic opportunities in farming and in rural communities. The aging of American agriculture and the depopulation of significant portions of rural America are continuing concerns that can be addressed through targeted research initiatives; they also can be addressed via increased farming and other economic opportunities during the design of broader research and technology development efforts.

Improved Plant and Animal Genetics. With growing knowledge of genetics, the methods to select the best genetics became more rapid, precise and predictable. Scientists select traits that improve yield through faster growth, disease resistance and improved resilience to climatic pressures. These goals still drive genetic decisions, and researchers now possess better tools and genomic knowledge of the domestic species, which

improves their ability to decide which plants and animals are used to generate offspring. For example, the exploration of plant genomes holds the potential for increased productivity, resistance to pests and disease and the ability to grow well in a wide array of environments. Deciphering the linkage of the genome to a plant's physical traits requires more tools. It also requires more knowledge of natural adaptations and future potential to adapt to environmental changes. Current genetic tools will be surpassed by those available in the future — if funding is there to develop them. Scientists are poised for amazing progress, but lack of funding hinders the next steps. A major reinvigoration of support and funding for plant and animal breeding is critical to develop cultivars and breeds that are adapted to the needs of specific regions, a wide variety of farming systems and a changing climate.

Animal Performance. Peak performance of animals will be required to meet future food security challenges while reducing the carbon footprint of animal agriculture. Research on novel nutritional and management factors can lead to improved feed efficiency. Exploring the genetic variation present in energetic efficiency may lead to game-changing improvements. Further research in reproductive performance will contribute greatly to increased whole-herd efficiency.

Soil Health and Conservation Practices. Today there is a renewed focus on restoring and improving soil health to achieve both production and environmental benefits. Research and education in support of improved farming systems and technological advancements will be critical to long-term, sustained food production capacity. Adding to the toolbox of available land management measures — no-till or low-till practices, buffer strips, cover crops, ecologically based pest management, composting, resource-conserving crop rotations and diversification, and more — can lead to improved agricultural productivity and environmental protection.

Disease Prevention and Treatment. In plants and animals, research performed at public and private institutions has led to the development of disease-resistant plant strains, antibiotics, vaccines, animals that are naturally immune to certain diseases and better biosecurity. Unfortunately, diseases continually evolve ways to overcome all these barriers. Future research funding must quicken the pace of new methods developed for resisting these diseases.

Future of Rural Communities. In the farm and rural economy, major signs that point to critical needs include: Increased farm consolidation; concentration of farmland ownership; steady aging of farmers; decline in open, competitive markets; high barriers to entry for new, young and beginning farmers; rural population loss in major sections of the country; farm labor shortages and low wages; and disproportionate rural poverty and unemployment. But with these challenges are opportunities such as new value-added farm-related businesses, growing new segments of American agriculture, new successful rural small business start-ups and signs of a revitalized interest in farming by young people. To address these concerns and seize the opportunities, an enhanced commitment to interdisciplinary and systems-based research and extension, technology assessment and outcome-based evaluation and reporting is needed.

Global Food Security. Global food production will need to increase to meet the needs of a growing population, especially with rising incomes and an expanding middle class in developing countries. This greater demand will put pressure on global food production systems to produce more in a sustainable manner. Meeting that goal will require advancements in research, technology and understanding of farming systems.

Agroecosystems. Research is needed to develop robust and resilient production systems, explore complex cropping rotations, evaluate the benefits of integrated crop and livestock production and enhance reliance on ecological processes to manage pests, weeds and diseases. Long-term research and extension initiatives should aim to understand the aggregate effects of farming at the landscape or watershed scale.

Animal Well-Being. Raising animals requires attention to the overall impact on the environment, including land, air and water use. Great strides have been made in resource use efficiency, but continuous improvement is needed to protect these natural resources. The demands of animal protein production must account for the well-being of farm animals, including housing, nutrition and other aspects of care, according to sound scientific principles that meet societal needs and expectations.

Animal-Human Health Intersection. The term “One Health” encompasses the concept of requiring interdisciplinary approaches to address the complex interaction between animal and human health. Policy and regulatory challenges addressed by One Health research includes zoonotic diseases (ones that can be passed between humans and animals), the use of antibiotics and nutritional studies. These challenges may be overcome by continued research to improve vaccines, food safety across the supply chain and animal health through improved nutrition. Advances in the animal and veterinary sciences will play a major role in the One Health concept, including more effective approaches to vaccine development, new dietary components that influence good health and better understanding and control of zoonoses with an emphasis on food safety.

Plant-Derived Products. The planet’s immense diversity of plants can yield a wide array of useful substances, but these assets have barely been tapped or characterized. Applications in human health, agriculture and manufacturing could be realized from this inexhaustible resource. Plants’ ability to survive under various climatic conditions can be harnessed to develop cultivated species that produce useful chemicals, compounds and other products.

Data Management. The advances in acquiring vast quantities of data about plants and animals are staggering. Now, massive data analysis is required to achieve reliable predictability. New tools need to be developed to manage huge volumes of data. These tools involve data storage and accessibility, including open access; statistical analysis; modeling and forecasting; and validation of results.

Climate and Agricultural Production. Because agriculture depends on the weather, variability and change in climate can affect production in many ways. Research is needed to help farmers, ranchers and forest landowners adapt to climate change and weather variability. Agricultural systems could be designed to not only be resilient to climate change, but to attenuate it. The USDA Climate Hubs, announced in 2014, are one response to this need on a regional basis. Extension will be needed to translate new science into the information and education necessary for farmers and ranchers to adapt and adjust their management to changing conditions.

Forestry

Forests have been a cornerstone for the health, well-being and quality of life of all Americans. The U.S. forest products industry produces \$200 billion in sales a year and employs about one million workers. When adding related industries, the number increases to 2.9 million employees. Forests provide environmental protection for watersheds and serve as a home for abundant, diverse wildlife. Forests have significant impact on improving air quality and reducing soil erosion. The United States has 751 million acres of forest land. Approximately 328 million acres (43.7 percent) are publicly owned, while the remaining 423 million acres are owned by private individuals, Native Americans or corporations. Each 1,000 acres of privately-owned forest creates eight jobs. More than 90 percent of the nation’s wood products come from private forests.

New Products Research. Retaining and expanding markets for wood-based products will require increased efforts in research and development devoted to new product development, improved raw material utilization and elimination of market access restrictions. The markets for U.S. forest products include paper and packaging, hardwood lumber products, sawn building materials, wood to energy and new products developed through nanotechnology. Woody cellulose nanotechnology research shows that cellulose nanocrystals and nanofibrils, when added to other materials, can result in products that are stronger, lighter, less expensive and made from renewable resources. The technology, which has tremendous potential for specific product uses, also could accelerate forest restoration by providing a new market for low-value fiber. Enhanced R&D investment and new public-private partnerships are needed to address use of forest products in green building materials and design, wood-to-energy, advanced pulping technology, forest restoration, forest inventory and analysis, and other areas of national importance to the forest sector.

Climate Variability and Ecological Health. Shifting weather patterns may result in changes in the frequency, intensity and timing of wildland fire; contribute to changes in insect infestations; and result in changes in the composition of vegetation and distribution of wildlife. Significant forestland losses are projected over the next

five decades as a result of increased urbanization and other changes in land use. Agricultural and forestry producers, land managers and others need information and decision-support tools developed through research to help them with adaptation strategies and greenhouse gas mitigation. Crop, animal, forest and range management strategies must take climate variability into account to ensure sustainability. The potential for forests and agricultural lands to serve as carbon sinks and to reduce greenhouse gas emissions must be quantified to support sound policies and environmental markets.

Agroforestry. Research can advance the use of agroforestry as a viable option for meeting the multiple demands of food, fiber, feed, fuel and natural resource conservation. Research and technology are needed to improve the application of agroforestry practices and principles in protecting water and soil resources; building landscape-level resiliency to climate change impacts; reconnecting ecological services across rural-urban lands and communities; providing innovative and sustainable bioenergy production systems; and creating multipurpose landscapes that produce food, fiber and energy and protect natural resources.

Biomass Energy. Research on incorporating biomass and feedstock crops into existing agriculture, forestry and agroforestry systems can help increase diversity of the rural economy and sustainable land management. New technology is needed to develop cost-effective, waste-to-energy systems that use animal manures, crop and forest residues and other materials as feedstocks.

Natural Resources

Agricultural production is a complex interaction of natural resource utilization, agricultural and management inputs and weather. Essential to the ability of agriculture in the United States to meet the exciting and daunting challenge of producing the food, fiber and biofuel feedstocks is research on how to manage natural resources impacted by these activities.

Soil Resources. At the same time demand for agricultural production is increasing, it is estimated that by 2030, 7 percent of the world's agricultural land that existed in 2002 will be converted to nonagricultural uses. Loss of productive agricultural land leads to pressure to expand agriculture into less productive areas. Decades of agricultural production have resulted in degradation of soil structure, chemistry and biology for many soils. The impact of this degradation has been masked by improved genetics and input management, but optimal productivity cannot be achieved from depleted soils. Increased soil research is required to address the challenge of eliminating erosion and increasing productivity. It is essential that crop production systems are developed that restore and improve the physical characteristics and biological function of soils, including infiltration, moisture holding capacity, organic matter and biological activity to provide an optimal soil interface for nutrient and water transfer to crop root systems.

Water Resources. Water utilization and consumption are critical factors of agricultural production. They are becoming more important as the need for increased production, diminished cropland acres and competing urban and industrial demand for water interact in a complex system of policy, economics and risk. Changing seasonal weather patterns in non-irrigated farming systems affect the availability (excess and deficit) of water necessary to support increased production yields that will be necessary to meet future needs. Diminishing aquifer resources for irrigated production systems limit the long-term viability of crop production in large geographic regions. High-value specialty crop production that exists in close proximity to large, growing population centers competes for diminishing freshwater resources. In irrigated and non-irrigated crop production systems, genetic research must improve plants' effective utilization of water to achieve optimal production per unit of water consumed. Irrigation efficiency must be improved to slow or stem the impact of water withdrawal on nearly finite aquifers. As water use efficiency is achieved, careful consideration must be given to protecting natural riparian systems that require surface and shallow sub-surface flow to maintain their ecological integrity.

Water Quality. Agriculture's contribution to nonpoint sources of pollution to U.S. water resources affects ecological stability and the viability of additional, downstream urban and rural uses. Reducing and eliminating the agricultural contribution of sediment, nutrients, pesticides, pathogens and pharmaceuticals are an economic

and environmental priority for agriculture. Crop production systems must be developed that eliminate soil loss from fields to maintain and improve soil productivity and reduce offsite impacts to water resources. Research must improve the utilization of crop and livestock inputs for productivity, economic efficiency and reduced loss into the environment. Research must develop new conservation practices that incorporate the science of buffers, saturated buffers, bioreactors and wetland establishment and restoration for pollutant mitigation. Research also must guide how these practices are efficiently applied to agricultural landscapes. The practices can reduce pollutant contribution to water resources and to different degrees provide landscape diversity in agricultural regions.

Wildlife Habitat. Research on preserving wildlife habitat should consider the potential impacts of new conservation practices as well as implications from emerging issues like climate change, invasive species and harvesting of biofuel crops.

In conclusion, research in the sustainable use of natural resources is essential for agriculture to become a less consumptive, more environmentally protective and economically efficient industry. This is essential to achieve near- and long-term goals for food security, environmental protection, economic viability and quality of life.

Food Science and Human Nutrition

As a result of advancing agricultural productivity through technology and innovation, the nation enjoys relatively abundant, safe, diverse and low-cost foods. As food demand rises, innovation in energy and water-conserving food production and processing technologies is needed to reduce the use of scarce resources. Innovation also must address food waste, a substantial issue domestically and in other parts of the world.

Worldwide Needs. The food system is global and interconnected, leading to increased security risks and threats. Both malnutrition and overnutrition are growing global issues. Finding solutions to meet the nutritional needs of populations in developing countries is an ongoing dilemma. The incidence of chronic diseases, including obesity and diabetes, are burdening the healthcare system in developed countries. Understanding the role of nutrients and foods in health is critically needed. Food is one of multiple-end goals from future development of sustainable systems of farming that take a holistic, agroecological perspective to the food system. Plant breeding and animal breeding will need to understand and respond to food and nutritional needs in the face of issues like climate change and economic opportunities like locally grown foods.

High-Priority Areas. Food science and human nutrition disciplines are central to addressing the global need to provide a safe, adequate, health-promoting and sustainable food supply. Funding to advance the key areas of these disciplines is needed to restore the productivity of food scientists and prevent a brain-drain that has begun. Among leaders in food science and human nutrition, there is general agreement on areas of research that are of highest priority:

Food Safety. The importance of safe food cannot be understated. Research must continue to contribute to the understanding of this broadly defined area.

Food Supply/Environment. This will require defining the influence of the food environment on food choices and the composition of foods and food ingredients, and creating public-private partnerships to achieve ideal food systems.

Health Maintenance Across the Lifespan. This will require understanding dietary requirements for optimal health and chronic disease prevention.

Healthy Growth, Development and Reproduction. This will require understanding dietary influences on epigenetic events and gene imprinting from conception to adulthood.

Medical Management. This will require understanding food and nutrient influences on disease processes and defining nutritional needs for patients with chronic disease.

Molecular Biology. How biotechnology, metagenomics and whole-genome solutions may answer food science questions will require basic research funding. Understanding the tools available through these areas of study also will lead to greater understanding of microbial ecology and impact food production.

Nutrition-Related Behaviors. This is will require defining how these behaviors are influenced by multiple drivers, including regulators in the brain and neural biochemistry.

Personalized Nutrition. This will require understanding the interrelationships between nutrients and genes; determining connections among environmental, chemical and biological networks; defining the role of the microbiome; and identifying tissue-specific sensitivities.

Sustainable Technology. Research is needed to develop strategies to reduce food waste, improve food quality and protect limited resources. For example, nanotechnology is one emerging area of research that can contribute to this goal.

A Profound Effect on Our Future

The nation's investments in agricultural research profoundly affect the future of the food and farming system. How the farm and food system will look a generation or more from now will be determined to a significant extent by the research investments and agenda that are pursued today. Investments must not only enhance food production capabilities, but also protect the environment, improve public health, increase farming opportunities and foster the vitality of rural communities and economies.

Adding to the urgency is the changing paradigm within which future agriculture must flourish. Sustainability, climate change and the bioeconomy cut across nearly all aspects of current and future agricultural research — a paradigm change characterized in part by rapidly shifting societal expectations, new pressures on agricultural land to provide renewable, nonfood products and an ever-shifting climate outlook that includes more weather extremes. Society increasingly expects that goods and services, both in and out of agriculture, be produced sustainably. There is an expectation that new materials such as biofuels and bioproducts be developed to support the transition away from nonrenewable sources. The basic building blocks of the bioeconomy are rooted in agricultural and biosciences research, including acquiring a greater understanding of natural systems; a clear assessment of environmental, sociological and economic impacts of moving to greater reliance on renewable resources; and harnessing new knowledge drawn from an ever-growing body of data generated in the biological sciences.

Advancing agricultural practices requires increased investment in research to continue to feed a growing population and provide for vital needs of people both here and abroad. The innovations realized by agricultural research have a tremendous track record of producing jobs, economic activity and societal benefits. All sectors of agriculture benefit from research advances, and these benefits are multiplied as they positively impact society as a whole. Funding to discover and apply these innovations must increase to continue an upward trajectory of human progress without depleting the planet's precious natural resources in the face of future challenges.

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APPENDIX A

Federal Collaborators with the USDA Agricultural Research Service (ARS)

Food and Drug Administration (FDA). ARS conducts research to support the FDA. ARS is conducting research on arsenic in rice, ecology of pathogens in livestock production systems, prevalence of food safety pathogens in specific food products and developing protocols for destroying microbial hazards associated with produce production.

National Institutes of Health (NIH). ARS and NIH collaborate on the National Food and Analysis Program in which USDA analyzes key food sources of various nutrients of public health interest to NIH; these updates are essential to keeping pace with how the changing food supply provides most nutrients. ARS conducts research in support of the NIH Centers of Excellence for Influenza Research and Surveillance.

Environmental Protection Agency (EPA). ARS provides research and technical support to EPA on issues ranging from repellent and pesticide trials to a federal position paper on bed bugs and ticks. ARS conducts research in support of IR-4 registration and on aerial spray drift to support EPA policy. ARS conducts tests of disinfectant efficacy for biological threat agents. The National Agricultural Library is working with EPA to support development of Life Cycle Analysis of production systems in agriculture.

Department of Defense (DoD). ARS research helps DoD protect warfighters from insects by developing new insecticides for public health, new personal protection systems, and new equipment for pesticide application. ARS conducts research on improved spray application technologies to increase the effectiveness of insect control to protect deployed warfighters from insect transmitted disease.

Department of Energy (DOE). ARS develops genetic resources and provides oilseed database support for DOE research on bioenergy and biomass.

National Science Foundation (NSF). Crop genomic sequence information developed in NSF-funded projects is conserved in ARS crop genome databases and ARS ensures that this information is made broadly accessible to researchers. Similarly ARS conserves and distributes plant genetic resources and mutant stocks developed by NSF genome projects after the NSF grants have ended. ARS led the development of “Opportunities for Interagency Partnering in Animal Biology.” There is ongoing work relating to animal genomics and related topics that are helping to develop a collaborative vision for future integrated research programs focused on an array of animal system components.

U.S. Geological Survey (USGS). ARS together with NOAA Fisheries have collaborated on development of new ingredients and improved feeds, with less marine fish meal, for aquatic species. USGS and ARS have worked together with U.S. Fish and Wildlife Service on drug approvals for aquaculture uses under minor use species legislation. ARS scientists are on the USGS Landsat Satellite Science Team. They play a key role in evaluating data from the Landsat 8 system launched during 2013, while ensuring that Landsat 8 data are successfully integrated with past, present, and future remotely sensed data.

Department of Farmland Security (DHS). ARS together with DHS conduct research and development of vaccines to protect American agriculture from foot-and-mouth disease and other exotic diseases of livestock. ARS conducts the basic research and hands new vaccines off to DHS for further development and transfer.

Centers for Disease Control and Prevention (CDC). ARS implements research in support of CDC at the Southeast Poultry Research Laboratory in Athens, Georgia, to assess the pathogenicity and infectivity of emerging influenza viruses.

National Aeronautics and Space Administration (NASA). ARS collaborates with NASA on remote sensing research related to agriculture and the climate. ARS provides ground truth data from the U.S. and from international collaborators.

APPENDIX B

Selected Discipline-Oriented Scientific Organizations: Food, Agriculture and Natural Resources

Major Contributors

Academy of Nutrition and Dietetics
American Dairy Science Association
American Society for Horticultural Sciences
American Society for Nutrition
American Society of Agricultural and
Biological Engineers
American Society of Agronomy
American Society of Animal Science
American Phytopathological Society
American Veterinary Medical Association
Consortium of Food, Agricultural and
Resource Economics

Crop Science Society of America
Entomological Society of America
Institute of Food Technologists
National Association of Plant Breeders
Poultry Science Association
Rural Sociological Society
Soil Science Society of America
Soil and Water Conservation Society
Society of American Foresters
Society of Nematologists
Weed Science Society of America

Significant Contributors

American Chemical Society
American Economic Association
American Geographical Society
American Meteorological Society
American Society for Microbiology
American Society of Mammalogists
American Sociological Association
American Water Resources Association
American Society of Plant Biologists
American Society of Plant Taxonomists
Animal Behavior Society
Association of American Geographers

Botanical Society of America
Ecological Society of America
Genetics Society of America
International Society for Molecular
Plant-Microbe Interactions
Mycological Society of America
National Ground Water Association
Society of Toxicology
Society of Systematic Biologists
Society for Integrative and Comparative
Biology
Society for In Vitro Biology

APPENDIX C

General Farm Organizations, Agricultural Commodity Organizations, Trade Associations and Selected Foundations

Alfalfa Council Organizations
Alliance to Feed the Future
American Bakers Association
American Cheese Society
American Dairy Association
American Dry Bean Board
American Egg Board
American Farm Bureau Federation
American Farmland Trust
American Feed Industry Association
American Fisheries Society
American Forest and Paper Association
American Horticultural Society
American Meat Institute
Agricultural Retailers Association
American Seed Trade Association
American Society of Agricultural Appraisers
American Society of Farm Managers and
Rural Appraisers
American Soybean Association
American Sugar Alliance
American Vineyard Foundation
Animal Agriculture Alliance
Animal Health Institute
Association for the Advancement of Industrial
Crops
Beer Institute
Biotechnology Industry Organization
CropLife America
Cattlemen's Beef Promotion and Research Board
Corn Refiners Association
Dairy Management, Inc.
Grocery Manufacturers Association
National Agri-Marketing Association
National Association of Wheat Growers
National Corn Growers Association
National Council of Farmer Cooperatives
National Association of American Wineries
National Association of Wheat Growers
National Biodiesel Board
National Broiler Council
National Cattlemen's Beef Association
National Cherry Growers and Industries
Foundation
National Chicken Council
National Corn Growers Association
National Cotton Council of America
National Grain and Feed Association
National Grange
National Farmers Union
National Meat Association
National Milk Producers Federation
National Pork Board
National Potato Council
National Turkey Federation
North American Farmers' Direct Marketing
Association
North American Millers' Association
Northwest Forestry Association
Organic Trade Association
Renewable Fuels Association
Samuel Roberts Noble Foundation
Southwest Council of Agribusiness
The Cotton Foundation
The Peanut Foundation
U.S. Rice Producers Association
United Soybean Board
U.S. Dairy Export Council
U.S. Feed Grains Council
U.S. Hide, Skin & Leather Association
U.S. Meat Export Federation
U.S. Poultry & Egg Council
U.S. Rice Federation
U.S. Wheat Associates

