Spurring Innovation in Food and Agriculture: A Review of the USDA Agriculture and Food Research Initiative Program

DETAILS

244 pages | 6 x 9 | PAPERBACK
ISBN 978-0-309-29956-5 | DOI 10.17226/18652

CONTRIBUTORS

Committee on a Review of the USDA Agriculture and Food Research Initiative; Board on Agriculture and Natural Resources; Division on Earth and Life Studies; National Research Council

SPURRING INNOVATION IN FOOD AND AGRICULTURE

A Review of the USDA Agriculture and Food Research Initiative Program

Committee on a Review of the USDA
Agriculture and Food Research Initiative

Board on Agriculture and Natural Resources

Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, NW Washington, DC 20001

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This study was supported by Contract USDA-NIFA-COOP-003601 between the National Academy of Sciences and the U.S. Department of Agriculture National Institute of Food and Agriculture. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

International Standard Book Number-13: 978-0-309-29956-5
International Standard Book Number-10: 0-309-29956-X

Additional copies of this report are available for sale from the National Academies Press, 500 Fifth Street, NW, Keck 360, Washington, DC 20001; (800) 624-6242 or (202) 334-3313; http://www.nap.edu.

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. C. D. Mote, Jr., is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Victor J. Dzau is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

www.national-academies.org

COMMITTEE ON A REVIEW OF THE USDA AGRICULTURE AND FOOD RESEARCH INITIATIVE

VICTOR L. LECHTENBERG (*Chair*), Purdue University, Lafeyette, IN
STEVEN S. BALLING, Del Monte Foods, Walnut Creek, CA
KEITH L. BELLI, University of Tennesee, Knoxville, TN
PETER J. BRUNS, Howard Hughes Medical Institute (*Retired*), Chevy Chase, MD
STEVEN T. BUCCOLA, Oregon State University, Corvallis, OR
JAMES C. CARRINGTON, Danforth Plant Science Center, St. Louis, MO
MACHI F. DILWORTH, National Science Foundation (retired), Arlington, VA
CUTBERTO GARZA, Boston College, Chestnut Hill, MA
RONNIE D. GREEN, University of Nebraska–Lincoln, Lincoln, NE
ROSEMARY R. HAGGETT, University of North Texas System, Dallas, TX
GENE HUGOSON, University of Minnesota, St. Paul, MN
BENNIE I. OSBURN, University of California, Davis, CA
PHILIP G. PARDEY, University of Minnesota, St. Paul, MN
SALLY J. ROCKEY, National Institutes of Health, Bethesda, MD
JULIANA M. RUZANTE, Pew Charitable Trusts, Washington, DC
JAMES J. ZUICHES, North Carolina State University (*Retired*), Chapel Hill, NC

Staff

PEGGY TSAI YIH, Study Director
EVONNE P.Y. TANG, Study Codirector (through October 2013)
JANET M. MULLIGAN, Senior Program Associate for Research
KATHLEEN REIMER, Senior Program Assistant (through January 2014)
JENNA BRISCOE, Program Assistant
ROBIN A. SCHOEN, Director, Board on Agriculture and Natural Resources
NORMAN GROSSBLATT, Senior Editor

BOARD ON AGRICULTURE AND NATURAL RESOURCES

Preface

The United States embarked on bold polices to enhance its food and agricultural system during the last half of the 19th century, investing first in the education of people and soon thereafter in research and discovery programs aimed at acquiring new knowledge needed to address the complex challenges of feeding a growing and hungry nation. Those policies, sustained over 125 years, have produced the most productive and efficient agricultural and food system in history. The policies and investments spurred ever-increasing productivity in all sectors of the food and agriculture system—productivity increases tied to technological advances and innovations in all forms.

The future poses new challenges. Agricultural productivity gains in the United States have trended downward over the last 20 years. Public investment in agricultural research has declined relative to other sectors of U.S. science and technology and relative to agricultural research investments of other nations. The United Nations forecasts that world demand for food will need to grow by at least 70% by 2050 to meet the needs of a global population of 9.6 billion people. Competition for funds to support fundamental research and translational endeavors are greater than ever, and the need to achieve and sustain increased productivity has never been greater.

The U.S. food and agricultural research system has become multifaceted, with investment by federal and state governments, private companies, and various philanthropic and nongovernment entities. Funds from at least four federal agencies support food and agricultural research; the U.S. Department of Agriculture (USDA) is the primary agency responsible for supporting innovations and advances in food and agriculture. USDA funds are allocated to support research through several mechanisms, including the Agriculture and Food Research Institute (AFRI). In 2008, Congress replaced USDA's National Research Initiative with AFRI, creating USDA's flagship competitive research grants program, and the 2008 Food, Conservation, and Energy Act, known as the Farm Bill, outlined the structure of the new program. The purpose of this present review was to assess the effectiveness of AFRI in meeting the goals laid out by Congress and its success in advancing innovations and competitiveness in the U.S. food and agriculture system. While this review was completed before the passage of the Agricultural Act of 2014 (known as the 2014 Farm Bill), the committee commends Congress for reaffirming the importance of the AFRI program, as evidenced in both the 2014 Farm Bill as well as in FY 2014 appropriations, which provided much needed funding increase to AFRI.

The committee expresses appreciation to USDA for cooperation and assistance in providing access to the information needed for it to do its work. Without USDA cooperation, this task could not have been accomplished. It also thanks the many resource people with whom it met, as their perspectives and input helped to inform this report. National Research Council staff have been incredibly skilled and efficient in supporting the committee members. On behalf of the committee, I want to thank them for their outstanding effort, pleasant demeanor, and overall competence in supporting the committee.

Victor L. Lechtenberg, *Chair*
Committee on a Review of the USDA
Agriculture and Food Research Initiative

Acknowledgments

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

May R. Berenbaum, University of Illinois at Urbana-Champaign
Deborah P. Delmer, Rockefeller Foundation (*Retired*)
Michael P. Doyle, University of Georgia
R. Corby Hovis, National Science Foundation
Michael R. Ladisch, Purdue University
James McFerson, Washington Tree Fruit Research Commission
Anna Palmisano, U.S. Department of Energy (*Retired*)
Lawrence B. Schook, University of Illinois at Urbana-Champaign
Norman R. Scott, Cornell University (*Emeritus*)
Spiro E. Stefanou, Pennsylvania State University
Laurian J. Unnevehr, International Food Policy Research Institute
Wendy Wintersteen, Iowa State University

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Richard R. Harwood at Michigan State University (*Emeritus*) and John Erdman, University of Illinois at Urbana-Champaign. Appointed by the National Research Council, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Contents

Tables, Figures, and Boxes

TABLES

FIGURES

BOXES

Select Acronyms and Abbreviations

AAAS	American Association for the Advancement of Science
AFRI	Agriculture and Food Research Initiative
APLU	Association of Public Land-Grant Universities
ARS	Agricultural Research Service
ASPB	American Society of Plant Biologists
BBSRC	Biotechnology and Biological Sciences Research Council
BIC	Brazil, India, and China
BRDi	Biomass Research and Development Initiative
BREAD	Basic Research to Enable Agricultural Development
CAP	Coordinated Agricultural Project
CAST	Council for Agricutural Science and Technology
COI	Conflict-of-Interest
Co-PI	Co-Principal Investigator
CRADA	Cooperative Research and Development Agreement
CRGO	Competitive Research Grants Office
CRIS	Current Research Information System
CSREES	U.S. Department of Agriculture, Cooperative State Research, Education, and Extension Service

DHHS	U.S. Department of Human Health Services
DOE	Department of Energy
DOI	Department of the Interior
EPA	U.S. Environmental Protection Agency
EPSCoR	Experimental Program for Stimulating Competitive Research
ERS	Economic Research Service
FAO	Food and Agriculture Organization
FASE	Food and Agricultural Science Enhancement
FY	Fiscal Year
GAO	Government Accountability Office
IFAFS	Initiative for Future Agricultural Food Systems
IOM	Institute of Medicine
LGU	Land-Grant University
NAE	National Academy of Engineering
NAREEAB	National Agricultural Research, Extension, Education, and Economics Advisory Board
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NASS	National Agricultural Statistics Service
NIFA	National Institute of Food and Agriculture
NIGMS	National Institute of General Medical Sciences
NIH	National Institutes of Health
NOAA	National Oceanic and Atmospheric Administration
NPL	National Program Leader
NRC	National Research Council
NRI	National Research Initiative
NSF	National Science Foundation
OTA	Office of Technology Assessment
PCAST	President's Council of Advisors on Science and Technology
PI	Principal Investigator
PPP	Purchasing-Power Parity

R&D	Research and Development
REE	Research, Education, and Economics
RFA	Request for Application
ROW	Rest of World
S&T	Science and Technology
SAES	State Agricultural Experiment Stations
SOP	Standard Operating Procedure
STAR METRICS	Science and Technology for America's Reinvestment: Measuring the Effect of Research on Innovation, Competitiveness and Science
STEC	Shiga toxin producing *Escherichia coli*
STEM	Science, Technology, Engineering, and Mathematics
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
WG	Working Group
WHO	World Health Organization

Summary

The past century's remarkable advances in agriculture have demonstrated how public support for agricultural research, education, and extension can enable talented U.S. scientists to improve food, nutrition, and agriculture. As new, complex challenges emerge to the sustainable production of food, fuel, and fiber for a growing and increasingly competitive global community, the innovative solutions stemming from investments in science and technology are needed now more than ever.

Research-induced improvements in agricultural productivity help ensure that the U.S. agriculture and food sectors remain internationally competitive. Historically, the United States has led the world in providing the necessary federal support for research and development (R&D) that spurred innovation in agriculture and enabled the country to become a major contributor to the global food, fiber, and biofuels economies. Yet its contribution as a major producer and exporter of agriculture and food produce has declined in relative terms over more recent times. Waning public investments in U.S. agricultural R&D will probably slow innovation and slow the growth of the knowledge base necessary to meet the ever-evolving challenges presented by increasingly competitive global markets, increasingly scarce natural resources, growing environmental issues, and expanding demands for healthy, safe, and accessible food for consumers in the United States and other countries. A continuation of this trend jeopardizes the United States' ability to maintain competitiveness in international agriculture and food markets, thereby undermining food and nutrition security in the United States and elsewhere in the world.

The U.S. Department of Agriculture (USDA) is the principal federal agency that addresses the interrelated issues concerning food, agriculture, natural resources, rural development, and nutrition. USDA has played a key role in supporting research for agriculture since the passage of the Hatch Act in 1887, but its use of competitive funding as a mechanism to support extramural research began more recently in 1977. A peer-reviewed, competitive grants program was proposed as a means of broadening the publicly funded agricultural research portfolio while also enhancing the foundational research that is indispensable for ensuring progress in the agricultural sciences and the economic sectors it serves. Since 1977, there have been several versions of competitive grant programs within USDA: Competitive Research Grants Office, National Research Initiative, Fund for Rural America, and the Initiative for Future Agricultural and Food Systems. The Food, Conservation, and Energy Act of 2008 (referred to as the 2008 Farm Bill) replaced the National Research Initiative with the Agriculture and Food Research Initiative (AFRI), and outlined specific priority areas, terms, and funding allocations for the new competitive grants program. The National Institute of Food and Agriculture (NIFA) was also established under the 2008 Farm Bill, and was charged with administering this new competitive grants program.

SCOPE AND APPROACH TO THE REVIEW

NIFA approached the National Research Council (NRC) in 2012 requesting an evaluation of the AFRI program in its early stages of implementation. In response to the request, the NRC appointed an ad hoc committee to conduct an independent assessment of the AFRI program, including a review of the quality and value of research funded by the program and the prospects of its success in meeting established goals and outcomes (see Statement of Task in Box S-1).

The committee conducted its assessment of the AFRI program based on members' expertise and on information collected from multiple sources. The extensive literature on the role of research and competitive grants for research in accelerating progress in the agricultural enterprise is cited throughout the report. To assess effectiveness of the program's operations, the committee solicited information from NIFA staff about the grant management processes. In addition, the committee gathered information from individuals who contributed to the conceptualization and implementation of NIFA and AFRI, government agencies, professional societies, and grantees of AFRI. The committee used an online survey tool to solicit input broadly from researchers, academic and extension leaders, reviewers, and users and beneficiaries of AFRI, which was a mechanism for providing additional insight from the applicant community.

The committee draws conclusions about the level of scientific effort

BOX S-1
Statement of Task

An NRC committee will perform an independent assessment of the AFRI program, including the quality and value of research funded by the program and the prospects for its success in meeting established goals and outcomes.

The assessment will:

- Examine the value, relevance, quality, fairness, and flexibility of AFRI.
- Consider whether NIFA funding mechanisms, including the process of setting annual funding priorities, the shift to five NIFA challenge areas, and the balance between challenge area grants and foundational program grants, are appropriate for meeting AFRI's desired goals and outcomes.
- Compare NIFA's decision to fund fewer, higher-dollar and longer-term grants through AFRI to the former National Research Initiative (NRI) approach of funding more, lower-dollar grants, in terms of achieving desired outcomes. Include an exploration of the relationship between the length of grants and their effectiveness in terms of outcomes.
- Examine indications of whether AFRI is achieving its stated goals and outcomes. Include in these considerations how well AFRI facilitates the integration of research, extension, and education; supports food production efforts; balances fundamental and applied investments; increases foundational knowledge while facilitating translational research; and contributes to preparing the future scientific workforce.
- Identify measures of the effectiveness and efficiency of AFRI's operation, from requests for applications and the panel review process (including the effectiveness of virtual grant review panels relative to face-to-face panels), to the awarding of grants.
- Evaluate the diversity of grant recipients and institutions that participate in the grants program, and examine the methods NIFA uses to facilitate the participation of a diversity of individuals and institutions (public and private, land-grant and non-land grant, minority).

The study also will examine AFRI's role in advancing science in relation to other research and grant programs inside of USDA (capacity and formula grants) as well as how complementary it is to other federal R&D programs, such as the National Science Foundation, the National Institutes of Health, and the Department of Energy, including the effectiveness of past joint-agency grant solicitations.

The study committee will prepare a report of its assessment. In addition to its findings and conclusions, the committee will identify aspects of the implementation of AFRI that could improve how it functions and its effectiveness in meeting its goals and outcomes. The committee will not make recommendations about funding levels for AFRI; however, it may draw conclusions about the level of scientific effort supported by AFRI and the adequacy of that effort in meeting the initiative's goals.

supported by AFRI and the adequacy of that effort in meeting the initiative's goals. The committee does not evaluate the quality of individual research grants, but provides a broader evaluation of the AFRI program. In reviewing the AFRI program, the committee focused its evaluation on AFRI and did not provide a detailed review of USDA's entire research, extension, and education portfolio nor did the committee conduct a detailed comparison of AFRI to other USDA programs (intramural and extramural) and funding mechanisms (formula and competitive grants). Such an assessment of the role and importance of competitive funds relative to formula grants was beyond the scope of this study.

CONCLUSIONS AND RECOMMENDATIONS

Need for Food and Agriculture Research

AFRI was created with the ambition of using the nation's most creative minds in research, education, and extension to address issues fundamental to human and social well-being. AFRI supports a wide range of research goals and communities by competitive, peer-reviewed grant programs. Activities that integrate research, education, and extension in food and agriculture through a competitive process are unique to AFRI. Given the broad mandate to support nearly all components of food and agriculture, the 2008 Farm Bill established a complex set of goals within six priority areas: (1) plant health and production and plant products; (2) animal health and production and animal products; (3) food safety, nutrition, and health; (4) renewable energy, natural resources, and environment; (5) agriculture systems and technology; and (6) agriculture economics and rural communities. However, there is continued weakness in the public commitment to food and agricultural R&D which is likely to lead to "more of the same": a steady decline in global competitiveness of U.S. food and agricultural production and an inability to respond adequately to health, sustainability, and environmental challenges in this important sector.

CONCLUSION 1: AFRI plays a critical and unique role in the nation's overall R&D portfolio because its mandated scope, mission, and responsibilities are focused on the most important national and international challenges facing food and agriculture. But it has not been given the adequate resources needed to meet contemporary and likely future challenges. Congress established AFRI to manage and carry out research that would address complex national and multistate issues in agriculture and food. The scope, intensity, complexity, and urgency of those issues have been increasing, and demands on AFRI exceed what can reasonably be expected given AFRI's recent funding levels. When AFRI was launched in 2008, the National Institute of Food and Agriculture (NIFA) made program management decisions on the basis of an assumption that appropriations would grow to authorized levels over the next several years. That assumption was not borne out, and many multiyear grants encumbered future years' appropriations. Although AFRI funding is growing, it has still not reached authorized levels.

RECOMMENDATION 1: The United States should strengthen its public investment in competitive agricultural R&D to ensure that it continues its role of a global leader in the innovations and technologies that are needed to promote health and well-being and to feed growing worldwide populations sustainably. AFRI's prospects for success in meeting stated goals and outcomes would improve if its funding and other support elements (such as reporting structures and monitoring abilities) were commensurate with the program's legislatively mandated scope.

Realignment of Program Structure to Match Mission, Mandate, and Budget

In attempting to understand AFRI's mission and structure, the committee requested a NIFA organization chart of units that were affiliated with AFRI and a diagram that showed AFRI's program structure. After several rounds of correspondence, it remained unclear to the committee how NIFA viewed AFRI's mission, how AFRI was structured, and who had direct reporting responsibilities for grant administration. Later communications with NIFA provided a more explicit basis for understanding AFRI's program structure with its two program areas (challenge and foundational), five challenge priority areas, six foundation priority areas, and five grant types—for which the committee concluded that the structure was unnecessarily complex.

In 2010, AFRI established the challenge-area program, which was based on a multidisciplinary approach to problem solving and required a wide array of disciplines and expertise to successfully address the most demanding, complex issues in food and agriculture. It was at this time that the large-scale Coordinated Agricultural Project (CAP) grants program was established to fund substantial investments in addressing key societal concerns. This high-stakes, potentially high-rewards approach for bringing about grand solutions and the impetus for moving the approach forward were based on the assumption that funding would reach authorization levels outlined in the 2008 Farm Bill.

While the goal of AFRI's new challenge-area program is worthy, the size of AFRI's budget does not allow a reasonable prospect of satisfying its congressional mandate to focus research on the six discipline areas of the 2008 Farm Bill (those areas remained the same for the 2014 Farm Bill) while adopting an ambitious grand-challenges research approach as other agencies (such as the National Science Foundation [NSF] and the National Institutes of Health [NIH]) have done. CAP grants have consumed an exceptionally large portion of AFRI's annual appropriations. Meeting the multiyear commitments has reduced the funds available for smaller-scale, more traditional, investigator-initiated grants—a development that, not surprisingly, is associated with a reduction in the number of applicants for AFRI grants relative to AFRI's predecessor. Emphasis on CAP grants and challenge areas has coincided with a growing year-to-year inconsistency in AFRI's project portfolio, which is unsustainable in itself and insufficient if the various legislative mandates are to be satisfied. Such inconsistency may be one explanation for the absolute decline in AFRI grant applications. The diversion of a large proportion of resources to CAP grants and challenge areas has impaired the flexibility needed to address emergent issues.

CONCLUSION 2: AFRI is unnecessarily complex, difficult to depict clearly, and characterized by overlapping components that do not clearly align with priorities identified in authorizing legislation. Program complexity impedes the measurement of progress relative to clear goals. The multiplicity of grant types, each with its own priorities that change from year to year, contributes to a sense of programmatic inconsistency and unpredictability. Proliferation of priority areas also has resulted in AFRI's inability to satisfy its congressional mandates.

RECOMMENDATION 2: NIFA should simplify the AFRI program structure by realigning it to more clearly address its specific mission and mandates as defined in authorizing legislation. Simplification of program structure to focus on the six foundation priority areas would improve efficiency, effectiveness, and transparency.

Rebalancing the Portfolio

AFRI's ambitious portfolio of multiple grant types is undercutting its mission to support fundamental research, which generates critical knowledge and tools for future applications. With a large proportion of AFRI's budget dedicated to addressing grand challenges, the focus of the program has shifted toward applied science at the expense of fundamental research.

Projects whose principal aim is the development of fundamental innovations in research, education, and extension receive less funding. The request-for-application (RFA) topics specified for foundational grants are increasingly narrow in scope and weighted toward applied research. Given its limited budget, if AFRI continues with that approach, the scientific workforce available to conduct fundamental research in the agricultural and food sciences may continue to severely diminish.

Conclusion 2-A: Fundamental research is critical to provide the knowledge base upon which future discoveries will be made, and expanding the stock of fundamental knowledge is AFRI's primary purpose. The balance of fundamental and applied research, however, has shifted toward the applied, with extension and education components mainly included as supporting elements of research grants.

Recommendation 2-A: To realign AFRI's portfolio with its legislative mandate, NIFA should review its priority for fundamental research. That should include an emphasis on proposals that will generate fundamental knowledge to support novel technologies, provide platforms for extension and education, and educate the next generation of food and agricultural scientists.

The Challenge-Area Program

The challenge areas are focused on five societal challenges determined by NIFA, and the foundation priority areas follow the six outlined priorities that are authorized in the 2008 Farm Bill. The challenge areas are prescriptive and focus on specific problems of interest (such as climate change), which were predetermined at the inception of the program in 2010. For that reason, the challenge areas have been perceived by the committee and the scientific community as lacking flexibility to address newly emerging problems and to incorporate rapid advances in science and technology. That is in contrast to the foundation priority areas (such as plant health and production and plant products) that are categorized by disciplines that span food and agriculture.

Conclusion 2-B: The current AFRI challenge areas are narrowly focused on specific issues, and the challenge and foundation priority areas are unnecessarily redundant.

Recommendation 2-B: As part of its realignment, AFRI should be simplified by eliminating the challenge-area program, and areas of research within the foundational program should be primarily investigator driven.

The Decline in Applicants, Awardees, and Trainees

On the basis of the committee's review of the number of graduate students and postdoctoral trainees supported by AFRI grants, it appears that students are increasingly being trained with funds from other federal agencies that have larger budgets. If sufficient competitive research funds are not available in agriculture for funding research and for training young scientists, researchers will seek out a larger portion of their overall support from agencies whose missions are not directly aligned with the food and agriculture sectors. In the long term, food and agriculture will lose talent to other fields of study that have stronger support.

Conclusion 2-C: The recent decline in the numbers of applicants, awardees, and trainees is a disturbing trend. It raises questions: Are scientists "following the money" and moving away from agricultural research? Are young scientists not being trained in agriculture?

Recommendation 2-C: AFRI should carefully examine the causes of the decline in the numbers of applicants, awardees, and trainees and adjust its grant programs to ensure that future generations of young scientists are not lost inadvertently from food and agriculture R&D because of funding policies.

Coordinated Agricultural Project Grants

Adjusting for the time since project initiation, there is evidence that the large project scope and complexity of these grants have resulted in fewer scholarly products (publications, papers, and presentations) per fixed amount of funding than was the case with less complex, smaller grants. High intraproject management and transaction costs required for very large projects probably have contributed to this phenomenon. The finding applies to large AFRI grants generally but especially to CAP grants. Early output data suggest that reducing the average project's scale and scope (represented by budget and number of principal investigators [PIs], respectively) would improve the output of scholarly products, at least in early phases. The committee is not saying that large grants are inappropriate, only that its early analyses show that as the scale of grants rises, the marginal output of published papers falls over the period that was examined. The committee recognizes that high transaction costs may in some projects be more than offset by the importance of the contributions in addressing the targeted problems (e.g., multi- and transdisciplinary collaboration in the broad research community).

Conclusion 2-D: The current AFRI appropriation cannot sustainably support the current policy of investing a disproportionate percentage of the AFRI budget on large CAP awards and simultaneously sustain a credible program of foundational, training, and Food and Agricultural Science Enhancement grants. The shift to funding fewer, higher-amount, and longer-term CAP grants also appears to have resulted in the early decreased output of scholarly products per dollar of AFRI funds invested.

Recommendation 2-D: AFRI should consider eliminating CAP grants as a grant category and committing more resources to other grant types.

Strategy and Collaboration

AFRI's research, extension, and education portfolio is appropriately targeted to meeting the nation's food and agricultural needs. However, its success depends on the generation of fundamental knowledge and the flow of new knowledge generated by other federally funded and private-sector research. AFRI can maximize its impact and resources by collaborating with other federal agencies and by strategically aligning its research with congressional mandates that target the highest-priority needs of the food and agriculture sectors.

CONCLUSION 3: AFRI does not have clearly articulated plans to guide its priority setting, management processes, and interagency collaboration. To evaluate AFRI's success it is critical to define goals and outcomes and thus enable the assessment of progress in meeting them. NIFA provided the committee with several documents that described a roadmap explaining how the challenge areas were developed to take into consideration the societal challenges outlined in the National Research Council *New Biology* report and pointed to individual RFAs for specific goals in each of the priority areas. But it did not provide a statement of overall goals, time frames for meeting them, or planned outcomes for assessing progress. For the purpose of the present review the committee assumed that the goals of AFRI were synonymous with those stated in the 2008 Farm Bill which were unchanged in the 2014 Farm Bill.

RECOMMENDATION 3: AFRI should develop a strategic plan that identifies priorities for its overall program goals for meeting them and a framework for assessing the program's progress. Such a plan is critical for providing program continuity, consistency, and predictability. A strategic plan would include a clear vision statement and strategies for implementing priorities. To develop a strategic plan, NIFA could revisit the intent of AFRI and broadly define acceptable topics so that AFRI programs can achieve greater flexibility. The plan could include less restrictive RFAs for which PIs can propose unconventional ideas and take more flexible approaches to the six broad priority areas mandated by the 2008 and 2014 Farm Bills.

Interagency Collaboration

Several other federal agencies—such as NSF, NIH, and the Department of Energy (DOE)—provide grants and conduct research in subjects tangentially related to food and agriculture, but USDA is the only federal agency whose mission is aimed directly at food and agriculture. To further USDA's mission and to leverage the efforts of sister agencies, USDA will need to take on a greater leadership role in coordinating research efforts across agencies.

Conclusion 3-A: Interagency efforts directed at food and agriculture need to be more strategic, more robust, and better coordinated across federal agencies.

Recommendation 3-A: NIFA and USDA should lead interagency efforts to effectively coordinate and collaborate across agencies on food and agricultural research.

External Advisory Council

Unlike NIH and NSF, AFRI does not have a formal, external, and strictly scientific advisory council. Such a council would be highly valuable for the following functions of the AFRI program: to guide, advise on, review, and assess on an ongoing basis priority setting, resource allocation, program policies, and peer-review and award-management processes. NIH and NSF each have advisory groups on which NIFA could model its AFRI Scientific Advisory Council.

Conclusion 3-B: AFRI needs an external advisory council to validate its strategic direction and to provide valuable guidance to national program leaders (NPLs) on programmatic decisions.

Recommendation 3-B: NIFA should form an AFRI Scientific Advisory Council that consists of members who represent the food and agricultural research, education, and extension professional communities.

Program Management

The AFRI program structure is unnecessarily complicated and is characterized by an elusive chain of command, and this complexity and lack of transparency has led to inefficient program management and operation. Given the goal of setting up the new program, developing program priorities, and balancing its portfolio to satisfy its congressional mandate, the committee expected that NIFA leadership would provide higher visibility for the program. AFRI is a program within NIFA that appears to be orphaned in that there is no clear line of leadership, strategy, and policy.

CONCLUSION 4: AFRI's complex and diffuse management structure has made it difficult to efficiently and effectively manage the program. AFRI has many stakeholders it needs to be responsive to: Congress, the administration, various producer groups and interests, numerous scientific disciplinary interests, and consumers. AFRI also needs to more explicitly track—and track for longer periods—the outcomes and contributions of the research that it funds.

RECOMMENDATION 4: To enhance program accountability and management, AFRI should have a dedicated leader who manages the program on a daily basis. Improved processes and procedures should be created for transparency, and AFRI's NPLs should be granted greater authority and flexibility to meet stated goals.

Agriculture and Food Research Initiative Director

Conclusion 4-A: AFRI is managed collectively by many people. No single administrator is responsible for overall program management or accountable for AFRI's performance.

Recommendation 4-A: NIFA should establish a clearer organizational structure and lines of authority for AFRI, including a designated director to lead, manage, and speak for its program, and NPLs dedicated to AFRI alone.

Program Continuity and Transparency

For foundational programs, the committee received comments from applicants and panel managers that the highly prescriptive nature of RFAs discourages submission of innovative ideas. Paperwork was also long and burdensome for applicants. Furthermore, research priorities were often not communicated in a timely manner, resulting in unnecessarily extended lags between grant cycles. AFRI's success will be determined in large part by how well the program attracts the best ideas from a broad community of qualified researchers in an array of disciplines.

Conclusion 4-B: The AFRI applicant community expressed frustration with the lack of continuity in the program offereings from one year to the next, which has resulted in the community's inability to plan, resubmit unsuccessful proposals, and renew successful projects.

Recommendation 4-B: NIFA should have a more consistent and predictable program portfolio and funding strategy to enable better planning by the food and agricultural research community.

Data Management

Data are needed to inform management decisions and improve assessments of program efficiency and effectiveness. NIFA was unable to provide the committee with data needed for addressing many aspects of the committee's tasks as some of the data had not been collected and some were internally inconsistent or could not be easily interpreted or summarized. One aspect that the committee was specifically tasked to examine was diversity of people and institutions supported by AFRI. AFRI does not collect additional data that would enable a robust assessment of the diversity of program applicants or awardees. On the basis of data on awarded projects, the committee found that AFRI is awarding grants to public and private institutions and to land-grant universities and non–land-grant universities in nearly the same ratios as did the former NRI program and approximately in proportion to the number of proposals emanating from such institutions.

The Current Research Information System (CRIS)[1] used by NIFA was not designed as a tool for managing competitive funds and is an inadequate aid for program-management decisions: it is difficult to navigate and manipulate for programmatic needs and not readily compatible with other systems. AFRI needs an information-management system that can provide the accurate information that is necessary for structured analyses of program activities and for analyzing and assessing project and programmatic outputs and outcomes. Conducting performance analyses will require systematic attention to medium-term and long-term outputs and, more importantly, projection of outcomes in the form of the science influenced, social and individual well-being, and products and incomes generated.

Conclusion 4-C: The AFRI program lacks a sufficiently robust information-management system and metrics for measuring key program impacts.

Recommendation 4-C: NIFA should use a more robust information-management system that would provide a basis for AFRI policy and strategic planning. The system should allow detailed assessment and management of the food and agricultural competitive research funding pool.

Post-Award Management

Project-output assessment affords only one perspective on the performance of AFRI. Some valuable benefits and contributions of the program cannot be captured by assessments of program outputs alone. Examples of the other benefits are outcomes such as AFRI's role in encouraging graduate students and young scientists to develop careers in food and agriculture, its role in advancing the quality of agriculture and food science and in increasing the knowledge base, and its contributions to the innovations that underpin economic development. Appropriate changes are needed to give NPLs the time and resources needed to provide a higher level of post-award management (including post-termination monitoring) designed to ensure that grants reach the most successful conclusions and outcomes attainable.

Conclusion 4-D: NIFA needs clearly defined metrics for measuring program outputs and outcomes that allow program managers to assess the value of AFRI-funded research.

[1] As of the writing of this report, the committee is aware of USDA's plans to retire CRIS and to replace it with another reporting system.

Recommendation 4-D: NIFA should develop the capability to regularly evaluate AFRI projects in terms of their outcomes, which would allow assessment of the economic and social impacts of the research that AFRI supports.

Greater Authority for National Program Leaders

The committee noted several ways in which NPLs were constrained in participating in funding decisions that would allow a better portfolio balance to align with AFRI's mission and goals. For example, funding decisions are typically based solely on peer-reviewed rankings without consideration of the funding portfolio's programmatic balance. That continues to occur despite NIFA's policy that reviewers' comments are advisory and not binding. Funding allocations to program areas are set before the award decision-making process, and this can limit the ability of NPLs to capitalize on innovative ideas presented in proposals and to pursue the most promising scientific opportunities. NPLs are PhD-level scientists in good standing in their own disciplinary communities who were recruited to manage AFRI grants on the basis of their scientific credentials, and they should be trusted to exercise their professional judgment. With such new responsibilities, the portfolios of AFRI NPLs would need to be rebalanced to allow proper attention to programmatic direction and post-award scientific management. Standard operating procedures (SOPs) would also need to include a mechanism for training new NPLs and panel managers.

Conclusion 4-E: In their project-funding decisions, NPLs are tasked to ensure that a maximum number of high-priority issues are addressed and that funded projects align maximally with program goals. Yet NPLs have been unnecessarily constrained in their efforts to manage and balance the AFRI portfolio.

Recommendation 4-E: NIFA should establish SOPs that provide greater opportunity for NPLs to contribute to final project-funding decisions.

CONCLUDING REMARKS

During the time the committee was conducting its review, Congress passed the 2014 Farm Bill and appropriated an increase in funding for AFRI in FY 2014. The reauthorization of the Farm Bill did not change the priorities for AFRI, reaffirming the importance of this program to sustain the nation's preeminence in knowledge generation and technology advances in the food and agricultural sectors. However, the 2014 Farm Bill contained a provision requiring non–land-grant universities to match funds for AFRI grants. This approach is counterproductive to the goal of attracting the broadest array of the nation's top scientific talent to research and to bringing nontraditional and novel approaches and solutions for food and agricultural challenges. In the future, NIFA should acquire data to determine the impact of this requirement on non–land-grant entities participating in the AFRI program.

NIFA and its AFRI program are essential elements of USDA and will be critical for enhancing the knowledge base needed to successfully address important issues in agriculture, food, and natural resources. The increase in FY 2014 appropriations for this flagship competitive research program is consistent with this report's findings, conclusions, and recommendations and suggests that USDA has a window of opportunity to establish NIFA as a strong science agency with AFRI at its core and to reinforce the value and mission of AFRI to the nation's well-being. The committee offers its recommendations in the hope that the suggested programmatic changes will enable NIFA to fulfill its mission of leading the food and agricultural sectors to a better future through research, education, and extension.

1

Introduction

Scientific research and the application of discoveries through extension and education programs have enabled remarkable advances in agricultural and food production in the last 100 years (Pardey and Beddow, 2013). Future discoveries and extension and education programs will continue to strengthen the foundation of the nation's competitiveness in the global marketplace. The knowledge and discoveries that drive innovations and technological advances require fundamental research. Applied and translational research uses the resulting concepts and knowledge to solve problems. In other words, applied research operates within the framework of knowledge provided by fundamental research, and extension helps to transform the products of research—both fundamental and applied—to improve agricultural production, farm income, environment, health, and the quality of life of consumers and producers. Skilled and creative researchers, educators, and extension specialists are necessary to carry out those functions and to address challenges faced by the agricultural and food sectors.

The mission of the U.S. Department of Agriculture (USDA) is to "provide leadership on food, agriculture, natural resources, rural development, nutrition, and related issues based on sound public policy, the best available science, and efficient management" (USDA, 2014). USDA has intramural and extramural research programs to address challenges in those areas. Through its National Institute of Food and Agriculture (NIFA), USDA has implemented the Agriculture and Food Research Initiative (AFRI) as its flagship competitive grants program.[1] AFRI is charged with

> funding research, education, and extension grants and integrated research, extension, and education grants that address key problems of national, regional, and multi-state importance in sustaining all components of agriculture, including farm efficiency and profitability, ranching, renewable energy, forestry (both urban and agroforestry), aquaculture, rural communities and entrepreneurship, human nutrition, food safety, biotechnology, and conventional breeding. Providing this support requires that AFRI advances fundamental sciences in support of agriculture and coordinates opportunities to build on these discoveries. This will necessitate efforts in education and extension that deliver science-based knowledge to people, allowing them to make informed practical decisions (USDA NIFA, 2012).

PURPOSE OF THIS STUDY

Four years after the AFRI program was created, USDA requested in 2012 that the National Research Council convene a committee of experts to conduct an independent assessment of the program. The committee was charged to examine the quality and value of research funded, the prospects for the program's success in achieving established goals and outcomes, the program's role in advancing science in relation to other research and grants programs within USDA, and the program's complementarity with R&D programs in other federal agencies. The statement of task is provided in Box 1-1.

Approach to the Statement of Task

The National Research Council convened a committee of 16 persons who were working or had worked in academic and nonprofit institutions, federal agencies or state government, industry, and agricultural production. (See Appendix A for committee membership and biographies.) Members collectively have extensive experience in management of competitive grants, program review, grant application and review, and assessment of return on investments. Thus, the perspectives of grant funders, recipients, researchers, and users of the products of research were represented on the committee.

The committee conducted its assessment of the AFRI program based on members' expertise and on information collected from multiple sources. The extensive literature on the role of research and competitive grants

[1]The AFRI program is the flagship competitive grants program within USDA, but USDA also has other competitive grants programs, such as the Small Business Innovation Research Program and the Specialty Crop Research Initiative.

BOX 1-1
Statement of Task

An NRC committee will perform an independent assessment of the AFRI program, including the quality and value of research funded by the program and the prospects for its success in meeting established goals and outcomes.

The assessment will:

- Examine the value, relevance, quality, fairness, and flexibility of AFRI.
- Consider whether NIFA funding mechanisms, including the process of setting annual funding priorities, the shift to five NIFA challenge areas, and the balance between challenge area grants and foundational program grants, are appropriate for meeting AFRI's desired goals and outcomes.
- Compare NIFA's decision to fund fewer, higher-dollar and longer-term grants through AFRI to the former National Research Initiative (NRI) approach of funding more, lower-dollar grants, in terms of achieving desired outcomes. Include an exploration of the relationship between the length of grants and their effectiveness in terms of outcomes.
- Examine indications of whether AFRI is achieving its stated goals and outcomes. Include in these considerations how well AFRI facilitates the integration of research, extension, and education; supports food production efforts; balances fundamental and applied investments; increases foundational knowledge while facilitating translational research; and contributes to preparing the future scientific workforce.
- Identify measures of the effectiveness and efficiency of AFRI's operation, from requests for applications and the panel review process (including the effectiveness of virtual grant review panels relative to face-to-face panels), to the awarding of grants.
- Evaluate the diversity of grant recipients and institutions that participate in the grants program, and examine the methods NIFA uses to facilitate the participation of a diversity of individuals and institutions (public and private, land-grant and non-land grant, minority).

The study also will examine AFRI's role in advancing science in relation to other research and grant programs inside of USDA (capacity and formula grants) as well as how complementary it is to other federal R&D programs, such as the National Science Foundation, the National Institutes of Health, and the Department of Energy, including the effectiveness of past joint-agency grant solicitations.

The study committee will prepare a report of its assessment. In addition to its findings and conclusions, the committee will identify aspects of the implementation of AFRI that could improve how it functions and its effectiveness in meeting its goals and outcomes. The committee will not make recommendations about funding levels for AFRI; however, it may draw conclusions about the level of scientific effort supported by AFRI and the adequacy of that effort in meeting the initiative's goals.

for research in accelerating progress in the agricultural enterprise is cited throughout the report. In addition, the committee gathered information from individuals who contributed to the conceptualization and implementation of NIFA and AFRI, government agencies, professional societies, and grantees of AFRI (see Appendix B on Presentations to the Committee). To assess effectiveness of the program operations, the committee solicited information from NIFA staff about the grant management processes. Data on grants awarded since the inception of AFRI from 2009 through the 2012 fiscal year (the most recent year for which data were available at the time of the study) were solicited to explore the relationship between resource input and early outputs. In addition, the committee used a Web-based questionnaire to solicit input broadly from researchers, academic and extension leaders, reviewers, and users and beneficiaries of AFRI (see Appendix C and D). The input collected online was not used in a statistical or quantitative analysis, thus the committee did not draw any conclusions from the comments it received. Rather, the comments provided insights into whether the committee had overlooked any aspect that needed to be examined in its review. Multiple sources of information were considered in drawing conclusions in this report.

Scope of the Review

The committee has drawn conclusions about the scientific effort supported by AFRI and the adequacy of that effort in meeting the initiative's goals. The committee did not evaluate the quality of individual research grants but broadly evaluated the AFRI program. In reviewing the AFRI program, the committee focused its evaluation on AFRI and did not review USDA's entire research, extension, and education portfolio in detail, nor did it conduct a comparison of AFRI with other USDA programs (intramural and extramural) and funding mechanisms (formula and competitive grants). Such an assessment of the role and importance of competitive funds relative to formula grants was beyond the scope of this study.

ADDRESSING U.S. PRIORITIES IN AGRICULTURE AND FOOD

Agriculture is a unique biological undertaking that nourishes people and makes substantial contributions to a country's economic well-being. The continued demand for a robust and broad knowledge base in the agricultural and food sectors is driven by unprecedented worldwide demographic changes, steadily increasing worldwide aspirations for improved quality of life, contemporary and future threats that arise from natural-resource scarcity (such as threats created by limitations of land and water availability, the use of nonrenewable energy resources, and climate change), and challenges posed by the desire to ensure food quality and safety (NRC, 2010b). Sustaining and adding to the robust knowledge base require constant renewal through innovations and increases in foundational knowledge to meet diverse human needs and adapt to ever-changing global conditions (World Bank, 2010). To meet those diverse needs, the 2008 Food, Conservation, and Energy Act (the 2008 Farm Bill; see Appendix E) outlined six high-priority areas for AFRI to address: (1) plant health and production and plant products; (2) animal health and production and animal products; (3) food safety, nutrition, and health; (4) renewable energy, natural resources, and environment; (5) agriculture systems and technology; and (6) agriculture economics and rural communities. The agricultural and food sectors are quite diverse, and the six high-priority areas cover many but not all of the issues facing agriculture and food in the United States.

Plant Health and Production and Plant Products

Healthy, productive plants are essential for meeting future demands for food, feed, fiber, and other plant-based products; minimizing post-harvest losses; and sustaining local, regional, and global economies (Flood, 2010). That the importance of plant diseases is not new is illustrated by the impact of the Irish potato famine in the middle of the 19th century. Global food trade and continuing changes in our biological environment bring constant threats of new diseases, such as wheat stem rust (Njau et al., 2010) and soybean rust (Schneider et al., 2005). Their cost can be staggering; for example, citrus greening, caused by *Candidatus Liberibacter asiaticus* (Halbert and Manjunath, 2004), is estimated to have led to losses of $9.3 billion—just in Florida (NRC, 2010a). Protecting crops from insects and from diseases caused by microorganisms, viruses, and nematodes is a major factor in sustaining crop yield and productivity. Pathways to plant protection include exploring natural variations found in crop germplasm and wild relatives; monitoring the emergence of pests, diseases, and weeds that are resistant to present crop-management practices; using genetics and genomics methods to identify resistance traits in crops; and using conventional crop breeding and modern biotechnological approaches to develop new resistant varieties (Enserink et al., 2013).

Animal Health and Production and Animal Products

Livestock and poultry health, production, and efficiency have advanced substantially over the last six decades and provided lower-cost, higher-quality foods for U.S. consumers and export markets. Even with those successes, there are opportunities for further improvements in health, welfare, and productivity through new technologies in genetics, nutrition, materials science, and biomedical technology that will sustainably provide safer food products for human consumption and enhance animal well-being. Emerging and re-emerging diseases that are transmissible between humans and animals (zoonotic diseases) by direct contact or through food and water remain important concerns because of the potential magnitude of their adverse effects on the economy and consumer health. Complicating that health threat is the potential for pathogens to cycle between domestic animals and wildlife. Environmental issues stemming from confined feeding operations have led to groundwater and surface-water contamination. Overuse of antibiotics has been associated with a rise in antibiotic resistance and calls for alternative means of preventing the resulting health threats in animals and people (Kennedy, 2013). The recently passed Food Safety Modernization Act of 2010 and concerns over environmental quality underscore the importance of these issues to the general public.

Food Safety

From 2000 to 2008, foodborne diseases (caused by bacteria, viruses, and parasites) led to about 48 million cases of illness, 128,000 hospitalizations, and 3,000 deaths each year in the United States (Scallan et al., 2011a,b). In that same time period, the annual cost of foodborne diseases was estimated to be as much as $51–78 billion (Scharff, 2012). However, the reported costs only reflect the 9.6 million cases caused by 31 known organisms, or about one-fifth of the cases estimated by the Centers for Disease Control and Prevention. The remaining 38.4 million cases are caused by unspecified agents that are unidentified because of weaknesses in surveillance and the lack of diagnostic tests to identify causal agents and for other reasons (Scallan et al., 2011a). Ensuring the safety of the U.S. food supply is also complicated by the increase in food imports.

Scientific studies of food safety generally call for better understanding of the ecology, toxicology, epidemiology, and impact of foodborne diseases; for improved pathways and protocols for reducing or preventing food contamination as products make their way from farm to table; and for improvement in the ability to detect contamination when it occurs. These recommendations remain challenging. For example, the use of sophisticated molecular methods not only allows for rapid pathogen detection in humans, food, and the environment but provides useful information that helps to link human illnesses during disease outbreaks, to identify sources of contamination, and often to prevent recurrence.

Nutrition and Health

Diets and disparities in food availability and accessibility affect human health and social and economic development (Bloom et al., 2011; WHO, 2013). Most deaths worldwide are now due to noncommunicable diseases (such as cardiovascular disease, cancer, and diabetes), and implementing dietary improvements can have profound effects on health (Hill et al., 2009; Lazarou et al., 2012; NRC, 2013b). Health-related concerns are also related to the disconnect between domestic agricultural production and the dietary patterns promoted by the U.S. Dietary Guidelines for Americans (USDA and DHHS, 2010). Current U.S. domestic food production cannot support consumption patterns aligned with the guidelines. Total vegetable, total fruit, and milk or milk alternatives meet only half the levels required by recommended consumption patterns (Krebs-Smith et al., 2010), while calories from solid fats, sugars, and alcohol are produced in abundance. Although total meat and grain production is sufficient to meet recommended intakes, the supply of whole grains falls short of recommendations (Krebs-Smith et al., 2010). Poor accessibility of healthy foods in low-income neighborhoods has been linked to increased risks of such diseases as obesity (Hilmers et al., 2012). Challenges for food and agricultural research, education, and extension programs include how best to support dietary guidelines through agricultural production research and an improved understanding of nutrient physiology and consumer behaviors related to diet and health.

Renewable Energy, Natural Resources, and the Environment

Increasing the use of renewable energy is one of several alternatives to U.S. dependence on fossil energy and petroleum-based fuels and to emission of greenhouse gases (NAS-NAE-NRC, 2009a,b, 2010; NRC, 2013a). Agriculture (including crop and forest resources) is a major supplier of biomass; research-based innovations are necessary to produce large quantities in an environmentally and economically sustainable manner. The annual production of well over a billion tons of biomass from forest and agricultural resources by 2030 has been shown to be feasible (DOE, 2011), especially with improved science and technology that could flow from enhanced research. Agricultural research also plays an important role in developing bioproducts that could reduce the country's reliance on a host of other petroleum-based products, from biodegradable plastics to fertilizers (White House, 2012; Vaneeckhaute et al., 2013). Adjusting agricultural production and marketing realities to future changes in crop-based bioenergy markets and other emerging bioeconomies will entail substantial changes in a host of arenas that will require biological, agroecological, and economic research to support the required adjustments (NRC, 2010b, 2011, 2012) and the policies under which the changes take place (NRC, 2011).

Environmental stewardship is critical for maintaining the quantity and quality of the land and water resources on which food and fiber production depends. Conservation tillage, cover cropping, and technologies for efficient water use and reuse could reduce resource demands and improve the environmental sustainability of agricultural production. "Performance and adoption of many of those practices could be further improved by additional biophysical, social, and economic research" (NRC, 2010b, p. 8). Discoveries and technological innovations also could result in dramatic improvements in the productivity and environmental resilience of biologically based food and agricultural production systems.

Agriculture Systems and Technology

Agriculture takes place in the context of a nested set of bioeconomic systems, starting with the biological and physical systems of crops, livestock, forests, soil, water, and climate. Harnessing those natural resources is accomplished through a variety of processes, tools, and technologies (Drinkwater, 2002). Producers often select tools and approaches in response to both natural constraints and social and economic forces generated by the broader food system. Collective decisions by producers have their own effects on natural and social systems. The scientific study of the interplay of elements within these systems is critical for the sustainability of agriculture as it sheds light on ways to optimize the production of multiple social goods (NRC, 2010b).

Agricultural Economics and Rural Communities

The changing global structure of markets—both production and consumption markets—affects rural economies as domestic and international markets are increasingly intertwined. The benefits of understanding and increasing access to such markets by producers and consumers are highlighted in *Frontiers of Agricultural Research: Food Health, Environment and Community* (NRC, 2003) and reiterated in the Food, Conservation, and Energy Act of 2008. One summary statement captures the situation for rural development, which still applies today: "Understanding the roles of social and human capital, entrepreneurism, and leadership in building successful rural communities constitutes a basic social science frontier" (NRC, 2003, p. 54).

Similarly, issues of food access and security and of food consumption patterns and diet have direct implications for nutritional health and obesity. The same 2003 National Research Council report called for more research on the economics of both and on optimizing the benefits of new technologies by understanding risk-management and decision-making processes at the farm and market levels. Informing the public and other stakeholders on the organization, design, and social processes of markets requires community-based models of innovation, testing, and application. The knowledge gained and the outreach efforts that follow could inform and influence public investment and policies that affect rural areas.

TRAINING, EDUCATION, AND EXTENSION

Talent Development and Scientific Workforce Needs

Through fellowship programs and student and postdoctoral support of research grants, USDA has enabled the preparation of researchers for the private and public sectors to address agricultural production, food processing, marketing, forestry, veterinary medicine, food safety, nutrition, and other subjects. That function remains relevant. A 2000 National Research Council report evaluating the National Research Initiative (NRI), the predecessor of AFRI, recommended that the "NRI continue to emphasize its mission of training and education" (NRC, 2000). Other National Research Council reports have argued for more trained scientists to provide increased forestry research and veterinary medicine capacity for the nation (NRC, 2002, 2013c). Furthermore, a 2012 report on agricultural preparedness issued by the President's Council of Advisors on Science and Technology (PCAST) took a forceful position for building capacity. To meet the need for a diverse and competent scientific workforce on agricultural and food issues, PCAST recommended an expansion of "a competitively awarded program for graduate students and postdoctoral researchers at a level of $180 million per year for at least 5 years." Although the PCAST goal has not been attained, a critical theme that echoes throughout those reports is that a robust workforce is essential if the United States is to face predictable and unpredictable challenges and opportunities in the food and agricultural sectors, especially given the aging population of U.S. agricultural scientists (Pardey et al., 2013).

Knowledge Transfer and Innovation

As fundamental research programs of federal agencies and state partners make new discoveries and enhance understanding in food and agriculture, effective knowledge transfer and dissemination approaches are becoming more sophisticated and complex. In addition to traditional classroom and laboratory-based education and training, policies and organizational structures have been put into place to speed the diffusion of knowledge and the adoption and commercialization of innovations. They include many legislative initiatives, not least among them the Patent and Trademark Act Amendments of 1980 (known as the Bayh–Dole Act), which established the general right of university recipients to apply for patents on innovations arising from most federally funded research, and the National

Technology Transfer and Advancement Act of 1995 that granted CRADA (cooperative research and development agreement) operators the right of first negotiation for an exclusive license for a prenegotiated field of use of any innovation developed under the agreement (Alston et al., 2010). In 1997, the National Science Foundation added a requirement of "measureable societal impacts" to its criteria for proposal evaluation. In 2006, the National Institutes of Health established its translational science programs. Translational efforts include applications, licensing, start-up of new ventures, development of prototypes, publications, patent applications, and extension of knowledge to users by multiple methods.

Supporters of such efforts have been inspired by the nearly century-long successful record of the Cooperative Extension Service, a federal, state, and local county partnership. Rather than in the classroom and laboratory, extension-based education takes place on farms, in homes, at business sites, and in various other community locations, both virtually and face-to-face. Extension programs currently extend knowledge about agriculture, food safety, consumer economics, financial literacy, nutrition and health, environmental quality, natural-resource management and sustainability, and climate variability through a network that has suffered funding decreases in the last 20 years (APLU, 2010). Even in the face of such retrenchment, extension remains an integral part of a food and agricultural system required to translate new knowledge to enhance economic success and improve consumer well-being.

ORGANIZATION OF THE REPORT

Chapter 2 describes the research and development landscape for food and agriculture and the role of AFRI in addressing critical issues in food and agriculture. Chapter 3 discusses the value of the AFRI program and its role in advancing science in relation to other research programs in USDA and competitive grants programs administered by other federal agencies. It also describes the evolution of the USDA competitive grants programs and briefly describes the scope of AFRI and its approach to funding. Chapter 4 illustrates how the research output from AFRI-funded research could be assessed and discusses information to be collected for future outcome assessments. Chapter 5 examines program-management pre-award processes (e.g., requests for applications), the grant-review process, the awarding of grants, and the post-award processes of the AFRI program. It also discusses the effectiveness of AFRI's operation and flexibility on the basis of the grant-management practices. Chapter 6 provides the committee's overall conclusions and recommendations related to its Statement of Task.

REFERENCES

Alston, J.M., M.A. Andersen, J.S. James, and P.G. Pardey. 2010. Persistence Pays: U.S. Agricultural Productivity Growth and the Benefits from Public R&D Spending. New York: Springer.

APLU (Association of Public and Land-Grant Universities). 2010. Appropriations Request: National Institute of Food and Agriculture. Available online at http://www.aplu.org/NetCommunity/Document.Doc?id=2251. Accessed December 16, 2013.

Bloom, D.E., E.T. Cafiero, E. Jané-Llopis, S. Abrahams-Gessel, L.R. Bloom, S. Fathima, A.B. Feigl, T. Gaziano, M. Mowafi, A. Pandya, K. Prettner, L. Rosenberg, B. Seligman, A.Z. Stein, and C. Weinstein. 2011. The Global Economic Burden of Noncommunicable Diseases. Geneva: World Economic Forum.

DOE (U.S. Department of Energy). 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. Oak Ridge, TN: Oak Ridge National Laboratory.

Drinkwater, L.E. 2002. Cropping systems research: Reconsidering agricultural experimental approaches. Hort Technology 12:355-361.

Enserink, M., P.J. Hines, S.N. Vignieri, N.S. Wigginton, and J.S. Yeston. 2013. Introduction: The Pesticide Paradox. Science 341(6147):728-729.

Flood, J. 2010. The importance of plant health to food security. Food Security 2:215-231.

Halbert, S.E., and K.L. Manjunath. 2004. Asian citrus psyllids (Sternorrhyncha: Psyllidae) and greening disease of citrus: A literature review and assessment of risk in Florida. Florida Entomologist 87:330-353.

Hill, A.M., J.A. Fleming, and P.M. Kris-Etherton. 2009. The role of diet and nutritional supplements in preventing and treating cardiovascular disease. Current Opinion in Cardiology 24(5):433-441.

Hilmers, A., D.C. Hilmers, and J. Dave. 2012. Neighborhood disparities in access to healthy foods and their effects on environmental justice. American Journal of Public Health 102(9):1644-1654.

Kennedy, D. 2013. Time to deal with antibiotics. Science 342:777.

Krebs-Smith, S.M., J. Reedy, and C. Bosire. 2010. Healthfulness of the U.S. food supply: Little improvement despite decades of dietary guidance. American Journal of Preventive Medicine 38(5):472-477.

Lazarou, C., D. Panagiotakos, and A.L. Matalas. 2012. The role of diet in prevention and management of type 2 diabetes: Implications for public health. Critical Reviews in Food Science and Nutrition 52(5):382-389.

NAS-NAE-NRC (National Academy of Sciences, National Academy of Engineering, National Research Council). 2009a. America's Energy Future: Technology and Transformation. Washington, DC: The National Academies Press.

———. 2009b. Liquid Transportation Fuels from Coal and Biomass: Technological Status, Costs, and Environmental Impacts. Washington, DC: The National Academies Press.

———. 2010. Electricity from Renewable Resources. Washington, DC: The National Academies Press.

Njau, P.N., Y. Jin, J. Huerta-Espino, B. Keller, and R.P. Singh. 2010. Identification and evaluation of sources of resistance to stem rust race Ug99 in wheat. Plant Disease 94:413-419.

NRC (National Research Council). 2000. National Research Initiative: A Vital Grants Program in Food, Fiber, and Natural Resources Research. Washington, DC: National Academy Press.

———. 2002. National Capacity in Forestry Research. Washington, DC: National Academy Press.

———. 2003. Frontiers in Agricultural Research: Food, Health, Environment, and Communities. Washington, DC: The National Academies Press.

———. 2010a. Strategic Planning for the Florida Citrus Industry: Addressing Citrus Greening. Washington, DC: The National Academies Press.

———. 2010b. Toward Sustainable Agricultural Systems in the 21st Century. Washington, DC: The National Academies Press.

———. 2011. Renewable Fuel Standard. Potential Economic and Environmental Effects of U.S. Biofuel Policy. Washington, DC: The National Academies Press.

———. 2012. Sustainable Development of Algal Biofuels in the United States. Washington, DC: The National Academies Press.

———. 2013a. Transitions to Alternative Vehicles and Fuels. Washington, DC: The National Academies Press.

———. 2013b. U.S. Health in International Perspective: Shorter Lives, Poorer Health. Washington, DC: The National Academies Press.

———. 2013c. Workforce Needs in Veterinary Medicine. Washington, DC: The National Academies Press.

Pardey, P.G., and J.M. Beddow. 2013. Agricultural Innovation: The United States in a Changing Global Reality. Chicago: Chicago Council on Global Affairs.

Pardey, P.G., J.M. Alston, and C. Chan-Kang. 2013. Public Food and Agricultural Research in the United States: The Rise and Decline of Public Investments, and Policies for Renewal. Washington, DC: AGree.

PCAST (President's Council of Advisors on Science and Technology). 2012. Report to the President on Agricultural Preparedness and the Agriculture Research Enterprise. Washington, DC: Executive Office of the President.

Scallan, E., P.M. Griffin, F.J. Angulo, R.V. Tauxe, and R.M. Hoekstra. 2011a. Foodborne illness acquired in the United States—unspecified agents. Emerging Infectious Diseases 17(1):16-22.

Scallan, E., R.M. Hoekstra, F.J. Angulo, R.V. Tauxe, M.A. Widdowson, S.L. Roy, J.L. Jones, and P.M. Griffin. 2011b. Foodborne illness acquired in the United States—major pathogens. Emerging Infectious Diseases 17(1):7-15.

Scharff, R.L. 2012. Economic burden from health losses due to foodborne illness in the United States. Journal of Food Protection 75(1):123-131.

Schneider, R.W., C.A. Hollier, and H.K. Whitam. 2005. First report of soybean rust caused by *Phakopsora pachyrhizi* in the continental United States. Plant Disease 89:774.

USDA (U.S. Department of Agriculture). 2014. Mission Statement. Available online at http://www.usda.gov/wps/portal/usda/usdahome?navid=MISSION_STATEMENT. Accessed July 22, 2014.

USDA NIFA (U.S. Department of Agriculture, National Institute of Food and Agriculture). 2012. Program synopsis: Agriculture and Food Research Initiative (AFRI) competitive grants program. Available online at http://www.nifa.usda.gov/funding/afri/afri_synopsis.html. Accessed April 18, 2013.

USDA and DHHS (U.S. Department of Agriculture and U.S. Department of Health and Human Services). 2010. Dietary Guidelines for Americans 2010. Washington, DC: U.S. Department of Agriculture and U.S. Department of Health and Human Services.

Vaneeckhaute, C., E. Meers, E. Michels, J. Buysse, and F.M.G. Tack. 2013. Ecological and economic benefits of the application of bio-based mineral fertilizers in modern agriculture. Biomass & Bioenergy 49:239-248.

White House. 2012. National Bioeconomy Blueprint. Washington, DC: The White House.

WHO (World Health Organization). 2013. Global Action Plan for the Prevention and Control of Non-Communicable Diseases 2013-2020. Geneva: World Health Organization.

World Bank. 2010. Designing and Implementing Agricultural Innovation Funds: Lessons from Competitive Research and Matching Grant Projects. Washington, DC: The World Bank.

2

The Global Landscape of Agricultural Research and Development

THE ROLE OF FOOD AND AGRICULTURAL RESEARCH AND DEVELOPMENT IN ECONOMICS AND COMPETITIVENESS

The Value of Agricultural Research and Development

Federal financial support for research and development (R&D) in food and agriculture is a critical policy instrument that the U.S. and other governments use to enhance agricultural productivity and improve the economic and environmental performance of the food and agricultural sectors. For over 100 years, R&D has contributed to a transformation of the U.S. food and agricultural sectors. It has fueled productivity growth and enabled U.S. farmers to generate more product per acre and per farmer with smaller input (e.g., water) per unit product. Research-induced improvements in productivity have helped U.S. agriculture to remain competitive in increasingly integrated global commodity markets and to achieve an environmentally sustainable supply of safe, nutritious, and lower-cost food, feed, fiber, and biomass for energy and other uses (Pardey et al., 2013).

Agricultural and food R&D sustains the agricultural workforce, the well-being of producers, rural and community development, food processing, food safety, nutrition, health, and consumer well-being (NRC, 2010a). It also helps to sustain various ecosystem benefits by reducing adverse externalities from agricultural production and other sectors of the economy (such as biodiversity loss). For example, enhancing the efficiency of production can reduce the adverse environmental effects of agriculture, and the use of conservation tillage and other crop-management methods can improve soil quality and can reduce fertilizer and other chemical use and runoff.

The most recent data indicate that U.S. consumers spent $1.3 trillion for food in 2011 (USDA-ERS, 2012a), which is equivalent to about 8% of the U.S. gross domestic product (Ag Marketing Resource Center, 2013). In 2012, the United States exported over $135 billion and imported $103 billion in agricultural products. The net export of $32 billion contributes to the U.S. trade balance (USDA-ERS, 2012b). Moreover, the United States remains the world's leading provider of international food aid (Hanrahan et al., 2011).

The United States remains a major contributor to the global food and fiber economy, but its relative contribution has decreased. In 1961, the United States accounted for 14.8% by value of the world's entire agricultural output.[1] By 2010, that share had declined to a still sizable 10.6%, with the Asia and Pacific region (including India and China) accounting for 48.6% of world agricultural output (compared with 29.1% in 1961). Nonetheless, the United States continues to be a major producer of many important food and feed commodities. In 2010, the United States accounted for 37.4% of the world's corn, 34.6% of soybean, 15.8% of sorghum, and 9.2% of wheat production.

The global prominence of the United States as a producer and exporter of food and other agricultural commodities and its competitiveness in increasingly integrated international markets are inextricably tied to research-induced improvements in agricultural productivity (Shane et al., 1998). Even though rates of return on productivity-enhancing research are demonstrably high, the growth in public and private spending on agriculture and food R&D in the United States has been slowing, and the share of public funds focused on farm productivity-enhancing research has declined.[2] Those surprising trends have led to a slowdown in U.S. farm productivity growth at a time when the market has begun to signal the end of a sustained period of more than 50 years of global agricultural abundance.

Productivity Consequences

Agricultural productivity growth has contributed remarkably to abundances of food and other agricultural products. For example, U.S. corn production increased from 2.7 billion bushels in 1900 to just under 12.4

[1]Calculations based on data reported in FAO (2012).

[2]Pardey et al. (2013a) reported that in 1976 about 65% of all state agricultural experiment station (SAES) research was oriented toward maintaining or enhancing farm productivity. That share rose to a contemporary peak of 69% in 1985 and had declined to only 56% of SAES research by 2009.

billion bushels in 2011, or 37.4% of the entire world's output of this crop (FAO, 2012; USDA-NASS, 2012). The increase was a result of increasing yields on a per-acre basis as the amount of land used for corn production decreased.[3] U.S. corn yields increased from an average of 28.1 bushels per acre in 1900 to 147.2 bushels per acre in 2011—a growth rate of 1.5% per year. Although some of the yield growth resulted from increases in the quantities of inputs used by farmers (such as fertilizers, herbicides, seeds, machinery, fuel, and irrigation), a sizable share of the measured growth in productivity reflects changes in the quality of inputs (such as the development of new varieties of corn, especially hybrid, and more recently, genetically engineered varieties), which stemmed from investments in R&D.[4]

The total value of U.S. agricultural output from 1949 to 2007 increased from $29.9 billion to $281.5 billion (Pardey and Beddow, 2013). However, the increase in aggregate input use has been comparably modest so that achieving the same output absent any productivity growth since 1949 would have required 78% more inputs. Put another way, productivity growth since 1949 saved $219.6 billion worth of inputs in 2007. In more concrete terms, an additional 729.5 million acres combined with an additional farm labor force of 1.76 million full-time annual equivalents and many more other inputs would have been needed to produce the 2007 output with 1949 technology.

Research-induced growth in U.S. agriculture and food productivity and production in the 20th century was remarkable in terms of the economic returns on the public dollars invested in that research. The research is carried out by national agencies (mainly USDA) and state agencies (mainly state agricultural experiment stations [SAESs]). Considering the SAES research, the national benefit-cost ratio for the investments averages $32 for every dollar invested in research, and returns on the investments range from 10:1 to 69:1, depending on the state in which the research is conducted (see Table 2-1). USDA intramural research resulted in a national benefit-cost ratio of 17.5:1—still a substantial social return on investment although it is generally lower than the national benefit-cost ratio for research and extension conducted by the states. These high rates of return illustrate a

[3]Although the long-run trend is a reduction in corn acreage relative to the acreage of 1900, corn acreage declined from 94.9 million acres in 1900 to 54.6 million in 1969 and had increased to 84.0 million acres in 2011.

[4]The 2010 National Research Council report entitled *The Impact of Genetically Engineered Crops on Farm Sustainability in the United States* concluded that "Farmers who have adopted GE crops have experienced lower cost of production and obtained higher yields in many cases because of more cost-effective weed control and reduced losses from insect pests" (NRC, 2010a, p. 9).

TABLE 2-1 Marginal Benefit-Cost Ratios for Public Research and Extension in the United States (expressed in present values of benefits and costs)

State or Region	Benefit-Cost Ratios (dollars of benefits per dollar of costs)	
	Own State	National
48 States		
Average	21.0	32.1
Minimum	2.4	9.9
Maximum	57.8	69.2
REGIONS		
Pacific	21.8	32.9
Mountain	20.0	31.6
Northern Plains	42.4	54.5
Southern Plains	20.2	31.0
Central	33.7	46.8
Southeast	15.1	26.7
Northeast	9.4	18.4

SOURCE: Adapted from Alston et al. (2011).

remarkably profitable undertaking for the nation but also suggest persistent underinvestment (Alston et al., 2011) and possibly forgone opportunities.[5]

A progressive slowing of U.S. (and global) agricultural productivity growth from the historically high growth rates of the 1960s, 1970s, and 1980s has been observed in the last 20 years (Table 2-2). In every region of the United States, average annual multifactor productivity growth rates for the more recent period, 1990–2007, were significantly lower than in the previous period, 1949–1990. The national average rate decreased from 2.02% per year in 1949–1990 to 1.18% per year in 1990–2007 (Pardey et al., 2013a). If the more recent, lower rate of multifactor productivity growth is sustained over the coming decades, the future path of U.S. agriculture will be much less prosperous than if productivity growth rates could be restored to those of the 1970s or 1980s.

To illustrate the magnitude of this effect, Alston et al. (2010, Chapter 11) projected U.S. agricultural multifactor productivity growth in alternative research spending scenarios. In a pessimistic scenario, with R&D spending growing in real terms at the 1990–2002 rate, the future rate of agricultural productivity growth slowed to just 0.11% per year during the 2040s, less

[5] An optimal strategy would be to increase spending on R&D until the marginal dollar spent earned a dollar in benefits, thus driving the marginal benefit-cost ratio down to 1. This conceptual link between high benefit-cost ratios results in the implication to call for more funding.

TABLE 2-2 Agricultural Multifactor Productivity Growth in the United States and Selected Regions

	Average Annual Productivity Growth Rates[b] (% per year)		
Regions[a]	1949–2007	1949–1990	1990–2007
United States	1.78	2.02	1.18
Northeast	1.72	2.16	0.67
Central	1.64	1.71	1.48
Northern Plains	2.04	2.32	1.38
Southern Plains	1.82	2.01	1.37
Southeast	1.96	1.49	0.68
Mountain	1.48	1.89	0.50
Pacific	1.82	2.02	1.33

[a]The regions are as follows: Mountain—Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming; Northern Plains—Kansas, Nebraska, North Dakota, South Dakota; Southern Plains—Arkansas, Louisiana, Mississippi, Oklahoma, Texas; Central—Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, Wisconsin; Southeast—Alabama, Florida, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, Virginia, West Virginia.

[b]The entries in this table are national (48 state) and regional and national (48 state) estimates of multifactor productivity growth rates that account for changes in the use of 58 categories of inputs in the periods examined: 32 categories of labor inputs, 12 categories of capital inputs (including 7 physical capital categories and 5 biological capital categories), 3 land categories, and 11 material input categories.

SOURCE: Pardey et al., 2013b. Reprinted with permission from AGree.

than one-tenth the rate achieved during 1942–2002 (which was 1.96% per year). Even in an optimistic scenario, with the real growth rate of R&D spending restored to that of 1949–2002, the rate of agricultural productivity growth would at first continue to decline and then recover only gradually to average 1.3% per year during the decade of the 2040s, given the long lags between investing in R&D and realizing the improved productivity performance attributable to the investment.

U.S. Agriculture in a Global Context

The United States remains the leading investor in agriculture and food R&D worldwide, but that leadership position has been eroded in recent decades. In 1980, the United States accounted for 23.1% of the $24.2 billion (in 2005 dollars based on purchasing-power parity exchange rates[6])

[6]Purchasing power parity is defined as "the rate of currency conversion that equalize[s] the purchasing power of different currencies by eliminating the differences in price levels between countries. In their simplest form, purchasing power parities are simply price relatives that show the ratio of the prices in national currencies of the same good or service in different countries" (OECD, 2014).

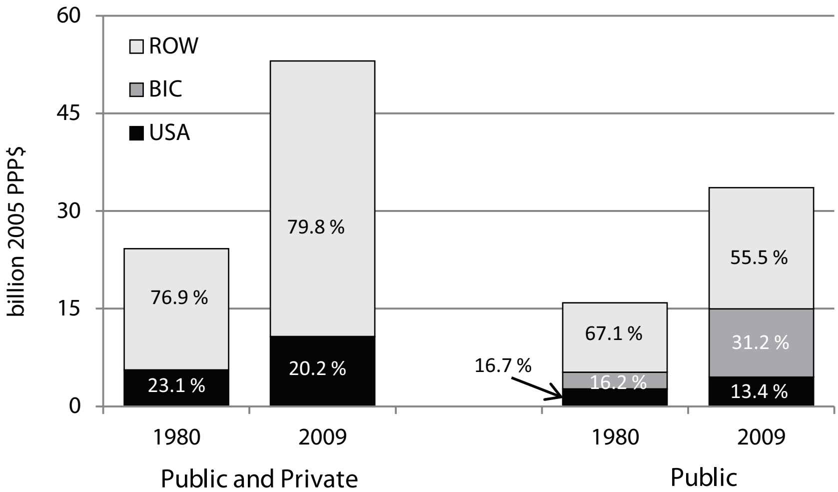

FIGURE 2-1 Agricultural and food R&D spending worldwide, 1980 and 2009. In the two left bars for public and private R&D, there is presently no information available on the breakout for BIC countries. BIC data are only available for public-only R&D. BIC = Brazil, India, and China; PPP = purchasing-power parity; ROW = rest of world.
SOURCE: Pardey et al., 2014.

invested worldwide in both public-sector and private-sector agricultural R&D (Figure 2-1) (Pardey et al., 2014). The U.S. global share dropped to 20.2% by 2009 as total public and private spending worldwide grew to just over $53 billion. The relative trends are similar for agricultural and food R&D performed by just the public sector—the U.S. global share decreased from 16.7% in 1980 to 13.4% in 2009, and the United States is now second to China in public investment in agriculture and food R&D. The big gains were made by Brazil, India, and China (the so-called BIC countries), whose combined global share of publicly performed agriculture and food R&D increased from 16.2% in 1980 to 31.2% in 2009.

A continued reduction in the U.S. global share of publicly performed food and agricultural research is not a foregone conclusion, but the trends are heavily influenced by policy choices made by the United States and other countries. Over the last three decades, the BIC countries opted to sustain high rates of growth in public investment in agriculture and food R&D while the United States slowed its analogous rate of growth (Figure 2-2). The changes in global R&D investment shares are dramatic, and the differences in the growth in public R&D spending between the United States and

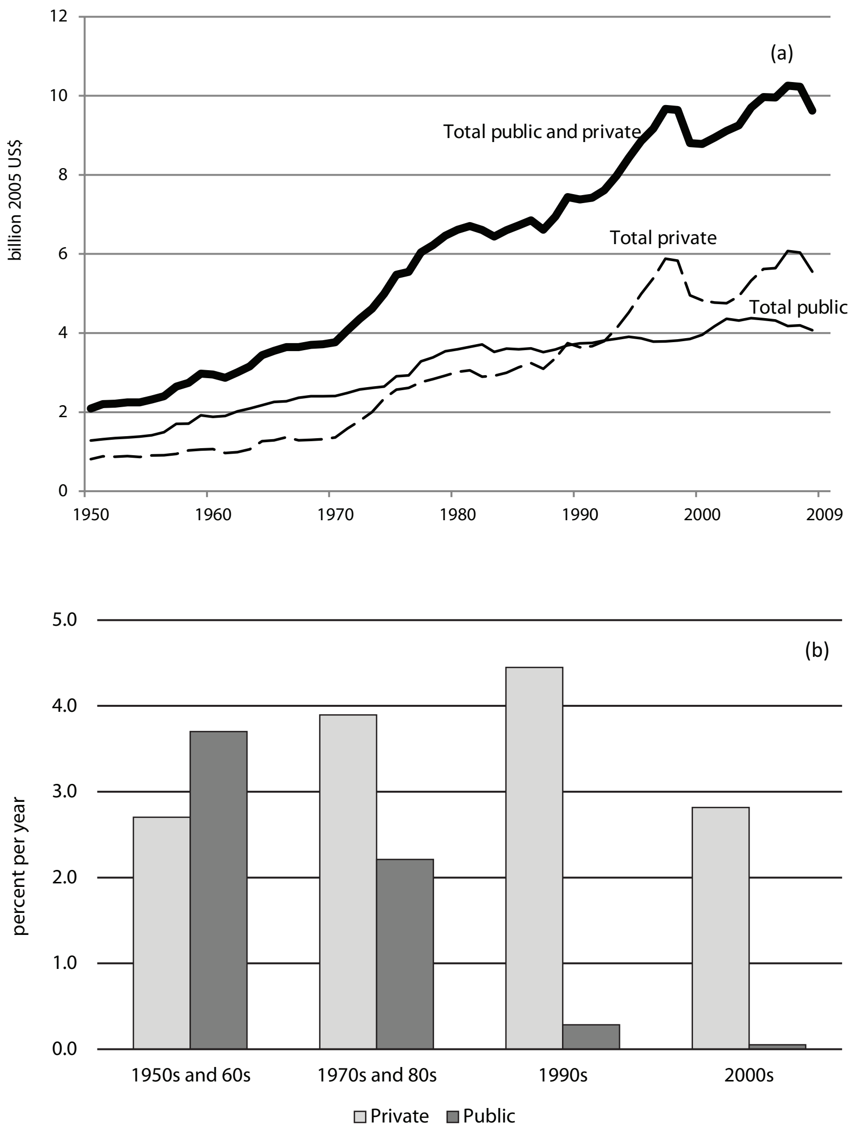

FIGURE 2-2 Public and private investments in food and agricultural R&D. Panel (a) shows public and private investment in R&D from 1950 to 2009. Panel (b) shows the real rate of growth in public and private R&D investment by decades. SOURCE: Dehmer and Pardey, 2014.

the BIC countries are widening. During 1980–2009, real public spending in the BIC countries as a group increased by an average of 4.3% per year compared with 2.04% per year in the United States. Over the last decade, the BIC countries ramped up their rate of spending, increasing by 7.3% per year compared with 1.04% per year in the United States. The President's Council of Advisors on Science and Technology stated in its report that "the waning public investment in agricultural research in the United States contributes significantly to the risk of losing its international leadership in agriculture" (PCAST, 2012, p. 5), particularly in contrast with the increasing investment by BIC countries. To maintain its global leadership in the agriculture and food sectors and maintain an edge in discovery and innovation, the United States needs to be cognizant of R&D trends in other countries.

U.S. Public and Private Trends

In 2009, an estimated $9.6 billion (2005 prices) was spent on all food and agricultural R&D performed in the United States, a figure that reflects investment by both public and private entities (Figure 2-2a).[7] That amount represented 2.9% of total spending on all R&D in the United States. The public sector performed about 40% of U.S. food and agricultural R&D compared with 22.1% of the total for all R&D, indicating a relatively larger public investment in food and agricultural R&D than in other R&D. Almost 32% of total food and agricultural R&D in 2009 was performed by universities and colleges compared with 14.8% of the total for all R&D. Similarly, 11.3% of food and agricultural R&D was performed in federal government research laboratories (such as intramural USDA research) compared with 7.7% of the total for all R&D. The atomistic nature of most farm operations and the difficulties of appropriating the returns to many agricultural innovations (e.g., many new crop varieties are self-replicating, so farmers can save and reuse varietal innovations without paying for them repeatedly) suggest that market failures in farm technologies are more pronounced than in other sectors, and this argues for a relatively greater public presence in agricultural R&D.

Over the last 50 years, private spending has grown faster than public spending (Figure 2-2b), and the private sector now conducts a larger share of the food and agricultural R&D in the United States than the public sector (Figure 2-2a). However, the private sector has a different emphasis on R&D from the public sector, which reflects different incentives and opportunities for returns on investment. For example, in the United States, around 80% of private research is developmental or nearly commercial (see Table 4.3 in NSB, 2012), whereas 80-90% of the public sector's research is foundational

[7]If forestry research is included, the corresponding 2009 total is $10.1 billion (2005 prices).

or applied research that provides the intellectual building blocks for developing the innovations that underpin growth in the food and agricultural sectors (USDA-CRIS, 2010). Moreover, food, beverage, and tobacco research conducted by companies—including Kraft, Kellogg, and Pepsico—is the largest category of private food and agricultural research in the United States, accounting for 36% of the 2009 total (Dehmer and Pardey, 2014). In contrast, the public sector accounted for just 23.6% of this research in 2009 in the United States (Dehmer and Pardey, 2014). With 84.5% of the value of 2011 U.S. food sales accruing to post-farm activities (which means that there are prospects of substantial commercial rewards for innovation in this part of the food supply chain) and with market-failure arguments for public engagement in this field being less pronounced, that is to be expected (USDA-ERS, 2013). Agriculture and chemical research (which includes biological research intended to develop new crop varieties and innovations designed to develop new herbicides, pesticides, and veterinary medicines) accounts for the next-largest share of private research, followed by research on new agricultural machinery and equipment (Dehmer and Pardey, 2014).[8] These trends are interesting to note and they raise questions about the relationship between public and private R&D investments (whether shrinking public R&D will lead to lower private R&D or the reverse) and whether the private sector will respond to decreasing U.S. public R&D by turning to the BIC countries for foundational research conducted outside the United States.

As noted earlier, the growth in public spending on food and agricultural R&D has slowed over the last several decades, and in fact real spending has trended down since 2002 (to at least 2009, the last year for which data are available). Spending on cooperative extension increased since it was established in 1915 at an average of 6.7% per year; but from 1950 to 1980, inflation-adjusted growth in extension spending slowed to 2.39% per year. During the period 1980–2006, real extension spending shrank by 0.25% per year.

Sources of Funding for Public Research

Public-sector food and agricultural R&D is conducted by scientists in SAES and associated universities and by scientists in federal USDA laboratories. Some U.S. government funding ($78.9 million in 2009) also supports agricultural R&D conducted by the international research centers that

[8]The Dehmer and Pardey (2014, in preparation) series spanning the period 1950–2009 is an entirely new compilation of U.S. private agriculture and food R&D spending. An earlier beta version of the series was reported by Alston et al. (2010). Fuglie et al. (2011) reported an alternative set of private-sector R&D estimates.

constitute the Consultative Group on International Agricultural Research. Of the $3.6 billion spent by state-affiliated institutions (the SAESs and other cooperating institutions) in 2009, 38.0% came from federal sources, 38.3% from state governments, 8.2% from industry grants and contracts, and 15.5% from income earned from sales, royalties, and various other sources. Research conducted by USDA laboratories ($1.53 billion) was almost entirely funded by the federal government (96%).

Historically, USDA has been the dominant federal government agency channeling funds to the SAESs. In 1975, USDA disbursed almost 74% of the federal funds that flowed to the SAESs (Figure 2-3). By 2009, that share had declined to 50% as funding from other federal agencies increased, including funding from the National Institutes of Health, the Environmental Protection Agency, the Department of Energy, and the National Science Foundation. Notwithstanding the declining share of federal support from USDA, the growth in federal funding from non-USDA agencies has been such that total federal funding has grown as a share of total SAES funding—from 28.6% in 1975 to 39.9% in 2009 (see Figure 2-3). That diversification of funding reflects a significant erosion in the ability of USDA to influence the agriculture and food-system research agenda in SAESs and universities. As the funding from other agencies has grown, the priorities

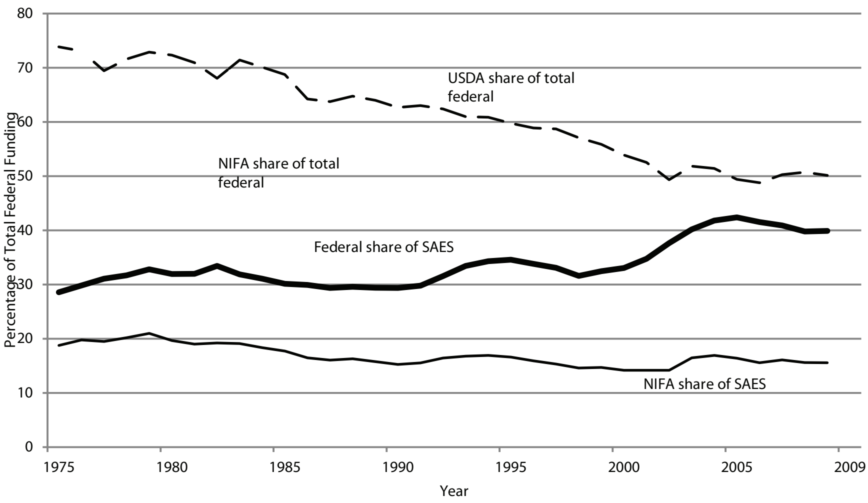

FIGURE 2-3 Roles of the federal government, including USDA, in funding SAES research, 1975–2009. NIFA = National Institute of Food and Agriculture.
SOURCE: (Pardey et al., 2013b). Reprinted with permission from AGree.

of the research conducted have been increasingly determined by those of other funding agencies.

With a decline in the share of SAES funding from USDA came a decline in the share of SAES funding administered by the National Institute of Food and Agriculture (NIFA; Figure 2-3). In 1975, NIFA funding—or specifically its precursor at that time within USDA (see Chapter 3)—accounted for 18.8% of total SAES funding. By 2009, the NIFA share had shrunk to 15.6% of the SAES funding total.

An additional implication of a steady decline in the USDA share of funding for research carried out by the SAESs and other research institutions is that talented investigators will probably shift from research directly relevant to agriculture (supported by USDA) to research that is less so. That potentially results in a gradual decrease in talent, knowledge, and innovation available to agriculture. With innovative agricultural researchers seeking much of their funding from non-USDA agencies, it becomes likely that USDA is not fully leveraging cutting-edge scientific and technological advances that are relevant to agriculture. As a result, the United States might not be adequately prepared to face future challenges, because the knowledge base needed to address them will have shrunk. Chapter 3 will address the special niche of the USDA Agriculture and Food Research Initiative in addressing the issue of R&D in agriculture and associated disciplines.

CONCLUSION

The agricultural and food sectors have served this country well, but given the changes in fiscal structures supporting them, it is unlikely that the rate of knowledge improvement and discovery through R&D has kept pace with increasing global competition and domestic needs for ensuring a safe, nutritious, and accessible food supply. The shrinking of public investment in U.S. agricultural R&D will probably slow innovation and slow the growth of the knowledge base necessary to meet evolving challenges presented by increasingly competitive global markets, increasing resource scarcity, growing environmental concerns (such as climate variability, water use, pollution), and the rapidly expanding food needs faced by the United States and thereby jeopardize the United States' ability to maintain competitiveness in international agricultural and food markets.

FINDING

Finding 2-1: Research and development investments, targeted specifically toward agriculture and food issues, are critical for sustaining innovation and for creating the knowledge base necessary to meet growing challenges of increasingly competitive global markets, and resource scarcity, growing environmental threats (such as climate variability, water use, pollution), and rapidly expanding food needs.

REFERENCES

Ag Marketing Resource Center. 2013. Food Consumption Trends. Iowa State University.

Alston, J.M., M.A. Andersen, J.S. James, and P.G. Pardey. 2010. Persistence Pays: U.S. Agricultural Productivity Growth and the Benefits from Public R&D Spending. New York: Springer.

———. 2011. The economic returns to U.S. public agricultural research. American Journal of Agricultural Economics 93(5):1257-1277.

Dehmer, S., and P.G. Pardey. 2014 (in preparation). Private Agriculture and Food R&D in the United States, 1953-2009. St Paul: University of Minnesota.

FAO (Food and Agriculture Organization of the United Nations). 2012. FAOSTAT database. Available online at http://faostat.fao.org/. Accessed October 2012.

Fuglie, K.O., P.W. Heisey, J.L. King, C.E. Pray, K. Day-Rubenstein, D. Schimmelpfennig, S.L. Wang, and R. Karmarkar-Deshmukh. 2011. Research Investments and Market Structure in the Food Processing, Agricultural Input, and Biofuel Industries Worldwide. Washington, DC: USDA Economic Research Service.

Hanrahan, C.E., C. Canada, and B.A. Banks. 2011. U.S. Agricultural Trade: Trends, Composition, Direction, and Policy. Washington, DC: Congressional Research Service.

NRC (National Research Council). 2010a. The Impact of Genetically Engineered Crops on Farm Sustainablity in the United States. Washington, DC: The National Academies Press.

———. 2010b. Toward Sustainable Agricultural Systems in the 21st Century. Washington, DC: The National Academies Press.

NSB (National Science Board). 2012. Table 4.3 in Science and Engineering Indicators 2012. Arlington VA: National Science Foundation.

OECD (Organisation for Economic Co-operation and Development). 2014. Purchasing Power Parities—Frequently Asked Questions. Available online at http://www.oecd.org/std/purchasingpowerparities-frequentlyaskedquestionsfaqs.htm#FAQ1 (Accessed July 29, 2014).

Pardey, P.G., and J.M. Beddow. 2013. Agricultural Innovation: The United States in a Changing Global Reality. Chicago: Chicago Council on Global Affairs.

Pardey, P.G., J.M. Alston, and C. Chan-Kang. 2013a. Public agricultural R&D over the past half century: An emerging new world order. Agricultural Economics 44 (s1): 103-113.

Pardey, P.G., J.M. Alston, and C. Chan-Kang. 2013b. Public Food and Agricultural Research in the United States: The Rise and Decline of Public Investments, and Policies for Renewal. Washington, DC: AGree.

Pardey, P.G., C. Chan-Kang, and S. Dehmer. 2014 (in preparation). Global Food and Agricultural R&D Spending, 1960-2009. InSTePP Brief. St. Paul: University of Minnesota.

PCAST (President's Council of Advisors on Science and Technology). 2012. Report to the President on Agricultural Preparedness and the Agriculture Research Enterprise. Washington, DC: Office of the President of the United States.

Shane, M., T.L. Roe, and M. Gopinath. 1998. U.S. Agricultural Growth and Productivity: An Economywide Perspective. Economic Research Service Report 34047. Washington, D.C.: U.S. Department of Agriculture.

USDA-CRIS (U.S. Department of Agriculture, Current Research Information System). 2010. Unpublished data files. Washington, D.C.: U.S. Department of Agriculture.

USDA-ERS (U.S. Department of Agriculture, Economic Research Service). 2012a. Fiscal Year Data Set. Available online at http://www.ers.usda.gov/data-products/foreign-agricultural-trade-of-the-united-states-%28fatus%29/fiscal-year.aspx#.UmfNvBBFZ-p. Accessed October 23, 2012.

———. 2012b. Food Expenditure Series. Table 10: Food away from home as a share of food expenditures. Available online at http://www.ers.usda.gov/data-products/food-expenditures.aspx. Accessed December 1, 2013.

———. 2013. ERS Food Dollar Series allows an in depth look at farm level commodity components of the U.S. food dollar. *Amber Waves*, July 2013. Available online at http://www.ers.usda.gov/amber-waves/2013-july/ers-food-dollar-series-allows-an-indepth-look-at-farm-level-components-of-the-us-food-dollar.aspx#.U_pW_PkhixU.

USDA-NASS (U.S. Department of Agriculture, National Agricultural Statistical Service). 2012. Quick Stats (agricultural statistics database). Available online at http://quickstats.nass.usda.gov. Accessed October 2012.

3

Value of the AFRI Program

Numerous reports have laid out visions and goals for an agricultural research and development (R&D) program and addressed the strengths, weaknesses, and directions of U.S. agricultural R&D, extension, and education programs over several decades (USDA-REE Task Force, 2004; PCAST, 2012; NRC, 1989, 2000, 2003). Although those reports have addressed the aspirations for agricultural R&D programs, no reports have assessed what would be missing if focused publicly funded programs of agriculture and food R&D, extension, and education did not exist. Such a review and assessment would be beneficial for understanding the place of the U.S. Department of Agriculture (USDA) Agriculture and Food Research Initiative (AFRI) in the research agenda of the United States and the incremental value of such a program. To address the value of AFRI, this chapter discusses the role of a competitively funded research, extension, and education program as a complement to other USDA programs funded via other mechanisms. It then explores AFRI in relation to the extramural research programs in other federal agencies. The chapter also describes the evolution of USDA's flagship competitive grants program, discusses the aspirations for AFRI, and describes the scope and structure of and funding for the program and how it addresses the Food, Conservation, and Energy Act of 2008 (referred to hereafter as the 2008 Farm Bill[1]).

The committee compares AFRI with other federally funded research programs to determine AFRI's contributions to the federal science and technology portfolio, focusing on legislative intents and mandates of each program. In a review of the program, it was beyond the committee's scope to provide corroborating evidence from the content of AFRI-funded projects or to determine AFRI's success in attracting research proposals that other federal agencies do not support. Empirical analysis of that nature would require methods such as keyword or other searches of AFRI project populations or samples, which would then be compared with the populations or samples of projects in other selected funding programs.

BRIEF HISTORY OF THE U.S. DEPARTMENT OF AGRICULTURE'S COMPETITIVE GRANT PROGRAMS

USDA has played a key role in supporting extramural research for agriculture since the passage of the Hatch Act in 1887, but its use of competitive funding as a mechanism to support extramural research began more recently (see Figure 3-1). A peer-review competitive grants program was proposed as a means of moving a publicly funded agricultural research portfolio toward the more basic end of the R&D spectrum.[2] A 1989 National Research Council report stated that "there is ample justification for increased allocations for the [competitive] grants program to a level that would approximate 20 percent of the USDA's research budget, at least one half of which would be for basic research related to agriculture" (NRC, 1989, pp. 49–50). Those recommendations were partially implemented. For

[1]The Agriculture Adjustment Act of 1933 was enacted originally to ensure an adequate food supply by providing financial assistance to farmers and nutrition assistance to feed the hungry during the Great Depression. Since then, Congress has required that a "Farm Bill" be updated and passed every 5 years. The Farm Bill is an omnibus bill that sets national agriculture, nutrition, conservation, and forestry policies, and authorizes annual expenditures for services and programs within the U.S. Department of Agriculture. Policies and funding for agricultural research, extension, and education are outlined in the Farm Bill, and the AFRI program was established by the 2008 Farm Bill.

[2]Basic research is defined by the Office of Management and Budget (OMB) as "systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind." Applied research is defined also by the OMB as "systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met." Development is defined by the OMB as "systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements." See http://www.nsf.gov/statistics/randdef/fedgov.cfm.

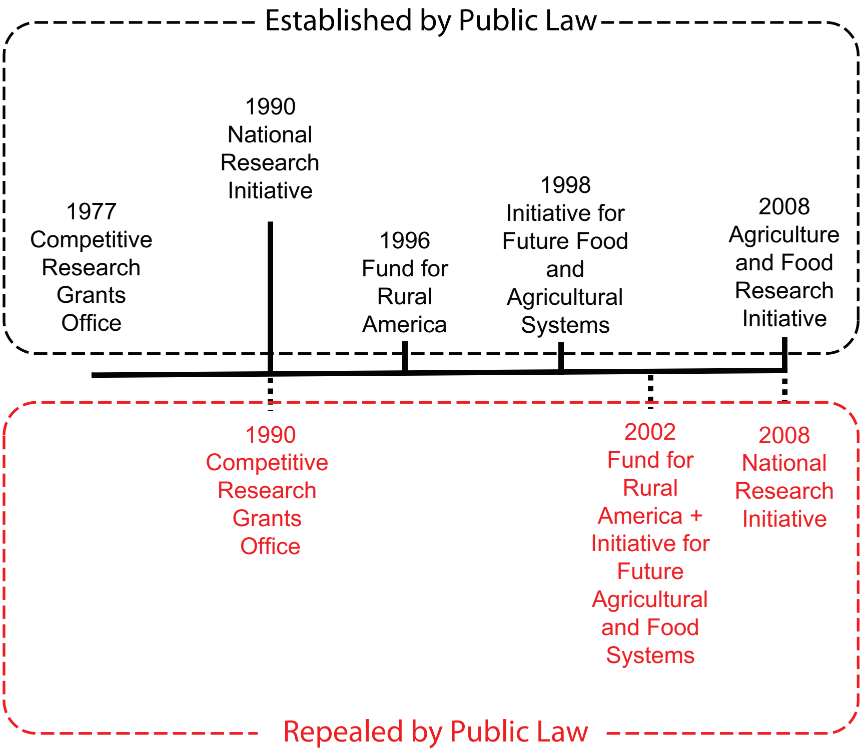

FIGURE 3-1 Timeline of establishment and repeal of USDA competitive grant programs.

example, the Competitive Research Grants Office (CRGO), the competitive granting mechanism initiated by the Food and Agriculture Act of 1977 (1977 Farm Bill), was established to support fundamental research, but grants awarded through CRGO represented only about 5% of total USDA research expenditures (see Table 3-1) (NRC, 1989; OTA, 1991).

The committee that prepared the 1989 National Research Council report *Investing in Research: A Proposal to Strengthen the Agricultural, Food, and Environmental System* recognized the importance of agriculture to the U.S. economy and the critical role that research plays in ensuring access to an abundant and safe supply of food while maintaining and enhancing the natural-resource base used for agriculture.

CRGO was replaced in 1990 by the National Research Initiative (NRI), which was charged with “funding research, education, and extension

TABLE 3-1 Authorized and Appropriated Funds for USDA Research Programs

			Appropriated as Share of		
Year	Authorized (millions of dollars)	Appropriated (millions of dollars)	Authorized	Total USDA Funding	Total Public Funding
Competitive Research Grants Office					
1977	25	15	60.0	3.3	2.4
1978	30	15	50.0	3.0	2.2
1979	35	15.5	44.3	2.7	2.1
1980	40	16	40.0	2.6	1.9
1981	50	17	34.0	2.5	1.8
1982	50	17	34.0	2.3	1.6
1983	50	17	34.0	2.2	1.6
1984	50	17	34.0	2.2	1.5
1985	50	46	92.0	5.8	3.7
1986	70	48.8	70.0	6.1	3.6
1987	70	40.6	58.0	5.1	2.8
1988	70	42.4	60.6	5.1	2.8
1989	70	39.7	56.7	4.4	2.4
1990	70	43.1	61.6	4.6	2.4
National Research Initiative					
1991	150	73	48.7	7.3	3.9
1992	275	97.50	35.5	9.0	5.0
1993	350	97.50	27.9	8.6	4.9
1994	400	112.20	28.1	9.5	5.3
1995	500	101	20.2	8.4	4.6

1996	500	94	18.8	8.0	4.3
1997	500	94	18.8	7.9	4.2
1998	500	97	19.4	8.1	4.1
1999	500	119	23.8	9.5	4.8
2000	500	119	23.8	8.9	4.5
2001	500	106	21.2	7.0	3.8
2002	500	120	24.0	7.1	4.0
2003	500	166	33.2	9.4	5.4
2004	500	164	32.8	8.8	5.2
2005	500	180	36.0	9.4	5.4
2006	500	215	43.0	11.2	6.3
2007	500	190	38.0	9.8	5.5
2008	500	190	38.0	9.6	5.2
***Fund for Rural America*[a]**					
1996	100	80	80.0	6.8	3.6
1997	100	80	80.0	6.7	3.5
1998	100	80	80.0	6.7	3.4
1999	100	60	60.0	4.8	2.4
***Initiative for Future Agriculture and Food Systems (IFAFS)*[b]**					
1999	120	120	100.0	9.5	4.9
2000	120	120	100.0	8.9	4.6
2001	120	----[c]			
2002	120	----[c]			

continued

TABLE 3-1 Contiued

Year	Authorized (millions of dollars)	Appropriated (millions of dollars)	Appropriated as Share of: Authorized	Appropriated as Share of: Total USDA Funding	Appropriated as Share of: Total Public Funding
Agriculture and Food Research Initiative [d]					
2008	700	190	27.1	9.6	5.2
2009	700	201	28.7	10.2	5.5
2010	700	262.50	37.5		
2011	700	264.50	37.8		
2012	700	266	38.0		
2013	700	277	39.6		
2014	700	291	41.6		

NOTE: Total USDA funding is the sum of Cooperative State Research, Extension, and Education Service–administered funds and other USDA funds and intramural USDA funding. Total public funding consists of total research spending by the state agricultural experiment stations (SAESs) plus intramural research expenditures by USDA. Total USDA and total public funding series are based on data extracted from USDA Current Research Information System data files and constitute InStePP (2013) estimates.

[a]Fund for Rural America introduced mandatory money for research programs.

[b]IFAFS is a mandatory spending program, not appropriated.

[c]Funding of IFAFS was limited because of appropriations language, which allowed only enough funds to manage already funded projects. $30–40 million was added to the NRI to provide funds for projects intended for IFAFS.

[d]Lack of data for total USDA and public funding for the post-2009 period.

activities to address key problems of national and regional importance in biological, environmental, physical, and social sciences relevant to agriculture, food, the environment, and communities on a peer-reviewed, competitive basis" (USDA-NIFA, 2009b). Congress authorized a total of $150 million for the NRI in FY 1991 with incremental increases up to $500 million by FY 1995. Those authorized amounts were never reached in any given year. A total of $69.2 million was committed to successful grantees in 1991 and $165.8 in 2007, less than 35% of the authorized amount (and less than 9% of total USDA funding in 2007).[3]

After its establishment, the NRI program was reviewed by the National Research Council two times, and that resulted in two reports: *Investing in the National Research Initiative: An Update of the Competitive Grants Program of the U.S. Department of Agriculture* (NRC, 1994) and *National Research Initiative: A Vital Competitive Grants Program in Food, Fiber, and Natural Resources Research* (NRC, 2000). Both reports reiterated the recommendation in the 1989 report to increase the NRI budget to $500 million (or $550 million after adjusting for inflation) because of the role of the program in enabling producers to meet increasing food needs, provide safe foods of high nutritional quality that are affordable and accessible, and protect and enhance the natural-resource base on which U.S. agriculture relies. The 2000 report recommended that USDA increase its competitive grants support by $500 million annually on the premise that: "(1) The pervasive needs and problems require large amounts of new knowledge and technology for their resolution. (2) Agricultural research provides a high return on investment. (3) The agricultural research system, as presently funded, is unable to provide the necessary financial support for the quality, amount, and breadth of science and technology necessary to address the problems" (NRC, 2000, p. 5).

Competitive grant programs in addition to the NRI existed briefly. The Federal Agriculture Improvement and Reform Act of 1996 (P.L. 104-127) established the Fund for Rural America "to develop knowledge-based solutions for rural economic development" (USDA-NIFA, 2001). One-third of the fund was designated for a competitive grants program, and one-third was for rural development projects. The other one-third of the fund could be used for either competitive research or rural development projects at the discretion of the Secretary of Agriculture. The Agricultural Research, Extension, and Education Reform Act of 1998 (P.L. 105-185) established the Initiative for Future Agricultural Food Systems (IFAFS) as a competitive grants program for research, extension, and education to address a

[3]Here, the USDA funding total was estimated as the total of USDA intramural research spending and federal funding to USDA that is used to conduct research in the state agricultural experiment stations and other cooperating institutions.

number of critical emerging agricultural issues related to food production, environmental quality, natural-resource management, and farm income. The program gave high priority to proposals that were multistate, multi-institutional, or multidisciplinary or proposals that integrated at least two of the three aspects of research, extension, and education. Both the Fund for Rural America and IFAFS were repealed in the 2002 Farm Bill (P.L. 107-172).

VISION FOR A COMPETITIVE GRANTS PROGRAM IN AGRICULTURE

The question arose of how a publicly funded competitive grants program for research, extension, and education could best serve societal interests in the U.S. agriculture and food sectors. Two prominent groups—the USDA Research, Education, and Economics (REE) Task Force and CREATE-21—addressed the question. The REE Task Force was appointed by the Secretary of the U.S. Department of Agriculture at the request of Congress (P.L. 107-171). It evaluated the merits of establishing one or more national institutes focused on disciplines important for the progress of agriculture and food science. A report titled *National Institute for Food and Agriculture: A Proposal* was submitted to the Secretary in July 2004 (USDA-REE Task Force, 2004). The report identified several major scientific, economic, and national security issues faced by the nation that could be addressed through an increased focus on competitive, extramural, and fundamental research. The major agricultural issues described by the task force are similar to the major societal challenges related to agriculture raised by numerous later reports (APLU, 2006; NRC, 2009; PCAST, 2012; White House, 2012; ASPB, 2013). Selected themes that permeate those reports are reflected in the challenges addressed in Chapter 1 of the present report and illustrate the continuing broad scope of food and agriculture issues.

The REE Task Force report envisioned a strengthened and increased competitive grants program in USDA and new (as opposed to reallocated) funds to expand competitive, fundamental research but in a strengthened science-based culture in USDA. Such a culture was proposed to require an independent agency that would report directly to the Secretary of Agriculture and be roughly modeled after the structure of National Institutes of Health (NIH) competitive funding.[4] The NIH model, with a director that reports to the Secretary for Health and Human Services, is based on priority-setting mechanisms that involve science-based councils that align

[4]NIH funding levels are significantly higher than USDA levels, with NIH receiving $30 billion for FY 2014 (NIH, 2014).

research priorities with national needs; a rigorous, strong peer-review culture and practice; a strong tradition of scientific merit-based funding decisions; consistency of review panels, funding expectations, staff support, and grants management over time; and funding of both direct project costs and full indirect costs on the basis of federally negotiated rates.

The CREATE-21 report also envisioned a strengthened competitive grants program in USDA. The Statement of Managers in the Conference Report to the 2008 Farm Bill most clearly states the goals articulated in the CREATE-21 report:

> The Managers believe that NIFA [National Institute of Food and Agriculture] will be commensurate in stature with other grant-making agencies across the Federal government, such as the National Institutes of Health and the National Science Foundation. The Managers intend for NIFA to be an independent, scientific, policy-setting agency for the food and agricultural sciences, which will reinvigorate our nation's investment in agricultural research, extension, and education (APLU, 2006).

The CREATE-21 report, which openly supported the REE Task Force report, made the case for increased competitive funding, repair of and improvement in the infrastructure of universities and institutions that do agricultural research, and strengthening of the organizational structure of competitive formula-based and intramural research programs of USDA.

OVERVIEW OF THE AGRICULTURE AND FOOD RESEARCH INITIATIVE

The 2008 Farm Bill (P.L. 110-234) constitutes the most recent congressional attempt (as of the writing of this report) to allocate more of the federal funds for agricultural R&D by peer-reviewed competitive means. It established AFRI, which replaced the NRI. As authorized in the bill, NIFA was created and structured, at least in part, according to the recommendations in the REE Task Force and CREATE-21 reports. However, the structure and implementation of NIFA and its competitive grants program, AFRI, differed markedly in many respects from those recommendations (Box 3-1).

Recognizing the historical commitment to and value of solving the problems of agriculture, a number of reports attempted to shift the organizational culture and structures to foster innovation. The REE Task Force report (2004) explicitly called for a "new culture" in USDA, and the CREATE 21 effort also envisioned a new organizational model. Neither was formally and explicitly established by Congress, but USDA's implementation of NIFA and AFRI is an attempt to create such a scientific envi-

BOX 3-1
Recommendations by the Research, Education, and Economics Task Force of the USDA and the CREATE-21 That Were Not Implemented

The Research, Education, and Economics (REE) Task Force of USDA made 13 recommendations in response to the charge to evaluate the merits of establishing one or more national institutes focused on disciplines important for the progress of agriculture and food science. The CREATE-21 report supported many of those recommendations, but not all were adopted in the implementation of NIFA and AFRI. Some examples include the following.

REPORTING

PROPOSAL: The formation of a National Institute for Food and Agriculture (NIFA) in USDA for the purpose of ensuring the technological superiority of American agriculture. The institute should report directly to the Secretary of Agriculture. It should be kept separate and managed differently from existing programs so that it can develop its own culture and establish its own methods of operation.

IMPLEMENTATION: The competitive, fundamental, extramural research program (AFRI) was placed with formula-funded research programs in NIFA. NIFA is not independent in USDA. The NIFA director reports to the Undersecretary of REE, who administers the Agricultural Research Service (ARS), the Economic Research Service (ERS), the National Agricultural Statistics Service (NASS), and NIFA.

ronment. The ownership of fundamental science associated with food and agriculture; its translation, extension, and dissemination; and the training of scientists by AFRI fit into that model.

Scope of the AFRI Program

AFRI encompasses some elements of the NRI, the competitive funding component of the Fund for Rural America, and IFAFS (Table 3-2). The six priority areas to be addressed by AFRI, as specified in the 2008 Farm Bill, are similar to the NRI's priority areas. They are

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

PROGRAM MISSION

PROPOSAL: The mission of the competitive grants program should be to supplement and enhance, not replace, the existing research programs of USDA.

IMPLEMENTATION: AFRI replaces the NRI and has a broader scope than the NRI (see Chapter 1).

BUDGET

PROPOSAL: The annual budget of the competitive grants program should build to $1 billion over a 5-year period.

IMPLEMENTATION: AFRI's budget from 2008 to 2012 ranged from $202 million to $264 million.

EXTERNAL ADVICE

PROPOSAL: Mechanisms should be put into place to ensure that the science funded by the competitive grants program is of the highest scientific caliber and relevant to national needs and priorities. The mechanisms should include

— Committees of scientists who apply rigorous scientific merit review to all proposals.

— A standing council of advisers to ensure the relevance and importance of the science that the competitive grants program funds.

IMPLEMENTATION: Although AFRI applies scientific merit review to all proposals, it does not have an advisory council that serves as an interface between scientists and stakeholders and helps AFRI to link national priorities with realistic scientific opportunities (see Chapter 4 for detailed discussion).

Program Areas

In its first year of operation, AFRI supported research, extension, and education in the six priority areas designated in the 2008 Farm Bill. In its second year, the approach to funding was restructured so that grant funding would be under two programs: either the foundational program or the challenge-area program. Each of these programs would delineate topic areas for investigation.

The foundational program supports research or integrated projects that contribute to knowledge that is critical for meeting current and future challenges in agriculture. Like the NRI, the AFRI foundational program is investigator-driven, and its program areas correspond with the six priority areas in the Farm Bill.

The challenge-area program, as its name implies, is more mission oriented and directs grants toward societal challenges "to discover solutions to major societal problems" in four areas—food, environment, energy, and health (USDA-NIFA, 2012). The approach was formulated after release of

TABLE 3-2 Characteristics of Competitive Grants Programs in USDA

	CRGO	NRI
Charge	Supporting fundamental research in food and agriculture	Funding research, education, and extension activities to address key problems of national and regional importance in biological, environmental, physical, and social sciences relevant to agriculture, food, the environment, and communities on a peer-reviewed, competitive basis
Program areas	• Plant sciences • Pest science • Animal sciences • Biotechnology • Human nutrition • Wood science and forest biology	• Plant systems • Animal systems • Nutrition, food quality, and health • Natural resources and the environment • Engineering, products, and processes • Markets, trade, and policy
Years in operation	1977–1990	1991–2008
Number of awards per year	193–455	298–832

Fund for Rural America	IFAFS	AFRI
Program partly for funding competitive research to develop knowledge-based solutions for rural economic development	Funding research, extension, and education to address a number of critical emerging agricultural issues related to food production, environmental quality, natural-resource management, and farm income	Funding research, education, and extension grants and integrated research, extension, and education grants that address key problems of national, regional, and multistate importance in sustaining all components of agriculture, including farm efficiency and profitability, ranching, renewable energy, forestry (both urban and agroforestry), aquaculture, rural communities and entrepreneurship, human nutrition, food safety, biotechnology, and conventional breeding
• Increasing international competitiveness, efficiency, and farm profitability • Reducing economic and health risks • Conserving and enhancing natural resources • Developing new crops, new crop uses, and new agricultural applications of biotechnology • Enhancing animal agricultural resources • Preserving plant and animal germplasm • Increasing economic opportunities in farming and rural communities • Expanding locally owned value-added processing	• Agricultural genome • Food safety, food technology, and human nutrition • New and alternative uses and production of agricultural commodities and products • Agricultural biotechnology • Natural-resource management, including precision agriculture • Farm efficiency and profitability, including the viability and competitiveness of small- and medium-size dairy, livestock, crop, and other commodity operations	• Plant health and production and plant products • Animal health and production and animal products • Food safety, nutrition, and health • Renewable energy, natural resources, and environment • Agriculture systems and technology • Agriculture economics and rural communities
1997–2002	1999–2002	2009 to present
		254–470

continued

TABLE 3-2 Continued

	CRGO	NRI
Amount authorized	$25–70 million	$150–500 million
Amount appropriated	$15–49 million	$73–215 million
Number of requests for applications (RFAs) per year		1 RFA
Fellowship programs		Postdoctoral fellowships integrated into all program areas and compete against other projects
Grant function	Single-function research	Single-function research and integrated projects[a]
Research solicitation	Investigator-initiated	Investigator-initiated

SOURCES: P.L. 95-113, 101-624, 104-127, 107-172, and 110-234; USDA Current Research Information System; InSTePP (2013).

the National Research Council report *A New Biology for the 21st Century* (referred to hereafter as the *New Biology* report; NRC, 2009). That report concluded that biological research had experienced many scientific and technological advances. The reintegration of subdisciplines in biology and the collaboration between biologists and scientists and engineers in other disciplines purposefully organized to address specific societal challenges could result in significant advances, perhaps in unexpected directions. Another National Research Council report, *Toward Sustainable Agricultural Systems in the 21st Century,* discussed the added value of an integrative, distinct, interdisciplinary approach to research in agriculture (NRC, 2010). It stated that "a holistic systems approach to research and development could identify opportunities for synergies and efficiencies that traditional disciplinary [sic] or production-focused research might miss" (NRC, 2010, p. 527).

Fund for Rural America	IFAFS	AFRI
$100 million	$120 million	$700 million
$80 million	$120 million	$171–233 million (awarded)
		1 foundational RFA, 1 fellowship RFA, and 5 challenge-area RFAs
		Predoctoral and postdoctoral fellowships solicited in a single RFA and compete against other fellowships only
National, regional, or multistate program oriented primarily toward extension programs and education programs demonstrating and supporting the competitiveness of U.S. agriculture	Priority to multistate, multi-institutional, or multidisciplinary or proposals that integrate at least two of the three aspects of research, extension, and education	Single-function research, education, or extension; and integrated projects
Outcome-driven		Outcome-driven and investigator-initiated

According to the *New Biology* report, there are four goals within which an integrative approach could make a substantial contribution:

- "Developing plants that could be sustainably produced for food in changing environments."
- "Understanding and maintaining ecosystem function and biodiversity under rapidly changing conditions."
- "Developing sustainable sources of bioenergy and biofuel as an alternative to fossil fuels."
- "Understanding individual health."

NIFA integrated the four goals from the *New Biology* report and six priority areas from the 2008 Farm Bill, and transformed them into the following five challenge areas in AFRI's requests for proposals (USDA-NIFA, 2010):

- Childhood-obesity prevention.
- Climate change.
- Global food security.
- Food safety.
- Sustainable bioenergy.

Each of the areas addresses a challenge at the systems level and is related to at least one priority area in the 2008 Farm Bill (USDA-NIFA, 2013b). For example, childhood-obesity prevention is related to nutrition and health, climate variability affects plant and animal production, global food security is closely tied to plant and animal health and production, and sustainable bioenergy is related to production and markets for biomass production for renewable energy. The challenge-area program aims to accelerate problem-solving in some focused areas by facilitating multidisciplinary research and integration of research, education, and extension.

In addition to the foundational program's request for application (RFA) and the five challenge-area RFAs, AFRI promoted a NIFA fellowship program RFA for the first time in 2010. The program offers predoctoral and postdoctoral fellowships.

Grant Types

Under the two program areas (foundational and challenge-area), there are five types of grants:

- Standard project grant.
- Coordinated agricultural project (CAP) grant.
- Planning and coordination grant.
- Conference grant.
- Food and agricultural science enhancement (FASE) grant.

The standard project grant and conference grant are the same as those in the NRI. The NRI funded CAPs but awarded fewer CAPs and awarded them over a shorter duration than AFRI. The FASE grants are similar to the NRI's enhancement award. AFRI responds to sections of the 2008 Farm Bill (Appendix C) by providing such strengthening grants as sabbatical grants, equipment grants, and seed grants and fellowships to outstanding predoctoral and postdoctoral candidates. The strengthening grants of the NRI and AFRI are limited to small and middle-size or minority-serving degree-granting institutions that previously had limited institutional success in receiving federal funds. In accordance with the 2008 Farm Bill, AFRI also provides strengthening grants to State Agricultural Experiment Stations (SAESs) or degree-granting institutions that are eligible for USDA Experimental Program for Stimulating Competitive Research (EPSCoR) funding and are eligible for reserved strengthening funds for research, education, extension, and integrated project grants. Each year, NIFA determines the states that are eligible for EPSCoR funding on the basis of their funding levels. The EPSCoR states have a funding level no higher than the 38th percentile of all states on the basis of a 3-year rolling average of AFRI, excluding FASE strengthening grants given to EPSCoR states and to small, middle-size, and minority-serving degree-granting institutions.

Projects funded within each grant type could be categorized as single-function research, single-function education, single-function extension, or integrated. Integrated projects would address a least two of the three functions. (See Appendix F for the different grant types and project functions funded in each program from 2009 to 2013.)

NIFA partners with other federal agencies for other programs that are announced in separate RFAs. Such partnerships have included research in biomedicine and agriculture using domestic animals jointly with NIH, plant genomics for bioenergy with the Department of Energy (DOE), and water sustainability and climate change with the National Science Foundation (NSF). Each of the partnerships is unique and is conducted through ad hoc grants-management arrangements. The agency partnerships offer a way for NIFA and USDA in general to use the AFRI program to leverage their interests with other resources.

Funding Over Time

Although the 2008 Farm Bill authorized $700 million to be appropriated for each of the fiscal years 2008–2012 to carry out AFRI's sponsored programs, appropriated funding has not reached that level since AFRI's inception (Figure 3-2). The total awards made each year have varied from about $171 million to about $233 million. Although the total amounts awarded by AFRI were similar or slightly higher than those awarded by the NRI (Figure 3-2), AFRI's mandate includes some elements of IFAFS and Fund for Rural America programs and has a broader scope than the NRI's (Table 3-2). Despite the broader scope, AFRI has made fewer and larger awards annually than the NRI did (Figure 3-3). The number of proposals submitted and the number of awards made have been declining since 2003 (Figure 3-3).

Although AFRI's research mandate is broader than those of the CRGO and the NRI, AFRI's appropriated budget has not been commensurate with its expanded mandate. The program budget grew from $14.5 million when CRGO was formed in 1979 to $73 million when CRGO was replaced by NRI in 1991 and has grown to $190 million since the NRI was replaced by AFRI. However, the numbers of proposals submitted and awards made

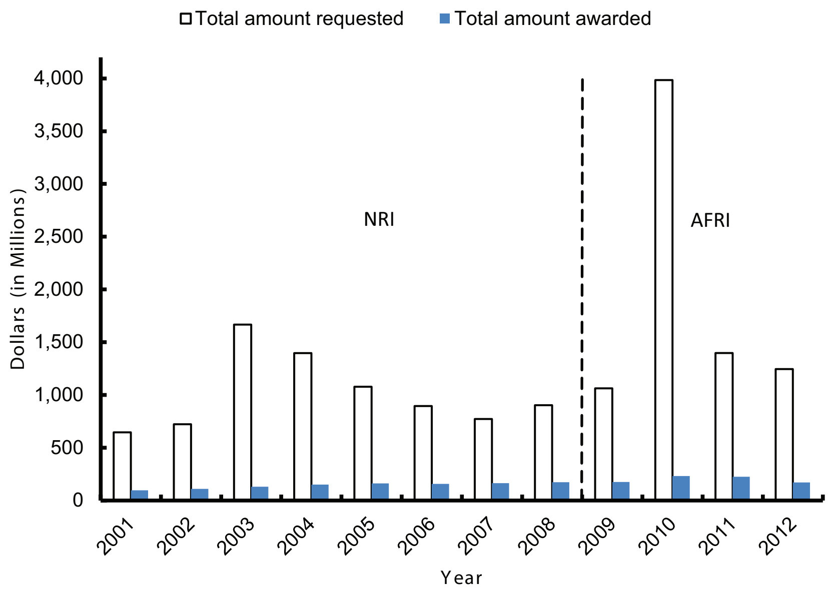

FIGURE 3-2 Total amounts requested from investigators and awarded by the NRI and AFRI, in nominal (inflation-unadjusted) terms.
SOURCES: USDA-CSREES, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008; USDA-NIFA, 2009a, 2011.

have decreased in the last 10–12 years (see Figures 3-3 and 3-4). Moreover, although the nominal amount of funding grew by an average of 8.7% per year from 1980 to 2007, after adjustment for the increased cost of agricultural R&D it grew annually in real terms by only 4.2% per year over the period.

ROLE OF COMPETITIVE U.S. DEPARTMENT OF AGRICULTURE GRANTS FOR RESEARCH, EDUCATION, AND EXTENSION

In reviewing the various reports from 2004 to 2013 that described grand challenges in food and agriculture (USDA-REE Task Force, 2004; APLU, 2006; NRC, 2009; CAST, 2010; PCAST, 2012; GAO, 2013), the committee noted that the reports took for granted the appropriateness for one specific agency to take the lead in agriculture and food for fundamental, translational, and application science as well as extension or outreach and educational training of future scientists and leaders in academe, industry, and rural communities. USDA is the only agency that has the express

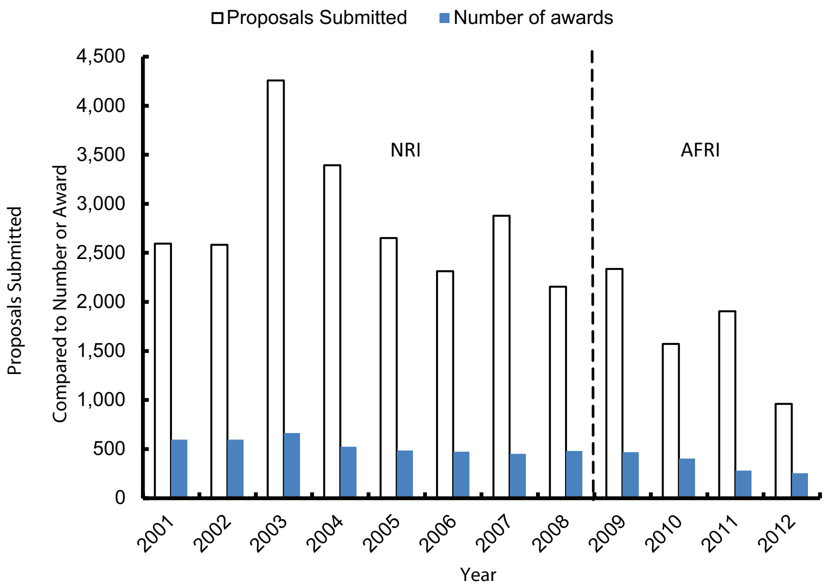

FIGURE 3-3 Numbers of proposals submitted to and awards made by the NRI and AFRI.
SOURCES: USDA-CSREES, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008; USDA-NIFA, 2009a, 2011.

mission in agriculture, food, and natural resources, and goals to conduct research (from fundamental science to practical application), outreach, and training to meet that mission. Under the leadership of the Undersecretary for Research, Education, and Economics (REE), NIFA funds extramural research, extension, and education, and ARS conducts intramural research.[5]

The competitive grant is the predominant form of public-sector research support in many health and basic science and engineering grants programs[6] where the application of research results is not constrained by geographic factors. Historically, competitive grants have been less common for agricultural research in the United States and in other countries. Public-sector agricultural research has often been geographically specific for agronomic or other reasons, and this may account for the development of funding and priority-setting processes that are responsive to various

[5]Other agencies that report to the Undersecretary for REE are ERS and NASS. ERS conducts intramural research on economics and social science, and NASS focuses on agricultural statistics.

[6]For example, NIH allocated 85% of its 2013 R&D funds competitively, and NSF, 100%.

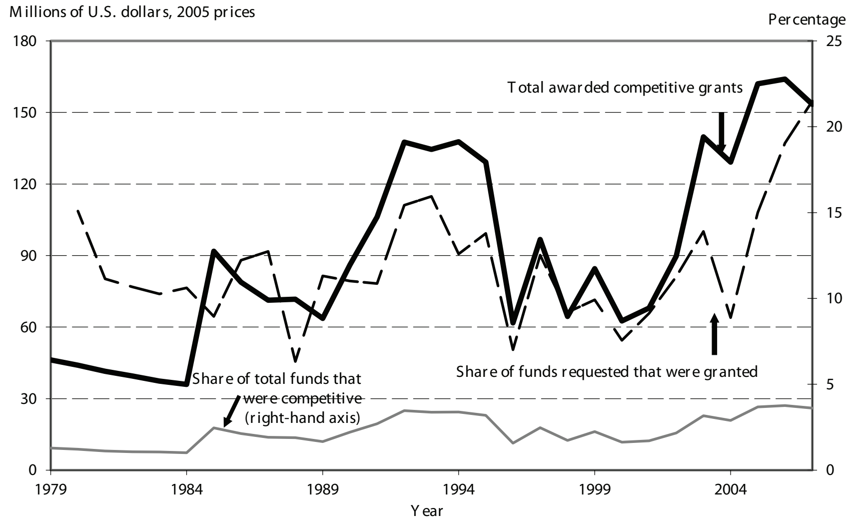

FIGURE 3-4 Competitive funding for U.S. agricultural research, 1979–2007. Note: Total awarded competitive grants were adjusted to 2005 prices by the using agricultural R&D price deflator developed by InSTePP (2013). SOURCE: InSTePP (2013) compilation based on unpublished USDA files.

locational and economic conditions and concerns rather than to strictly scientific problem-based research foci (Schultz, 1971; NRC, 1994; Shields, 2012). While the locational and geographic constraints on applications of agricultural research still exist, much of the fundamental research that underpins today's scientific advances in food and agriculture is not so constrained. Modern, successful plant genetics and breeding programs, for example, integrate molecular techniques with classical breeding methodologies. While the classical breeding and phenotypic evaluations may be location constrained, the underlying advances in the molecular research is not so constrained and is especially well suited to competitive funding processes where the funding decisions are based solely on the project's likelihood of yielding the greatest scientific knowledge.

The competitive grant is an appropriate mechanism for revealing and funding new research opportunities that add to the pool of basic and applied knowledge and that strengthen disciplines, generate broadly applicable technologies (including those with applications across geographic boundaries, e.g., across states), and effectively address national and regional priorities. The advantages of competitive grants include (NRC, 1989, 1994, 2000; USDA-REE Task Force, 2004)

- Flexibility in changing the focus of a research program on the basis of scientific opportunities and societal priorities.
- The potential to attract the best talent through open competition.
- Selection of the best among diverse ideas and approaches proposed.
- Through professional and peer review, potential to ensure that research resources flow in the directions that have the greatest expected payoff.
- The capacity to balance and complement other research resources and programs.

Possible disadvantages include (Azoulay et al., 2011; Ness, 2012)

- Conducting requests for proposals and peer review is time-consuming and expensive.
- The competitive process for awarding grants adds an element of uncertainty compared with other types of funding arrangements.
- The short duration of grant cycles (up to 5 years) does not provide support for research and related activities that require long-term effort, perhaps for decades.
- It may be inappropriate to have competitive funding of SAES research that is supported primarily by core formula and state funding.
- The peer-review system might discourage risky research.

Agencies have developed different ways to optimize the competitive grants mechanism for supporting extramural, investigator-initiated research. NSF focuses on basic research, which it defines as "systematic study toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind" (NSF, 2014). Given NSF's focus, the advantages of the competitive process make it an appropriate grant-making mechanism for that agency. NSF also supports grants for long-term projects, such as observing systems[7] and Long-Term Ecological Research.[8] NIH conducts intramural and extramural programs of research. The extramural program takes advantage of investigator-driven research to continuously encourage innovations and expand the knowledge base in biomedical sciences. The intramural program conducts basic, translational, and clinical research and provides opportunities for long-term and high-impact research that are less likely to be funded via a competitive mechanism.

Similar to NIH, USDA also has intramural (ARS) and extramural

[7]See, for example, http://oceanobservatories.org/ and http://www.neoninc.org/.
[8]See, for example, http://www.lternet.edu/.

(NIFA) programs. NIFA's flagship competitive grants program[9] is AFRI. Both ARS and NIFA support research along the fundamental-to-applied spectrum in part because fundamental research and applied research are on a continuum in which there is not always a clear distinction between the two types. As is the case with NIH intramural programs, ARS supports long-term and high-risk projects that are not amenable to competitive grant cycles. They include support of long-term agricultural research sites,[10] animal and plant germplasm repositories, facilities for sequencing relevant pathogens (such as avian influenza[11]), and critical community data resources (such as Gramene: A Resource for Comparative Grass Genomics[12] and the Maize Genetics and Genomics Database[13]). The intramural research program also conducts research to support USDA's regulatory functions and is designed to mobilize resources more quickly than a competitive grant program to conduct research for emergency responses (e.g., responses to avian influenza).

In addition to competitive grants, NIFA provides support for research, extension, and education activities at land-grant and other cooperating institutions through grants to these institutions on the basis of a formula designated by legislation.[14] Formula grants provide support for capacity and infrastructure in each state through cooperative agreements with state experimental stations. The grants have multiple uses, including support for

- Experiment-station infrastructure.
- Scientist salaries that maintain subject-area capacity.
- Long-term maintenance research, such as research in plant breeding for insect and disease resistance.
- Local site-specific issues that demand rapid response.
- Startup funds for new researchers.
- Bridging funds between external grant support.
- The conduct of research and extension activities by experiment station–supported faculty and staff.

[9]In addition to AFRI, NIFA funds competitive grant programs for specific targets, for example, the Small Business Innovation Research Program and Specialty Crop Research Initiative.

[10]Available online: http://www.ars.usda.gov/Research/docs.htm?docid=21984. Accessed December 23, 2013.

[11]Available online: http://www.ars.usda.gov/is/pr/2008/080530.htm. Accessed December 23, 2013.

[12]Available online: http://www.gramene.org/. Accessed December 23, 2013.

[13]Available online: http://www.maizegdb.org/. Accessed December 23, 2013.

[14]Formula grants for food and agriculture were created under the Hatch Act of 1887, the Smith-Lever Act of 1914, the McIntire-Stennis Act of 1962, and the Evans-Allen Program under the National Agricultural Research, Extension, and Teaching Policy Act of 1977.

Once funds are disbursed to the SAESs, decisions on how to allocate them are made at the local level by directors of SAESs and Cooperative Extension Services, subject to the constraints identified in the federal acts by which the funds are made available (GAO, 2013). Because of the decentralized structure of formula grants, research stemming from formula grants tends to address issues in food and agriculture that are targeted to local or regional priorities.

Agriculture is a biological production process, so it is especially sensitive to local agroecological (e.g., soil, climate) realities. That gives rise to the requirement that at least some aspects of agricultural R&D be geographically oriented and thus provides a rationale for disbursing extramural USDA funds via formula grants and other means for research conducted at the state or regional level (NRC, 1994; Franz, 2007; Shields, 2012). Research funded by AFRI is not intended to compete with formula funding or with intramural research done within ARS, and the national program leaders of NIFA manage both AFRI and formula grants. Each funding mechanism is intended for different purposes. AFRI is intended to support competitively peer-reviewed science to address priorities in food and agriculture that are of national and multistate importance and to diversify institutions that participate in research, extension, and education beyond land-grant universities and experiment stations.

In 2013, the Government Accountability Office (GAO) was "asked to assess how [ARS and NIFA] ensure the efficient use of their resources for research" and concluded that there was little evidence of duplicative projects between external NIFA grants through AFRI and ARS (GAO, 2013). Although the research focus in NIFA and ARS had overlapping topical themes, each agency has developed safeguards that use the Current Research Information System (CRIS) to help to prevent funding duplicative projects. However, GAO noted opportunities for improvement in the comprehensiveness of the CRIS reported by ARS, the scope of CRIS reviews by NIFA (AFRI is within the scope, but other NIFA programs are not), and the user friendliness of CRIS. USDA is incorporating the VIVO[15] system to improve its data management and contribute to Science and Technology for America's Reinvestment: Measuring the Effect of Research on Innovation, Competitiveness and Science (STAR METRICS; NIH, 2013).

[15] "An open source semantic web platform that enables the discovery of research and scholarship across disciplinary and administrative boundaries through interlinked profiles of people and other research-related information" (Börner et al., 2012).

OTHER AGENCIES' COMPETITIVE GRANTS PROGRAMS RELATED TO AGRICULTURE

Other agencies fund some competitive research relevant to food and agriculture, but to the extent to which these programs overlap, the research that they fund appears complementary rather than duplicative and inappropriate (Table 3-3). In areas relevant to agriculture, NSF supports basic research in plant and animal sciences, engineering, and education (NSF, 2011). In addition to core programs in the Directorate for Biological Sciences, specific programs such as Basic Research to Enable Agricultural Development (BREAD), Surpassing Evolution: Transformative Approaches to Enhance the Efficiency of Photosynthesis, and Nitrogen: Improving on Nature (NITROGEN), support fundamental research in support of global food production. NSF has played a key leadership role in the multiagency Plant Genome Research Program that was initiated in 1998 as part of the National Plant Genome Initiative.

Some of the core NIH extramural funding programs in nutrition, obesity, and genetics in humans and animal models may fund projects conducted by agricultural researchers addressing important issues relevant to food and agriculture, but the mission focus of the agency is human health (NIH, 2011). For example, NIH supports research on poultry, but the focus is on poultry's role as model organisms for biomedical research. Fundamental knowledge gleaned from research supported by the Ecology and Evolution of Infectious Diseases Initiative, cosponsored by NIH and NSF, may have relevance to infectious disease in agricultural animals.

Given its interest in supporting research in alternative and renewable sources of energy, it is not surprising that DOE has supported research in bioenergy, plant feedstock, biomass genomics, related technologies, and relevant ecosystems (DOE, 2013a,b). Since 2006, DOE and USDA have worked together to support fundamental research that would lead to large quantities of high-quality biomass, most recently through the joint Biomass Research and Development Initiative (BRDi, 2013). DOE focuses on the technologies for conversion of biomass to fuels and on characteristics of biomass that could enhance conversion. USDA supports research on increasing the on-farm productivity of biomass intended for energy uses.

The mission of the U.S. Environmental Protection Agency (EPA) is to protect human health and the environment (AAAS, 2013). EPA is actively engaged in funding research conducted at the SAESs related to the regulation of bioengineered crops and agricultural chemicals and issues concerning resistance management in crops. There has been collaboration between the USDA and EPA in the area of nanotechnology grants with a significant focus on the environment.

The National Aeronautics and Space Administration (NASA) has supported research on the agricultural impact of natural and human-induced changes in the water and energy cycle, the effects of agriculture on the carbon cycle, and agricultural land-use and land-cover changes. Extramural research topics relevant to agriculture include earth science research, land-cover and land-use changes, and carbon cycle and ecosystems (NASA, 2013).

Of all the federal agency grants programs, AFRI is the only one that focuses exclusively on food and agriculture and its components, including agricultural plant and animal systems; human nutrition; such natural resources as aquaculture and forestry; environmental issues associated with agricultural ecosystems and engineering associated with these topics; rural economies, markets, trade, and policy; and families, youth, and communities. The Council for Agricultural Science and Technology report notes that USDA expends about $3.1 billion on intramural and extramural research, whereas the other federal agencies spend only about $700 million on agricultural, food, and natural-resource R&D; and that competitive grants from AFRI have a focus on the mission of the food system (CAST, 2010). Thus, it is likely that much investigator-driven research directly relevant to the high-priority topics of national interest in food and agriculture would be missing if AFRI did not exist. Furthermore, integration of research with extension and education is found only in AFRI and USDA.

The 2009 *New Biology* report recognized a major point of inflection in biological research. It called for more collaboration among agencies because integration among biology disciplines and with other science and engineering disciplines would permit a deeper understanding of biology and would lead to new insights through that tackling of issues from different disciplinary perspectives (NRC, 2009). Achieving such integration requires "deep knowledge in one discipline and basic 'fluency' in several" (NRC, 2009, p. 20); this concept parallels the strengths of agricultural scientists. For example, plant scientists that specialize in plant breeding need to be familiar with plant diseases, insect pests, soil microbiology, agronomy, and the food attributes of plants. The ecosystem model of agricultural production requires depths of strength and diversity of scientific connectivity and an appropriate agency to support them.

The report also noted that "solving practical problems will require, and in turn lead to, advances in fundamental understanding" (NRC, 2009, p. 15). That parallels the value of an organizational unit responsible for all elements of the R&D process from problem identification to fundamental research. Such breadth of scope promotes an increased understanding of the underlying principles, which enables these to be translated into applications or practices for farmers, growers, and ranchers who implement the applications and practices, and also provides an opportunity for researchers to receive feedback. The pace at which discoveries are made and the application of practical solutions in agricultural fields could be expected to

TABLE 3-3 Federal Agencies That Support Extramural Research Programs Relevant to Agriculture[a]

Agency	Mission Statement[b]	Examples of Areas Relevant to Agriculture	Examples of Extramural Research Programs Relevant to Agriculture	Examples of Interagency Programs with AFRI[c]
USDA	To provide leadership on food, agriculture, natural resources, rural development, nutrition, and related issues based on sound public policy, the best available science, and efficient management[b]			
NSF	To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes (NSF Act of 1950, P.L. 81-507)[a]	Fundamental plant and animal science, agricultural engineering, education, and social science	• Core programs in the Directorate for Biological Sciences • Plant Genome Research Program • Basic Research to Enable Agricultural Development (BREAD) program & BREAD Ideas Challenge • Surpassing Evolution: Transformative Approaches to Enhance the Efficiency of Photosynthesis • Nitrogen: Improving on Nature (NITROGEN)	• Plant Genome Research Program; other agency partners include USDA-ARS, USFS, DOE, NIH, EPA, USAID, DOI, and the Smithsonian Institution • National Robotics Initiative; other partner agencies are NASA and NIH • Water sustainability and climate

NIH	To seek fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to enhance health, lengthen life, and reduce the burdens of illness and disability	Nutrition and human health and animal health	• Core programs in nutrition and obesity research • Core programs in research on animal models, resources, genetics, and health	• Ecology and Evolution of Infectious Diseases; other partner agencies are NSF and Biotechnology and Biological Sciences Research Council of the United Kingdom
DOE	To ensure America's security and prosperity by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions[c]	Bioenergy, renewable energy, and energy efficiency	• Bioenergy research centers (DOE, 2013a)	• Plant Feedstock Genomics for Bioenergy
EPA	To protect human health and the environment	Impact of agriculture on natural resources and the environment	• Nanotechnology	• None

continued

TABLE 3-3 Continued

Agency	Mission Statement[b]	Examples of Areas Relevant to Agriculture	Examples of Extramural Research Programs Relevant to Agriculture	Examples of Interagency Programs with AFRI[c]
NASA	• Aeronautics: to solve the challenges that still exist in our nation's air transportation system: air traffic congestion, safety, and environmental impacts • Human Exploration and Operations: to operate the International Space Station operations, develop commercial spaceflight opportunities, and conduct human exploration beyond low Earth orbit • Science: to explore the Earth, solar system, and universe beyond; chart the best route of discovery; and reap the benefits of Earth and space exploration for society • Space Technology: to develop, demonstrate, and infuse revolutionary, high-payoff technologies that expand the boundaries of the aerospace enterprise	Agricultural impact of natural and human-induced changes in the water and energy cycle, effects of agriculture on carbon cycle, and agricultural land-use and land-cover changes	• Earth-science research • Land-cover and land-use changes • Carbon cycle and ecosystems (NASA, 2013)	• Carbon cycle science; other partner agency is NOAA

NOTES: Interagency programs can involve more than two agencies. Each program is listed under its lead agency. DOI = U.S. Department of the Interior; NOAA = National Oceanic and Atmospheric Administration; USAID = U.S. Agency for International Development; USFS = U.S. Forest Service.

[a]Several other agencies include minor amounts of funding in their portfolios for specific mission-focused research and outreach. They include the Department of Health and Human Services (Food and Drug Administration, Center for Veterinary Medicine, and Centers for Disease Control and Prevention), USAID (only international food and agricultural development), Department of Homeland Security (DHS), and Department of Defense (DoD). For example, DoD provides grant funding to extension programs focused on early childhood education for military families, and DHS funds work directly connected to biosecurity related to potential acts of terrorism or threat.

[b]SOURCES: USDA, 2010; NIH, 2011; NSF, 2011; DOE, 2013b; EPA, 2013.

[c]SOURCE: AAAS, 2013.

[d]SOURCE: USDA-NIFA, 2013a.

be drastically reduced without a program, such as AFRI, that works with stakeholders in prioritizing problems, solicits proposals for research to address challenges in agriculture, identifies the best approach among the multiples suggested by a diverse group of investigators from different types of institutions, and funds the research. A President's Council of Advisors on Science and Technology (PCAST) study (PCAST, 2012) argued for an innovation ecosystem and a rebalancing of funding to meet societal priorities. It recommended a major investment in NSF for basic science relevant to agriculture, but more important, it strongly supported the role of AFRI in responding to global food, water, and agricultural challenges. An example of NSF funding of basic research that would be beneficial to agriculture is its funding of photosynthesis research. Yet for such basic research to be translated and applied to plant crops requires a different emphasis that integrates fundamental research, translation, extension, and education of the next generation of scientists, which is central to AFRI. Collaboration and cooperation across agencies is a key message of the PCAST report.

Table 3-3 shows that there have been cooperative approaches among agencies at the nexus of their mission interests. The multiagency Plant Genome Research Program, the Biomass Research and Development Initiative cosponsored by USDA and DOE, and the interagency efforts between USDA and NIH to fund the sequencing of several major livestock genomes are examples of successful collaborative approaches. USDA continuously seeks opportunities for partnering with the other mission agencies whereby joint competitive grants programs can advance agricultural research (USDA-NIFA, 2013a). Such joint programs do not fund inappropriate duplicative work but rather complementary efforts that involve independent approaches or overall strategies to confirm, overturn, or extend particular research findings (IOM, 1991).

For various reasons, the private sector is unlikely to conduct research relevant to many of the challenges mentioned in Chapter 1 and covered more extensively in other reports (NRC, 1989, 2000, 2003; USDA-REE Task Force, 2004; PCAST, 2012). First, it often cannot recover its investment in public goods, such as clean air and water or reduction in soil erosion. Second, minor crops, alternative cropping systems, and diverse ecosystem modeling may constitute too small a market for profit making or be too complex to determine the pricing of improvements. Third, issues of domestic and international marketing, policies for trade, and community and rural development are not likely to have high priority in the private sector. Fourth, although some of the new knowledge arising from R&D investments in nutrition, diet, and health can yield substantial public-health benefits, it might be difficult for the private sector to reap sufficient benefits by way of new food or health-related products and processes.

CONCLUSIONS

Many independent reviews conducted since the 1970s have recognized the important role of a competitive grants program for funding research that addresses national priorities in agriculture and food. They have emphasized a serious mismatch between the resources allocated to the USDA competitive grants programs and the scope of issues that the funding mechanism is mandated to address. Recognizing the important role of research, extension, and education in addressing agriculture and food priorities, Congress established AFRI with an authorized annual budget of $700 million. The six priority areas outlined in the 2008 Farm Bill remain highly relevant to contemporary challenges facing agriculture. Despite the expansion of its scope relative to that of its predecessors (the NRI and CRGO), AFRI's appropriated budget has been about one-third of authorized levels since its inception. Compared with the NRI, there has been a modest increase in resources, yet AFRI has the more ambitious mandate of addressing agricultural issues through research, extension, and education while integrating multiple disciplines, and this has strained the program.

AFRI funds extramural research that complements ARS's intramural research, with the latter supporting long-term, high-risk or high-priority projects that are not amenable to short-term competitive grant cycles. The national scope of AFRI's projects also complements the local and regional scope and capacity-sustaining purpose of formula grants. If AFRI did not exist, other federal research funding agencies could not accomplish its missions, and it is highly unlikely that the private sector would fill the gap.

A comparison of agency mission statements (in Table 3-3) makes it clear that other agencies address some research relevant to agriculture, and cooperative and collaborative cross-agency efforts reduce the likelihood of wasteful duplication. AFRI uses interagency partnerships or joint calls for proposals with other federal agencies to leverage available resources and to ensure complementarity rather than duplication in research funded by partner agencies. The committee finds that such multiagency cooperation and collaboration are critical for leveraging the scientific community's multidisciplinarity and drawing in new scientists to solve foundational and more mission-oriented problems faced by the agricultural and food sectors. Development of formal interagency mechanisms that focus on challenges for food and agriculture within the greater bioeconomy would be appropriate for further leveraging and strategic coordination of the federal portfolio in this critically important sector of science and application. It is worth noting that different federal agencies are overseen by different congressional committees, and any broad strategy for leveraging and coordinating agencies' efforts in agricultural research would need support of those congressional committees.

Ultimately, AFRI's mission, the societal problems that it addresses, and the communities that it represents are not niches but fundamental elements of the U.S. and global economy. Without AFRI or its equivalent, there would be a major gap in the U.S. research, extension, and education portfolio. Past performance of the food and agricultural public sectors indicates that results of research, education, and extension supported by AFRI drive the bioeconomy forward, strengthen and enhance the food system, contribute to global economic development, and improve nutrition and the environment.

As previously mentioned, the committee's observations are based on the legislative and administrative language used in the inauguration and management of the research programs examined. Examining how well those legislatively prescribed goals in the funded topics have been realized would require project-level analysis that was beyond the committee's scope and resources, but such an examination would be highly desirable.

FINDINGS

Finding 3-1: Without the AFRI program or its equivalent, there would be a major gap in the U.S. research, extension, and education portfolio.

Finding 3-2: Even though the dollar amount for the AFRI program has remained constant, the number of proposals submitted and the number of awards made have declined.

Finding 3-3: Interagency leveraging of resources in agriculture and food could be more strategic, more robust, and better coordinated across federal agencies.

REFERENCES

AAAS (American Association for the Advancement of Science). 2013. Current Summary Table: AAAS Estimates of R&D in FY 2014 R&D by Agency. Available online at http://www.aaas.org/spp/rd/. Accessed April 29, 2013.

APLU (Association of Public Land-Grant Universities). 2006. Creating Research, Extension, and Teaching Excellence for the 21st Century. Available online at http://www.create-21.org/. Accessed August 12, 2013.

ASPB (American Society of Plant Biologists). 2013. Unleashing a Decade of Innovation in Plant Science—A Vision for 2015-2025. Rockville, MD: American Society of Plant Biologists.

Azoulay, P., J.S. Graff Zivin, and G. Manso. 2011. Incentives and Creativity: Evidence from the Academic Life Sciences. Available online at http://faculty.haas.berkeley.edu/manso/hhmi.pdf. Accessed August 28, 2013.

Börner, K., M. Conlon, J. Corson-Rikert, and Y. Ding. 2012. VIVO: A Semantic Approach to Scholarly Networking and Discovery. San Francisco, CA: Morgan and Claypool Publishing.

BRDi (Biomass Research and Development Initiative). 2013. Biomass Research and Development Initiative. Available online at http://www.biomassboard.gov/initiative/initiative.html. Accessed August 19, 2013.

CAST (Council for Agricutural Science and Technology). 2010. Agricultural Productivity Strategies for the Future: Addressing U.S. and Global Challenges. Ames, IA: Council for Agricultural Science and Technology.

DOE (U.S. Department of Energy). 2013a. DOE Bioenergy Research Centers. Available online at http://genomicscience.energy.gov/centers/. Accessed May 1, 2013.

———. 2013b. Mission. Available online at http://www.doe.gov/mission. Accessed April 28, 2013.

EPA (U.S. Environmental Protection Agency). 2013. About EPA. Available online at http://www2.epa.gov/aboutepa.

Franz, C. 2007. Functional plant products in veterinary medicine and animal nutrition. Planta Medica 73(9):799.

GAO (Government Accountability Office). 2013. Two USDA Agencies Can Enhance Safeguards Against Project Duplication and Strengthen Collaborative Planning. Washington, DC: Government Accountability Office.

IOM (Institute of Medicine). 1991. Research and Service Programs in the PHS: Challenges in Organization. Washington, DC: National Academy Press.

NASA (National Aeronautics and Space Administration). 2013. Research Opportunities in Space and Earth Sciences 2013. Table 3: Solicated research programs. Available online at http://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=345761/solicitationId=%7B01BFD3EE-87EF-FC55-1F52-EB37A9F139F0%7D/viewSolicitationDocument=1/Table%203%20ROSES13.html. Accessed May 1, 2013.

Ness, R. 2012. Innovation Generation. New York: Oxford University Press.

NIH (National Institutes of Health). 2011. Mission. Available online at http://www.nih.gov/about/mission.htm. Accessed April 29, 2013.

———. 2013. What is STAR METRICS? Available online at https://www.starmetrics.nih.gov/. Accessed August 19, 2013.

———. 2014. About NIH: NIH Budget. Available online at http://www.nih.gov/about/budget.htm (accessed July 31, 2014).

NRC (National Research Council). 1989. Investing in Research. A Proposal to Strengthen the Agricultural, Food, and Environmental System. Washington, DC: National Academy Press.

———. 1994. Investing in the National Research Initiative: An Update of the Competitive Grants Program of the U.S. Department of Agriculture. Washington, DC: National Academy Press.

———. 2000. National Research Initiative. A Vital Competitive Grants Program in Food, Fiber, and Natural-Resources Research. Washington, DC: National Academy Press.

———. 2003. Frontiers in Agricultural Research: Food, Health, Environment, and Communities. Washington, DC: The National Academies Press.

———. 2009. A New Biology for the 21st Century. Washington, DC: The National Academies Press.

———. 2010. Toward Sustainable Agricultural Systems in the 21st Century. Washington, DC: The National Academies Press.

NSF (National Science Foundation). 2011. Empowering the Nation Through Discovey and Innovation. NSF Strategic Plan for Fiscal Years (FY) 2011-2016. Arlington, VA: National Science Foundation.

———. 2014. Definitions of Research and Development: An Annotated Compilation of Official Sources. Available online at http://www.nsf.gov/statistics/randdef/fedgov.cfm#ombc. Accessed August 19, 2014.

OTA (Office of Technology Assessment). 1991. Federally Funded Research: Decisions for a Decade. Washington, DC: Office of Technology Assessment.

PCAST (President's Council of Advisors on Science and Technology). 2012. Report to the President on Agricultural Preparedness and the Agriculture Research Enterprise. Washington, DC: Executive Office of the President.

Schultz, T.W. 1971. The allocation of resources to research. In Resource Allocation in Agricultural Research, W.L. Fishel, ed. Minneapolis: University of Minnesota Press.

Shields, D.A. 2012. Agricultural Research, Education, and Extension: Issues and Background. Washington, DC.

USDA (U.S. Department of Agriculture). 2010. Strategic Plan. FY 2010-2015. Washington, DC: U.S. Department of Agriculture.

USDA-CSREES (U.S. Department of Agriculture, Cooperative State Research, Education, and Extension Service). 2001. NRI Annual Report: Fiscal Year 2001. National Research Initiative Competitive Grants Program. Washington, DC: U.S. Department of Agriculture.

———. 2002. National Research Initiative Competitive Grants Program Annual Report Fiscal Year 2002. Washington, DC: U.S. Department of Agriculture.

———. 2003. National Research Initiative Competitive Grants Program Annual Report Fiscal Year 2003. Washington, DC: U.S. Department of Agriculture.

———. 2004. National Research Initiative Competitive Grants Program Annual Report Fiscal Year 2004. Washington, DC: U.S. Department of Agriculture.

———. 2005. National Research Initiative Competitive Grants Program Annual Report Fiscal Year 2005. Washington, DC: U.S. Department of Agriculture.

———. 2006. National Research Initiative Competitive Grants Program Annual Report Fiscal Year 2006. Washington, DC: U.S. Department of Agriculture.

———. 2007. National Research Initiative Competitive Grants Program Annual Report Fiscal Year 2007. Washington, DC: U.S. Department of Agriculture.

———. 2008. NRI Annual Report Fiscal Year 2008. Washington, DC: U.S. Department of Agriculture.

USDA-NIFA (U.S. Department of Agriculture, National Institute of Food and Agriculture). 2001. USDA to Request Proposal for $9.5 Million Fund for Rural America. Available online at http://www.csrees.usda.gov/funding/nri/nri_about.html. Accessed August 9, 2013.

———. 2009a. AFRI. Agriculture and Food Research Initiative. 2009 Annual Synopsis. Washington, DC: U.S. Department of Agriculture.

———. 2009b. Program synopsis: National Research Initiative (NRI) competitive grants program. Available online at http://www.csrees.usda.gov/funding/nri/nri_about.html. Accessed April 17, 2013.

———. 2010. NIFA director Roger Beachy hosted webcast to discuss the Agriculture and Food Research Initiative. Available online at http://www.nifa.usda.gov/newsroom/webcast.html. Accessed May 6, 2013.

———. 2011. AFRI. Agriculture and Food Research Initiative. 2010 Annual Synopsis. Washington, DC: U.S. Department of Agriculture.

———. 2012. Program synopsis: Agriculture and Food Research Initiative (AFRI) competitive grants program. Available online at http://www.nifa.usda.gov/funding/afri/afri_synopsis.html. Accessed April 18, 2013.

———. 2013a. Agriculture and Food Research Initiative (AFRI) Interagency Programs. Available online at http://www.csrees.usda.gov/funding/afri/afri_interagency_programs.html. Accessed May1, 2013.

———. 2013b. Analysis of AFRI in Relation to the 2008 Farm Bill Priority Areas. Washington, DC: U.S. Department of Agriculture.

USDA-REE Task Force (The Research, Education and Economics Task Force of the U. S. Department of Agriculture). 2004. National Institute for Food and Agriculture: A Proposal. Washington, DC: U.S. Department of Agriculture.

White House. 2012. National Bioeconomy Blueprint. Washington, DC: The White House.

4

A Quantitative Assessment of Project Input-Output Relationships in the Agriculture and Food Research Initiative

The ultimate value of research, extension, and education activities is best assessed in terms of important outcomes such as technical improvements, productivity growth, material and social welfare, and individual and population health. Those outcomes are sensitive to program policy and design, including the mix of activities—fundamental or transformative[1] research, applied or translational research,[2] training, product development, and societal implementation of knowledge gained in service of desired outcomes. In particular, one can ask whether the U.S. Department of Agriculture (USDA) Agriculture and Food Research Initiative (AFRI)'s fundamental (knowledge or discovery) projects achieve the following outcomes:

- Support new research that would not otherwise have been done.
- Address an important problem.
- Involve leading scientists.

[1]A transformative approach to research and extension would "apply a systems perspective to agricultural research to identify and understand the significance of the linkages between farming components and how their interconnectedness and interactions with the environment make systems robust and resilient over time." "Transformative changes include the development of new farming systems that represent a dramatic departure from the dominant systems of present-day American agriculture and capitalize on synergies and efficiencies associated with complex natural systems and broader social and economic forces using integrative approaches to research and extension at both the farm and landscape levels" (NRC, 2010, p. 2).

[2]*Translational research,* a term used in biomedical sciences, could also be applied to agriculture. There are two kinds of translation: the process of applying discoveries generated in the laboratory to the field, which leads to testing by producers, and the translation of research to enhance the adoption of best practices in the community.

- Serve as a catalyst for other research.
- Yield transformative insight.

Similarly, one could ask whether AFRI applied projects

- Direct financial support toward new products or activities that would not otherwise have been feasible.
- Address important problems.
- Involve key sectors of agriculture, food, or natural resources.
- Serve as a catalyst for other applied research.
- Yield a transformative product.

AFRI's short history does not allow a comprehensive outcome assessment, because product development, changes in program activities, and the overall societal consequences of fundamental or applied-cum-translational research typically take more than 5 years and could take decades to materialize (Alston et al., 1995). Therefore, the assessment in this chapter is confined to the more immediate task of assessing AFRI's effectiveness in terms of the relationships between AFRI program inputs (or costs) and such program outputs that can now be readily measured, including the number of publications produced, presentations delivered, and students and postdoctoral fellows trained. It is necessary, although not sufficient, to know those outputs if one is to assess the wider technical, economic, and social effects just listed. Such a study can be conducted only in the future when sufficient time has elapsed to permit observing and addressing the questions about outcomes listed above. Thus, early inferences related to AFRI's value are useful not just in their own right but in identifying relationships that merit careful continuing scrutiny.

CHANGES IN STATISTICAL PROFILES OF NATIONAL RESEARCH INITIATIVE AND AGRICULTURE AND FOOD RESEARCH INITIATIVE PROJECTS

It is useful first to examine how project-level sample means of important outputs and policies have changed, beginning with the late USDA National Research Initiative (NRI) period and proceeding through AFRI 2012.[3] This brief history of the National Institute of Food and Agriculture (NIFA) competitive grants program is divided into three phases:

[3]To conduct this exploratory analysis, we used a compilation of competitive grant-specific information for each of the years 2008–2012 supplied by USDA NIFA.

- The final year (2008) of the NRI program.
- AFRI's first 2 years (2009–2010).
- AFRI's second 2 years (2011–2012).

This last period (AFRI 2011–2012) marked the initiation of challenge-area grants, an important scaling-up of the Coordinated Agricultural Project (CAP) program, and corresponding changes in how project subject areas were categorized. It therefore merits attention separately from the period (AFRI 2009–2010) that characterized the transition from the NRI to the AFRI program.

Profiles of Average Projects

A complete profile of both means and standard deviations of all three phases can be found in Tables G-1 through G-3 in Appendix G. For the purposes of this discussion, we concentrate on selected variables that either have changed noticeably or are interesting because of their relative stability (Table 4-1).

A crucial development in 2011–2012 was the rise in average budget size—a near tripling from the $439,000 in 2009–2010 to $1,119,555 in 2011–2012. That dramatic increase was due to the increase in the number and size of CAP grants, especially those of $10 million or more. That rise led to a prominent positive skew in the distribution of award sizes, which distorted the mean's significance. An examination of median award sizes, which are much less sensitive to skew, confirms that point. In NRI 2008, the median budget ($375,000) was nearly as high as the mean ($391,850). In AFRI 2009–2010, the median remained at $375,000 even as the mean rose to $439,395. In AFRI 2011–2012, the median rose by only 29% to $484,000, but the mean nearly tripled to $1,197,980.

The increase in budget size was accompanied by a lengthening mean project duration, from NRI's 32 months to 42 months in AFRI 2009–2010 and 38 months in AFRI 2011–2012. There was also a steady rise from 2.9 to 4.3 in the mean number of principal investigators, reflecting an emphasis shift toward multi-institution, multidisciplinary projects. Turning to project composition, the mean percentage of a project that was basic research fell from 61.5% in NRI 2008 to 54.8% in AFRI 2011–2012; this was accompanied by rising extension or education components from 6.3% in NRI 2008 to 10.8% in AFRI 2011–2012.

Beyond project scale, there have been notable changes in project locus; "locus" being defined as the nature of the projects themselves, including subject area, type of performing institution, and rank of project director. The transition from NRI 2008 to AFRI 2009–2010 saw little change in the proportions of grants awarded by subject area (as defined by the foun-

TABLE 4-1 Profile of NRI (2008) and AFRI (2009–2012) Projects Showing Means of Selected Attributes

	2008 (NRI)	2009–2010 (AFRI)	2011–2012 (AFRI)
PROJECT SCALE			
Budget	$393,000	$439,000	$1,196,000
Project duration (months)	31.6	41.7	37.8
PROJECT SCOPE			
Project complexity			
Number of co-principal investigators	2.9	3.5	4.3
Project composition			
Basic research	61.5%	60.2%	54.9%
Applied research	32.3%	29.0%	33.5%
Extension or education	6.3%	10.8%	10.8%
PROJECT LOCUS			
Subject area			
Plants	31%	37%	12% (26%)[a]
Animals	21%	21%	11% (24%)
Food and nutrition	15%	15%	5% (11%)
Social sciences	7%	5%	8% (17%)
Bioproducts	5%	4%	7% (15%)
Ecosystems	21%	18%	3% (7%)
Type of performing institution			
Federal	5%	5%	4%
Private research	3%	3%	2%
Private university	4%	5%	6%
Public non–land-grant university	8%	10%	10%
Land-grant university	80%	77%	78%
Rank of project director			
Professor	48%	40%	32%
Associate professor	19%	18%	18%
Assistant professor	20%	29%	22%
Federal scientist or other	9%	5%	2%
Predoctorate or postdoctorate	4%	8%	26%
OTHER FACTORS			
Laboratory assistance			
Undergraduate full-time equivalent months	7.7	10.5	12.9
Graduate full-time equivalent months	18.3	25.0	34.0
Postdoctorate full-time equivalent months	13.1	11.8	19.4

[a]No attempt was made to map challenge-area program subject areas into those used by the foundational program. Hence, numbers in parentheses denote subject-area percentages in the foundational program only, which amounted to only 46% of projects funded in 2011–2012.

dational program). With the introduction of challenge-area grants, a new coding system was used in which predoctoral and postdoctoral fellowship and challenge-area subjects were distinguished from those in the foundational program. The challenge-area subject categories differed from those in the 2009–2010 foundation-grant coding system, and the committee did not attempt to map one into the other. Rather, two figures are shown in the 2011–2012 column of Table 4-1's subject-area percentages. The unparenthesized figure is the number of grants in that area divided by the total number of AFRI grants, including challenge-area and fellowship awards. The parenthesized figure is divided instead by the number of foundational AFRI grants only. The former thus sum to a number (0.46) less than 1.00 and give an unclear indication of subject emphasis. The latter are more useful in that regard, although limited to foundation grants. They show a marked decline between 2009–2011 and 2011–2012 in the proportions of awards going to plant science, ecosystems, and food and nutrition, and large boosts to the proportions going to social sciences and bioproducts. For instance, plant science received 37% of AFRI awards in 2009–2010 and only 26% in 2011–2012. At the same time, awards for bioproducts rose from 4% to 15%, and for ecosystems dropped from 18% to 7%.

Proportions of awards granted by performing-institution type changed little in the transition from NRI to AFRI. The great majority of projects (77–88%) were awarded to land-grant universities; no other institution type received more than 10% in a given period.

The distribution of awards by principal-investigator (PI) rank reveals a gradual decline in the percentages going to AFRI-supported professors (from 48% in NRI 2008 to 32% in AFRI 2011–2012) and to federal scientists and others (from 9% in NRI 2008 to 2% in AFRI 2011–2012). At the same time, because of the initiation of the Food and Agricultural Science Enhancement (FASE) program, the proportion of awards going to predoctorates and postdoctorates rose dramatically from 4% in NRI 2008 to an average of 26% for AFRI 2011–2012. The average number of undergraduate, graduate, and postdoctoral laboratory assistants per project rose steadily during that same interval.[4]

Profiles of the Average Dollar

Several components of the award profile change substantially when the allocations of the average dollar rather than the average project are examined. For example, comparisons of dollar allocations—that is, expenditure shares—in the three NRI and AFRI periods are shown in Figure 4-1. The

[4]As will be noted in Chapter 5, AFRI awards to pre- and postdoctorates fell from 33% to 13% between 2010 and 2011, suggesting a return to the lower rates of the previous 3 years.

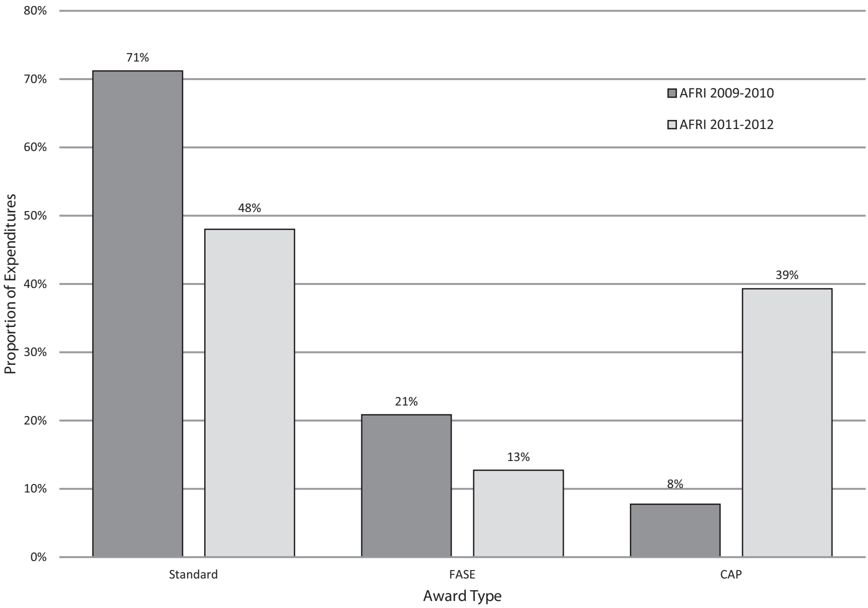

FIGURE 4-1 Share of program expenditures by award type.

expenditure percentages by award type shown in Figure 4-1 exclude NRI 2008 because there were no FASE grants under the NRI. Although the percentage of projects awarded as FASE grants rose from 29% to 39% between 2009–2010 and 2011–2012, Figure 4-1 shows that the proportion of AFRI expenditures going to FASE grants fell from 21% to 13%. Similarly, the proportion of expenditures going to standard grants fell from 71% to 48% even though the proportional number of awards fell only from 63% to 53%. The total funds awarded during the two periods rose by 14%, from $463.5 million in 2009–2010 to $530.5 million in 2011–2012 (see Table 3-1). Offsetting the decline in the amount of funding going to FASE and standard grants was a dramatic increase in the funds directed to CAP grants.

Although the share of projects awarded CAP grants rose only from 1% to 3% between AFRI 2009–2010 and AFRI 2011–2012, Figure 4-1 shows that the corresponding proportion of AFRI dollars going to CAP grants rose dramatically from 8% to 39% percent. The reason for the discrepancy is that the funds awarded to the average CAP grant were much larger than the average FASE or standard grant. In 2011–2012, for example, the mean CAP budget was $15,333,700 and supported nearly 20 co-investigators.

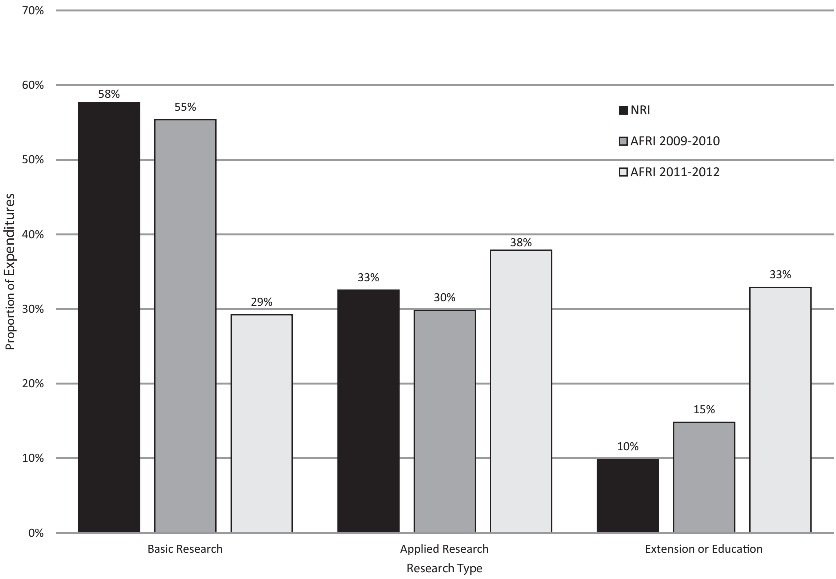

FIGURE 4-2 Share of program expenditures by type of research.

Figure 4-2 shows program expenditures by project composition or function. The proportion of AFRI money going to fundamental research changed little between the final NRI year and the first 2 years of the AFRI program (from 58% to 55%). It then plunged to 29% in AFRI's second 2 years. The proportion going to applied research rose from 30% in 2009–2010 to 38% in 2011–2012. However, most of the decline in funding for fundamental research between AFRI's first and second 2-year periods is explained by the rise from 15% to 33% in extension and education expenditures. The source of that abrupt change can also be attributed to the CAP grants, which tend to be far more extension- and education-oriented than other grants. Furthermore, even within the CAP grants, the proportion of money allocated to extension and education rose from 2009–2010 to 2011–2012. Some 33% of CAP resources awarded in 2009–2010 went to extension and education, whereas 47% of resources awarded in 2011–2012 went to these functions.[5]

[5]The CAP grants initiated in 2011–2012 were in the challenge-area programs. In contrast, the CAP grants initiated in 2009–2010 were awarded before the inauguration of the challenge-area programs.

CONSIDERATIONS FOR AN ANALYSIS OF PROGRAM PRODUCTIVITY

The main purpose of this chapter is to provide a preliminary assessment of the input–output relationship of AFRI grants in which research output is measured in terms of communication products such as publications and presentations. The analysis consists of estimating how AFRI policies affect the input–output relationships. Because AFRI selects the projects that it funds, its investment and management policies are evident in the characteristics of the funded projects. The policies are to be distinguished from such project-management issues as the request-for-application process (discussed under "Program Management" in Chapter 5) although policies and project-management issues overlap to some extent.

The robustness of these and any other regression estimates is highest when data on the horizontal (explanatory-variable) axis and vertical (dependent-variable) axis are distributed evenly throughout the ranges of interest. Successive re-estimation of our regression model with a number of alternative explanatory variables suggests that model robustness was moderately good. That said, the estimated input–output relationships are best deemed illustrative given, among other things, the truncated nature of the data with which the committee had to work. Zero outputs tend to bunch the data around the vertical (budget) axis, detracting from the even-data-distribution ideal. For brevity and clarity, detailed descriptions of methods and statistical results in this chapter are kept to a minimum; the focus instead is on the committee's principal findings. Additional tables and figures can be found in Appendix G.

Assessing Research Input-Output Relationships

The use of bibliometric indicators to assess quantitatively the relationship between research inputs and outputs has received some, albeit only modest, attention in a variety of disciplines and grants programs. Researchers have used various proxies as measures of knowledge output, including the number of papers that a scientist has published, the number of patents awarded, the number of citations to them in articles or other patents, and the status of the journal or patent that has granted a citation. Some of the early conceptual foundations of this approach are in Evenson and Kislev (1975), Jaffe (1986), Griliches (1990), and Adams (1990). The following represents only a sample of this literature.

Research outputs can be expressed either as an annual flow of information or as the accumulated stock of knowledge capital. One strand of the literature has used such flows or stocks to explain individual or institutional performance. The Evenson–Kislev and Adams studies, for example, demonstrate how changes in agricultural scientists' knowledge boost farm productivity performance. Zucker et al. (1998) show that biotechnology firms are drawn into areas geographically near "star" scientists—measured by the scientists' success in attracting literature citations. Buccola et al. (2009) and Nag et al. (2012) document how publication success attracts public and private research funds into a university biology laboratory.

Most of the bibliometric literature has focused on the knowledge-production function, namely, the determinants of knowledge output itself. In one of the earlier such studies, Pardey (1989) examined the effects of state agricultural research expenditures on agriculturally relevant scientific knowledge, using as a proxy the quality-adjusted publication output of a scientist sample. These expenditures have few short-run but substantial long-run knowledge benefits (Pardey, 1989).

In the same knowledge-production framework, Levin and Stephan (1991) showed evidence that academic scientists publish less as they age, presumably because as one ages a publication has progressively smaller implications for one's future career. Foltz et al. (2003) examined how an academic scientist's patent awards are influenced by university type, the presence on campus of a technology-transfer office, and dynamic factors. Carayol and Matt (2004) regressed publication and patent outputs on such laboratory inputs as technical assistants and on the principal investigator's characteristics. Azoulay et al. (2007) provided evidence that patent output is influenced by the "scientific opportunities" in a patent's field as much as by the scientist's skill or funding. Gulbrandsen and Smeby (2005) documented the role of industry funding in driving research toward more collaborative and translational research and toward higher publication rates; their results are consistent with the finding by Xia and Buccola (2005) that industry funding lifts patent-cited publication rates. Turner and Mairesse (2003) examined similar questions among French physicists.

Campbell et al. (2010) used bibliometrics to study competitive grant peer-review effectiveness and the ties between funding and scholarly performance. Fortin and Currie (2013) examined the relative impact, in terms of publication and citation rates, of funding a few large projects or a larger number of small projects. Cummings and Kiesler (2005) found multidisciplinary projects to be as productive as single-discipline projects, but multi-institution projects to be less productive than single-institution projects. Trochim et al. (2008) proposed concept and logic mapping with bibliometric and expenditure analysis to examine the productivity of large, federally funded scientific research initiatives.

In general, research output (however measured) can be considered relative to either the average dollar expended or the additional ("marginal") dollar invested. The average rate of knowledge production attributed to AFRI expenditures is the total amount of research output per dollar of (i.e., in proportion to) project budget expenditures (input). This is one measure of the productivity of AFRI investments. Alternatively, the marginal rate of knowledge production is the amount of additional output created by an additional expenditure dollar or additional unit of such project feature as duration. The principal focus in this chapter is on marginal response, although as will be seen, per-unit outputs are also a useful way of assessing research productivity.

An important category of policy questions concerns project scale—specifically, what is the implication of project size on research productivity? Budget is one dimension of project scale. Another is the number of months that principal investigators will be given to reach their objectives with the budget provided. And time itself is a resource: more of it provides greater opportunity to generate laboratory or field data and to adapt to unexpected study outcomes. But continuing support for too long may invite a scientist's other, newer projects and interests to interfere with AFRI-funded research.

Research productivity issues also arise regarding project locus: that is, the nature of the project attempted and the types of principal investigators and institutions that attempt it. Locus attributes include project subject area, scientific discipline, project composition or function (research, extension, or education), performing-institution type, and rank of the principal investigator. Programs such as microbial genomics or food safety, for example, may differ in the opportunities available for high-profile innovation. Decisions about how AFRI money will be allocated among subject areas and which categories of researchers and institutions will be chosen to conduct analyses therefore might affect AFRI's average return rates.

Conceptually distinct from a locus attribute, although often difficult to distinguish in practice, is project breadth or scope. One scope attribute is the variety of functions—research, extension, and education—to be combined in a single project. Single-function projects do little to coordinate research with extension effort. But they save on coordination cost by leaving the coordination function to the literature, to professional conferences, or other means. The scope of a project also has implications for the number and variety of institutions, disciplines, and principal investigators involved in a given study and in the variety of funding agencies other than AFRI that are supporting each investigator. Expanding a project's scope in the functional or institutional dimension likely affects the research input-output relationship, and thus, potentially, the productivity of AFRI-funded research. AFRI has, or should be able to obtain, all the information needed to evaluate each of the above factors empirically. The approach to the preliminary analysis described in this chapter is to use project-level data to specify and estimate AFRI budget functions. The results show the budgets granted at given output rates and project characteristics or, equivalently, the outputs generated by given project scale, locus, and scope attributes.

Research Output Metrics and Project Attributes

Variables used in the analysis, and their sample means and standard deviations, are shown in Tables G-1 to G-3 in Appendix G.

Research Output Metrics

Project-level metrics of research output used here are

(a) The number of refereed journal articles published by the participants in a specified AFRI project through July 2013, as indicated in the articles' acknowledgment footnotes.
(b) The per-article number of literature citations received by those articles up to July 2013.
(c) The number of nonrefereed communications—such as conference presentations, proceedings, posters, abstracts, theses, and working papers—that are produced up to the time of project termination and that the principal investigators attributed to the project.

Journal-article metrics (a) and (b) were not provided by NIFA but instead were drawn from Google Scholar queries. Metrics (a) and (c) can be regarded as indicators of the amount of research output, whereas metric (b) is in a sense a measure of the quality or communication intensity of the research. The early stages of many projects complicate the regression modeling of citation rates, and they are excluded from the budget-function analysis. However, the citation rates were examined graphically.

Project Scale

The first and primary scale factor is the total funds provided per project. The questions to be addressed are how much output—that is, how many refereed and nonrefereed articles and presentations—AFRI produces per dollar invested and how many additional articles are published when progressively larger project budgets are provided. The latter is estimated as the slope of the relationship between the project budget and the number of scholarly publications attributed to that project. Project duration (years between project start date and end date) is an additional scale factor that needs to be included with budget size. If the coefficient of the duration variable is negative after controlling for the overall size of the project budget, project duration is deemed excessive in that reducing the length of the project would have increased the number of articles without additional cost. Likewise, project duration would be deemed too short if the coefficient is positive.

Project Locus

Project locus variables are ones that influence the nature of the funded research and those who conduct it. They include

- Research subject area.
- Type of performing institution.
- Project director's rank.
- Type of award.

When project scale and scope (see below) are controlled for, locus factors likely have their own bearing on expected research output. Refereed journal articles are generated or cited more abundantly in some agricultural research fields than they are in others, and AFRI researchers may intrinsically appear more productive (when research output is denominated in terms of the number of publications) in some fields than in others.

In terms of generating published (or more cited) outputs, some types of institutions, and project directors at some ranks, may be more successful than others. Challenge-area grants are relatively topical, suggesting that citations to their scientific articles might come more quickly but fall off more rapidly than those from more fundamental projects. The relative success of FASE and standard-grant projects in a given scale, scope, and subject-area category is difficult to assess in the absence of empirical analysis. Because CAP-grant indicators are listed in the NIFA data alongside the FASE-grant and standard-grant indicators, they were included in the set of project attributes considered in this chapter's analysis.

Project Scope

NIFA has spent considerable time in thinking about the appropriate scope or variety of performing institutions, principal investigators, and research discovery and communication functions to include in a single project. One of its principal moves on replacing the NRI with AFRI was to put greater emphasis on projects with broader scope. The new orientation is expressed partly in the CAP grants, in which the breadth of project activities is particularly large. But many interinstitutional and interfunctional activities are also present in standard projects as well as in CAP projects.

To indicate a project's scope, the following parameters were specified:

- The number of co-PIs cooperating in the project and hence, presumably, the variety of the human capital brought to bear on the research problem.

- The presence of current non-AFRI support for the PIs and thus interagency cooperation in funding a PI's overall work.
- The proportions of research, extension, and education involved in the project—the more even the proportions, the broader the functional scope.
- The proportional mix of basic versus applied work in research projects.
- Whether the project is supported by a CAP grant.

These specific parameters each reflect a different scope dimension although they are partly redundant in that, for example, the average CAP grant involves more co-PIs, functions, and performing agencies than does the average standard grant.

To evaluate the association between project scope and productivity, the committee assessed how peer-reviewed and non–peer-reviewed communications were affected when project scope was expanded, while budget size was held fixed. In addition, the committee examined how project scope affects the consequences of budget's size on the measured publication performance of a project. This was achieved by estimating regression interaction terms between the relevant scope and output variables. In any event, although greater scope normally involves greater cost and thus greater project scale, scope and scale may have qualitatively distinct effects on expected scholarly communications. The distinction between a locus effect and a scope effect on scholarly publications is partly ambiguous, as mentioned above.

NIFA provided the committee with most of the data needed to construct the project scale, locus, and scope variables in related spreadsheets. National Research Council staff collated the data into a master file suitable for regression analyses. Gaps and inconsistencies in the data provided by NIFA are discussed in Appendix H. NIFA keeps track of publications only up to project termination, which is well before many of the articles associated with AFRI funding have yet to appear. NIFA also did not provide data on the citation performance of these articles. Oregon State University staff[6] downloaded from Google Scholar each project's refereed journal-article and citation count, which Google Scholar has identified by way of (and only to the extent of) the project and funding-agency acknowledgments on the front page of each article. The downloads included AFRI's nonrefereed papers and presentations as filtered from the Current Research Information System (CRIS) reports provided by NIFA. These data were not available for 2008 NRI projects. A detailed description of data processing for the analysis performed in this chapter is included in Appendix H.

[6]The committee thanks Yunguang Chen for his assistance in obtaining the data on journal-article and citation counts from Google Scholar.

PRODUCTIVITY ASSESSMENT OF PROJECT DATA

The analyses here take the form of regressing project budgets—as the dependent variable—on the projects' refereed and nonrefereed journal-article outputs and on such project characteristics as duration, number of PIs, award type, performing-institution type, research–extension mix, subject area, and project vintage. Budget functions of this type describe relationships between selected characteristics and funding levels at given expected refereed-publication or nonrefereed-publication rates. Solving for the article-publication rate yields the effect of the indicated characteristic or budget on article output.

The fact that inadequate time has passed for all likely publications to appear implies a downward bias in expected article-output rate. The regression's focus on marginal effects—that is, on the output changes induced by input changes—ameliorates that difficulty substantially because such changes are only weakly related to output and input levels. Improved confidence in the committee's provisional inferences will require continued collection of AFRI outputs, including projects that have been terminated.

With those considerations in mind, the committee first assessed AFRI 2009–2010 before the introduction of challenge-area grants and the substantial expansion of project sizes and scope in early 2011. The committee then examined the challenge-area grants, which were introduced in the 2011–2012 period and it was also when mean project sizes expanded.

Productivity Analysis, Agriculture and Food Research Initiative 2009–2010

Every AFRI project output and input (characteristic or policy) variable was initially regressed against 2009–2010 project budgets and separately against 2011–2012 budgets. In each analysis, most of the statistically nonsignificant factors were progressively removed and the relationships iteratively reestimated until mostly significant factors remained. Final results for both 2009–2010 and 2011–2012 are given in Table G-4 in Appendix G.

Analytical Results: Policy Factors

Nonrefereed forms of research output (including conference presentations) were always highly nonsignificant in the 2009–2010 fits and removed from the specification. The implication is not that nonrefereed communications were meager or that grant support was irrelevant to their production but that, once laboratory and field setup costs were met, additional budget did not lead to greater output when all other factors were constant.

The rank of the project director also was nonsignificant despite that the rank with the lowest mean output (pre- or postdoctoral project director) was used as the base group, maximizing the opportunities that the ranks included would have statistically significant output effects. When other factors were controlled for, that is, directors at all ranks were on average equally successful in producing scholarly communications.

Support to the project director from other federal or nonfederal sources consistently had no effect on scholarly communications after budgets were accounted for. That does not imply that the presence of other support was unimportant in AFRI recipients' scholarly productivity. Rather, it suggests that in selecting and funding projects and implicitly the PIs involved in them, AFRI has successfully taken account of the non-AFRI contributions to its awardees' productivity. With one exception, performing-institution type had no output-constant budget implication either. Projects performed at public non–land-grant, federal, and private research entities were no more or less productive than those at land-grant universities. The exception is that those at private universities required greater budgets on average than did land-grant universities to produce a given number of scholarly communications. For example, private universities (such as the Massachusetts Institute of Technology, Yale University, New York University, and Northwestern University) required $210,700 more than land-grant institutions to produce the same overall publication rate.

The distribution of a project's functions among fundamental research, applied research, extension, and education—a potentially important element of project scope—had only a weak effect on the number of communications. The negative budget effect of boosting a project's fundamental-research component weakly suggests that the greater a study's fundamental content, the less expensive it is to produce another communication.

Other policy factors generally had robust influences on output-constant program budgets. It is especially important to see that greater journal-article output is statistically associated with a larger budget when PI numbers, project duration, and other project characteristics are held constant. However, FASE awardees required $86,000 less to generate a given journal-publication rate than did standard awardees. CAP grants, in contrast, expended $2,296,900 more than standard grants for a similar scholarly communication rate.

Project scale and scope policies merit close attention because they are relatively easily adjusted but have important efficiency implications. In terms of scale, project duration had a highly significantly positive effect in the 2009–2010 linear regression. Other inputs constant, this indicated AFRI was paying for additional project time for which it received no additional output. Holding budget constant, an additional project month reduced the number of journal articles produced per project. On the scope side, the analysis similarly suggested that when budget and other controlled factors were held at sample means, an additional PI in a project reduced journal-article output.

These estimated output effects of another $10,000 of budget, another PI, and another month of project duration—respectively controlling for the remaining two—are summarized in Table 4-2. Each entry shows the effect of one more unit of the variable in the left-hand column on the variable in the top row. For example, the first column of the matrix shows the respective influence of $10,000 of additional budget, one more PI, and one more project month on refereed journal-article output. In cell (i), for instance, the –1.49 is the above-mentioned mean article-production loss incurred when one more PI is added to the project while budget, project duration, and all other modeled factors are held constant.

Sources of Scale and Scope Inefficiency

The 0.47 in cell (iii) of Table 4-2 indicates that when holding article output and project duration fixed, adding $10,000 more to the budget required nearly one-half an additional PI and vice versa. Such a mutual rise in budget and PI numbers might be reasonable if it boosts output. However, output is held constant in this table row. Consequently, as the number of PIs rises, the average PI becomes increasingly inefficient in the use of non-PI budget inputs to produce journal articles. Thus also, reducing PI numbers allows some non-PI inputs to be saved. Once they are fully saved, budget and PI numbers would begin to trade off with one another, so the marginal effect of each on the other in cell (iii) would be negative rather than positive. Boosting the number of PIs would allow a given number of journal communications to be produced with fewer non-PI expenses. The fact that they do not trade off suggests these efficiency opportunities remained unexploited and hence that resource allocation in AFRI 2009–2010 projects was not maximally productive in terms of our output criterion.

This observed complementary relationship, at constant output, between budget and PI numbers in Table 4-2 is bound to have a negative influence on either budget's or PI number's effect on journal-article output because the ratio of these two effects is what constitutes the relationship between output-constant budget and PI numbers. In AFRI 2009–2010, the budget's marginal impact on journal publishing was positive (0.69) and PI's marginal effect was negative (–1.49). More importantly, AFRI's inability to exploit the complementarities between variable and fixed research resources guaranteed that one of the two factors would have a desirably positive output influence and the other an undesirably negative one.

The possibility that boosting a project input could negatively affect output is best understood by distinguishing between the portion of the input devoted to setting the project up and the portion used to exploit the setup to produce outputs. Projects that mainly extend an earlier study, for instance, presumably have lower setup costs than do projects that begin a

TABLE 4-2 Research Marginal Productivity: Pairwise Effects of Selected Factors, AFRI, 2009–2010

	(1) Number of Refereed Articles	(2) Number of PIs	(3) Project Budget	(4) Project Duration
(1) Number of refereed articles				
(2) Number of principal investigators	(i) –1.49			
(3) $10,000 of project budget	(ii) 0.69	(iii) 0.47		
(4) One month of project duration	(iv) –0.76	(v) –0.51	(vi) 1.09	

NOTE: The number in a given cell is the effect on the variable above of applying one more unit of the variable on the left. Roman numerals in parentheses are cell numbers.

new line of research. Figure 4-3 depicts a stylized relationship between a research project's setup cost and its marginal (directly output-producing) cost. The same technology is depicted in the bottom as in the top diagram. Until enough resources (budget, PIs, and project duration) have been devoted to set up experiments or field trials, no outputs can appear. Outputs may then arise if additional resources are applied. But the additional output created by an additional input unit typically declines as the input volume grows because increasing demands are being placed on the project's remaining (fixed) inputs such as PI time and institutional infrastructure. At the peak of the curve, the variable inputs crowd in on the fixed inputs to such extent that output begins to fall as additional variable input units, such as undergraduate students, are brought in. Budget allocations in that region of declining output are wasteful. Increased awareness of these relationships can help identify signs of inefficient study-resource use.

Points A and B in Figure 4-3 show two alternative operating points on such a science production function. *Per-unit* output is the slope of the line drawn from the origin to AFRI's operating point—A in the top diagram and B in the bottom diagram. In both cases, regardless of how much input is used, per-unit output is positive. Marginal output is the slope of the tangent to the production function at the operating point. That slope is highly sensitive to input level. Because in the top diagram the input is used moderately, marginal output is positive.[7] In the bottom diagram, so much input is used that marginal output is negative: an additional input unit reduces output.

Principal-Investigator (Scope) Effects

No manager seeking to maximize output with given resources, or to minimize resources needed for a desired output, would accept less output in the face of additional input. Yet early evidence suggests that PI deployments in the average AFRI 2009–2010 projects seem to have been in such a situation. The rationale for adding PIs presumably was to broaden the scope of resources available to solve the problems addressed (e.g., in the variety of disciplines, subject matter, and laboratory and field information). But that added variety may exacerbate communication and coordination costs and use cash that could have been used more productively.

These additional coordination costs could be justified on several bases. One justification is that novel ideas and solutions emerge from collaborative research among disciplines and institutions. Truly interdisciplinary research of that nature requires understanding one another's disciplinary language and challenges (NRC, 2004). The fact that, at sample means in 2009–2010, additional PI numbers had a negative journal-article effect suggests

[7]Because of the presence of setup cost and the production function's concave shape, marginal output typically is greater than per-unit output.

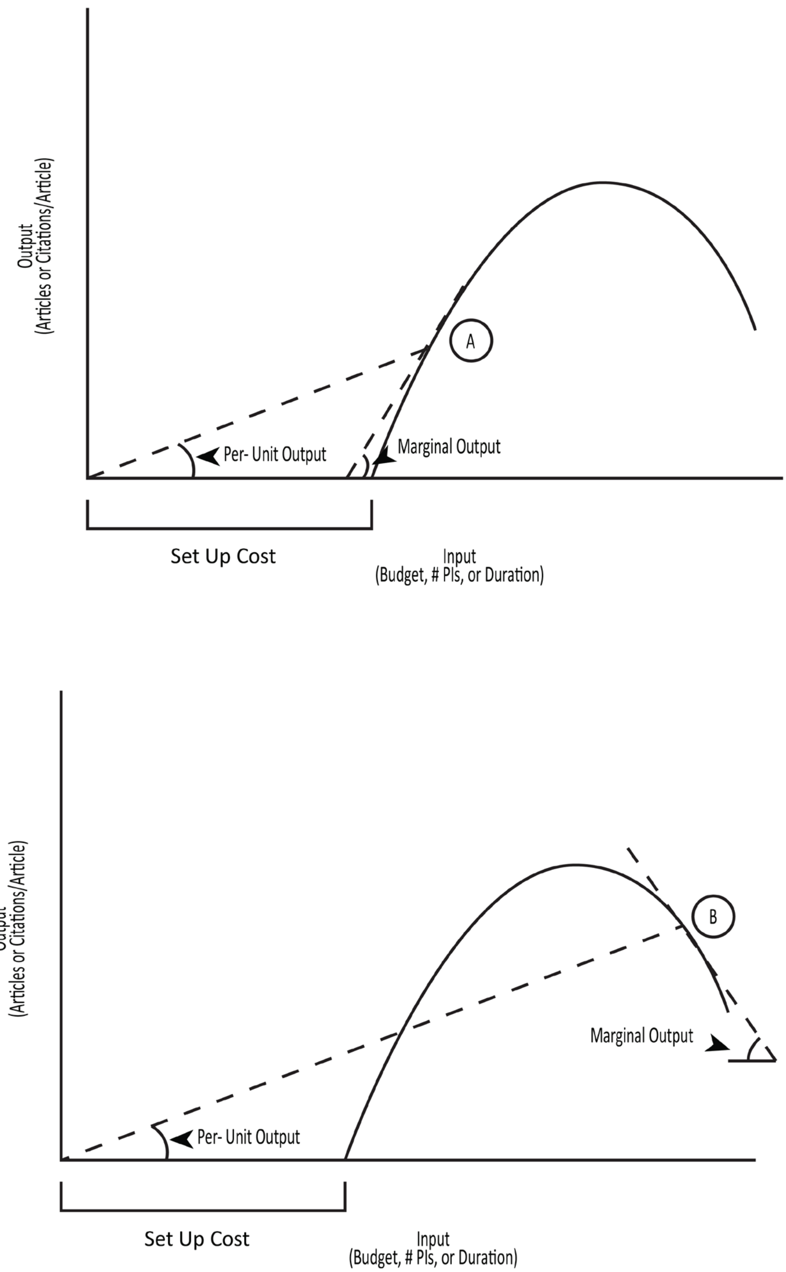

FIGURE 4-3 Stylized relationship between setup cost, per-unit output, and marginal cost.

that coordination costs outweighed diversity and specialization benefits. Cummings and Kiesler (2007) showed similar findings in their study of the National Science Foundation's Information Technology Research program. If in the longer term, however, especially large projects can be shown to produce more innovative or longer-lasting effects than possible without disciplinary integration, the shorter-term inefficiencies would be justified.

When PI numbers and institutional overhead are held constant, an additional budget dollar is an additional liquid resource. The natural inclination would thus be to allocate that extra dollar to communication among PIs, students, and interest groups. In other words, the extra dollar would encourage and be associated with a more integrated project. To the degree that it is, communication costs in the larger projects substitute for, rather than produce, journal articles, presumably because the PIs' lost scientific productivity and article-writing time are inadequately compensated by the publication benefit of the intraproject communication. On the basis of this committee's analysis of bibliometric outputs, and with only a few years to observe it, the productivity of the average AFRI project was considerably lower than might have been expected given the size of the budget and number of PIs.

Project-Duration (Scale) Effects

Finally, consider the efficiency with which study time is assigned to AFRI projects (last row of Table 4-2). As with the relationship between budget and PI numbers, a test of study-time efficiency is to ask whether the project's budget and duration trade off with one another in producing a given output. Cell (vi) of Table 4-2 shows, at least with the early bibliometric output data, that they do not trade off. If refereed-article output is held constant, another month of project time requires $10,900 of additional budget. Thus, in the period examined, scholarly communication rate was maintained even when both duration and budget were reduced. In the presence of a budget's positive effect (cell ii) on article output, this unexploited complementarity implies that the longer the project, the lower its journal output (cell iv).[8] Although the average project month brings positive output, adding one more month reduces it. The average project, that is, was allowed too many months given the budget and other resources supplied. The virtues of additional operating time were overwhelmed by the operational entropy that additional time encouraged.

[8]Full differentiation implies that when the marginal rate of technical substitution between two inputs is positive, and one of the two has positive marginal effect on output, the other must have negative marginal effect on output. Thus, for example, given in Table 4-2 that the marginal effect in cell (vi) is positive, the marginal effect in cell (ii) or cell (iv) must be negative and the other positive.

During the 2009–2010 period, when challenge-area grants had not yet been established, AFRI projects appear to have been too lengthy (a scale problem) and involved too many PIs (a scope problem) to make efficient use of AFRI resources. Budgets and PI numbers, like budgets and project durations, were jointly too high for the number of communications generated. The situation was not merely a scale diseconomy, namely, in which additional input volume reduces output per unit of input. Total output actually declined as input volumes were expanded. At the margin, in other words, another PI and project month were acting as negative inputs. Substantial reductions in both scale and scope thus would have boosted efficiency at least over the short term and possibly the medium and long term. A more general discussion of the conceptual pros and cons of the decentralized vs centralized form of scientific inquiry is outside the scope of the committee's review.

Productivity Analysis, Agriculture and Food Research Initiative 2011–2012

As in the AFRI 2009–2010 analysis, every variable except laboratory assistance was initially included in the 2011–2012 regressions. Project-director rank and institution type were largely nonsignificant, implying as before that the AFRI proposal selection and funding process was successful in equating eventual productivity rates across investigator ranks and institution types.

Policy Factors

As in the 2009–2010 analysis, the committee did not detect a significant relationship between current support from other federal or nonfederal entities on the one hand and the number of scholarly communications (output-constant cost or cost-constant output) on the other. Discernible publication-rate differences were not found either—controlling for the remaining factors—between the fellowship, challenge-area, or FASE programs and the standard-grant base group. Nor were they found between project subject areas, relative either to the ecosystem base group or—judging from coefficient:standard error ratios—to one another. The nonsignificances of these publication rate differences might be explained by the especially early stage at which the 2011–2012 projects were being examined. Less than 55 months had elapsed since the inception of many of them, and 80% of projects were incomplete at the time of the analysis. In any event, all these support-source, grant-type, and subject-area factors were eliminated from the analysis and the 2011–2012 regressions refitted.

A key finding of the 2011–2012 study was that, despite the recentness of these projects and hence the low per-dollar output rates to date, refereed and nonrefereed paper output were each associated highly positively with the budget provided. Refereed journal-article's *t*-statistic was indeed greater in the 2011–2012 assessment than in the 2009–2010 one. When project scope, scale, and other included program factors are controlled for, more published output requires more funding, and more funding generates more output. In particular, raising a project budget by 1% raises article output by 15.9%, similar to the return rate in 2009–2010. A program's early stages, therefore, do not appear to be too early to begin an analysis of program effectiveness, despite that results are only anticipatory.

Controlling even for other scale and scope measures like PI numbers and project duration, CAP grants appear to have been more output-inefficient in 2011–2012 than they were in 2009–2010. In particular, CAP projects in 2011–2012 required close to $9 million more than standard grants did to generate the same early scholarly output rates. This great discrepancy in project output might be explained partly by the long delay in a large project between project setup and publication appearance. That delay would be especially noticeable when, as here, analysis is conducted only 1.5–2.5 years after project inception. However, it is probably explained also by the great rise in the number and size of CAP projects in 2011–2012, which by further skewing the AFRI project-size distribution (see Figures G-1 through G-3 in Appendix G for project-size distribution graphs) may also have exacerbated the difficulty of distinguishing between the CAP effect itself and the more general scale and scope effects.

Public non–land-grant universities received about $450,000 more than other institution types did in 2011–2012 to generate the same output rate—indicative of an inefficiency twice as large as private universities had in 2009–2010. Furthermore, the greater a project's basic-research component, the less costly at given communication rate it continued to be in 2011–2012. Boosting a project's basic research share by 10 percentage points reduced output-constant budget by about $2,500, although the probability of a nonzero effect was only around 80%.

As in 2009–2010, the most prominent scale and scope effects on publication-rate-constant budget were positive and statistically highly significant. In the scale dimension, project durations remained excessive. Cutting one month of project time would have saved an average of about $20,600 in budget with no loss in output rate. In the scope dimension, the mean number of PIs in a project continues to be inefficient: adding one more PI would have inflated by $262,600 the budget needed to achieve a given refereed-publication rate. In other words, if budget is held constant, adding one PI reduces the refereed-publication rate. In fact, the marginal efficiency of PI deployment in AFRI projects fell in 2011–2012 by nearly half compared with 2009–2010.

Scale and Scope Effects

Table 4-3 provides insight into the sources of scale and scope effects on publication rates. Cell (i) shows that producing more nonrefereed papers comes at the price of fewer refereed ones when budget, PI numbers, and project duration are held constant. That is, any initial complementarities between these two types of communication have been successfully exploited. However, AFRI does not trade off budget size for PI numbers at a given output rate. The positive sign in cell (vi) shows that both could have been reduced while maintaining constant publication success. A consequence is that even when PI numbers are held constant, another $10,000 brings higher refereed-article and nonrefereed-article production, and another PI at constant budget reduces both these outputs [see cells (ii), (iii), (iv), and (v)]. Similarly in the scale domain, there is not a tradeoff between budget and project duration [cell (x)]. Instead, budget and project time can simultaneously be sacrificed even if output rate is held constant. Given that greater budget boosts output, adding a no-cost month to the average project would have reduced output.

In summary, budget, PI numbers, and project duration were jointly too great in 2011–2012 to most efficiently produce early scholarly outputs. This relationship appears to hold despite that, as in 2009–2010, budgets on their own were correlated strongly with early publication rates. In other words, excessive project scope rather than scale appears to have been the principal inefficiency factor, even though scope expansion inevitably requires scale expansion. With the greater emphasis in 2011–2012 on CAP grants and other complex PI arrangements, this challenge has intensified. Further addressing such potential shortcomings probably will require a better understanding of how project scope and scale combine to influence publication rate.

Interaction results in the 2011–2012 model (see Table G-4 in Appendix G) reinforce this observation. The interaction there between PI numbers and refereed-article production is statistically significant and positive, implying that the greater the number of PIs on a project, the higher the cost to produce one more refereed article. Similarly, interaction between project duration and nonrefereed-paper production is positive and significant, implying that greater project time raised the cost of another nonrefereed article. In other words, longer projects brought lower rates of nonrefereed publication return to the next budget dollar. This observation is consistent with an additional project month's own negative effect on nonrefereed-paper production, when other factors are held constant [cell (viii), Table 4-3]. That is significant because quality among nonrefereed publications—including conference proceedings, abstracts, bulletins, and student theses—likely varies more than it does among refereed publications.

TABLE 4-3 Research Productivity: Pairwise Effects of Selected Factors, AFRI, 2011–2012

	(1) Number of Refereed Articles	(2) Number of Nonrefereed Articles	(3) Number of PIs	(4) Project Budget	(5) Project Duration
(1) Number of refereed articles					
(2) Number of nonrefereed articles	(i) −1.96				
(3) Number of principal investigators	(ii) −3.07	(iii) −1.57			
(4) $10,000 of project budget	(iv) 0.12	(v) 0.06	(vi) 0.04		
(5) Months of project duration	(vii) −0.24	(viii) −0.12	(ix) −0.08	(x) 0.49	

NOTE: The number in a given cell is the effect on the variable above of applying one more unit of the variable on the left. Roman numerals in parentheses are cell numbers.

CONCLUSIONS

In its *Research, Education, and Economics Action Plan* (USDA, 2012), USDA observed that "accountability is necessary to determine if we are moving science in the right direction" and asked itself "Are we making the world better with our science?" (p. 34). The question could be rephrased to ask whether USDA research and education projects could be shown to directly or indirectly contribute to the Department's mandate, which includes improvement in agricultural productivity, economic growth, job creation, food safety and security enhancement, and ecosystem sustainability.

In this chapter, the committee addressed those outcomes in terms of the more immediate program outputs that may support long-term aims, and examined the output and outcomes from the perspective of only several years since the projects were initiated. Impact factors and readership sizes of the journals in which AFRI articles appeared were not accounted for. However, the AFRI dataset used provides rich, cross-sectional information. In particular, it provides cross-project comparisons of AFRI study inputs and their successes in achieving early communication outputs. Such cross-sectional richness probably accounts for much of the regressions' rather high goodness-of-fit, and for the coefficient stability observed across time-interval and equation specifications.

Early data suggest that although each new budget dollar has enhanced publication rate, the average AFRI project's scope or complexity has been excessive, and increasingly so in recent years. Efficiency impairment was such that publication rates rose even when the budget was held constant and project scope fell. The difficulty with complex projects may be their high intraproject coordination and communication costs, which would have pushed variable expenses too far above fixed or infrastructural costs. Because greater complexity requires more money, this difficulty would lead to excessive budgets as well, even though another dollar of budget has, on its own account, been shown in the analysis to be highly productive.

Rates of return in this chapter have been expressed in terms of scholarly communications. A more complete assessment would involve converting these rates into the types of social-outcome measures referred to in Chapter 2, such as a communication's contribution to agricultural production value. Presuming that a researcher's compensation is on average proportional to his or her economic contribution, one method of doing so is to draw on information about a publication rate's influences on researcher salary (keeping in mind that factors such as journal impact and researcher salary are highly discipline specific). Although the committee did not have an opportunity to pursue that kind of analysis, AFRI might in a future estimate of its research contributions consider weighting publication outputs by their mean marginal impacts on scientist salaries.

Bibliometric approaches, however, are not the only ones available for assessing program output. A more direct approach would be to compare a study's findings with its principal investigators' prior expectations of what the findings would be. The difference between a project's expectations and eventual outcomes constitute the magnitude of the scientific discovery, rigorously expressible in the form of a likelihood value. Bayesian approaches for estimating these discovery magnitudes have been used to assess individual scientific projects. More recently, the method has been extended to the analysis of an entire program such as AFRI's. The approach requires only that proposals include the principal investigators' probabilistic anticipations of their main results, which then can be compared with the completed experiments or surveys (Qin, 2012).

FINDINGS

Finding 4-1: In measuring AFRI's effectiveness, analysis of early publication data suggests that although each new AFRI dollar boosts publication output, the average project's scope and complexity have been excessive. In particular, reducing average project complexity—represented especially in the number of the project's PIs—would substantially improve publication output at no cost to AFRI's budget. That critique extends beyond the CAP program to include many non-CAP grants. Less compelling evidence suggests that mean project duration has also been somewhat excessive. Such near-term output assessment provides only one perspective on AFRI performance. Improved performance analyses will require systematic attention to long-term outputs and, more importantly, to project outcomes in the form of the science influenced, social well being, and products and incomes generated. AFRI's history is still too short to allow that sort of assessment.

Finding 4-2: In the present report, refereed publications and their citation rates were drawn from Google Scholar. However, such online data sources are not as effective in keeping up with the abstracts, conference papers, speeches, posters, dissertations, and station reports that are financed with AFRI money and that form an important part of AFRI project communication and program assessment. Some nonrefereed output data are, up to the project's official termination date, available in CRIS but difficult to assemble and require much organization before analysis can be performed. The committee assumes that AFRI management would encounter similar difficulties.

REFERENCES

Adams, J.D. 1990. Fundamental stocks of knowledge and productivity growth. Journal of Political Economy 98(4):673-702.

Alston, J.M., G.W. Norton, and P.G. Pardey. 1995. Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting. Ithaca, NY: Cornell University Press.

Azoulay, P., W. Ding, and T. Stuart. 2007. The determinants of faculty patenting behavior: Demographics or opportunities? Journal of Economic Behavior & Organization 63(4):599-623.

Buccola, S., D. Ervin, and H. Yang. 2009. Research choice and finance in university bioscience. Southern Economic Journal 75:1238-1255.

Campbell, D., M. Picard-Aitken, G. Côté, J. Caruso, R. Valentim, S. Edmonds, G.T. Williams, B. Macaluso, J.-P. Robitaille, N. Bastien, M.-C. Laframboise, L.-M. Lebeau, P. Mirabel, V. Larivière, and É. Archambault. 2010. Bibliometrics as a performance measurement tool for research evaluation: The case of research funded by the National Cancer Institute of Canada. American Journal of Evaluation 31(1):66-83.

Carayol, N., and M. Matt. 2004. Does research organization influence academic production?: Laboratory level evidence from a large European university. Research Policy 33(8):1081-1102.

Cummings, J.N., and S. Kiesler. 2005. Collaborative research across disciplinary and organizational boundaries. Social Studies of Science 35(5):703-722.

Cummings, J.N., and S. Kiesler. 2007. Coordination costs and project outcomes in multi-university collaborations. Research Policy 36:1620-1634.

Evenson, R.E., and Y. Kislev. 1975. Agricultural Research and Productivity. New Haven, CT: Yale University Press.

Foltz, J.D., K. Kim, and B. Barham. 2003. A dynamic analysis of university agricultural biotechnology patent production. American Journal of Agricultural Economics 85:187-197.

Fortin, J.-M., and D.J. Currie. 2013. Big science vs. little science: How scientific impact scales with funding. PLoS ONE 8(6):e65263.

Griliches, Z. 1990. Patent statistics as economic indicators: A survey. Journal of Economic Literature 28:1661-1717.

Gulbrandsen, M., and J.-C. Smeby. 2005. Industry funding and university professors' research performance. Research Policy 34(6):932-950.

Jaffe, A.B. 1986. Technological opportunity and spillovers of R&D: Evidence from firms' patents, profits, and market value. American Economic Review 76(5):984-1001.

Levin, S.G., and P.E. Stephan. 1991. Research productivity over the life cycle: Evidence for academic scientists. American Economic Review 81(1):114-132.

Nag, S., H. Yang, S. Buccola, and D. Ervin. 2012. Productivity and financial support in academic bioscience. Applied Economics 45(19):2817-2826.

NRC (National Research Council). 2004. Facilitating Interdisciplinary Research. Washington, DC: The National Academies Press.

Pardey, P.G. 1989. The agricultural knowledge production function: An empirical look. Review of Economics and Statistics 71(3):453-461.

Qin, L. 2012. The Economics of a Research Program: Knowledge Production, Cost, and Technical Efficiency. PhD Dissertation, Oregon State University.

Trochim, W.M., S.E. Marcus, L.C. Mâsse, R.P. Moser, and P.C. Weld. 2008. The evaluation of large research initiatives: A participatory integrative mixed-methods approach. American Journal of Evaluation 29(1):8-28.

Turner, L., and J. Mairesse. 2003. Individual productivity differences in scientific research: An econometric study of the publications of French physicists. Available online at http://www.nber.org/CRIW/papers/mairesse.pdf.

USDA (U.S. Department of Agriculture). 2012. Research, Education, and Economics Action Plan. Washington, DC: U.S. Department of Agriculture.

Xia, Y., and S. Buccola. 2005. University life science programs and agricultural biotechnology. American Journal of Agricultural Economics 87:229-243.

Zucker, L.G., M.R. Darby, and M.B. Brewer. 1998. Intellectual human capital and the birth of U.S. biotechnology enterprises. American Economic Review 88(1):290-306.

5

Program Management

The Agriculture and Food Research Initiative (AFRI) supports a wide array of research goals and communities through competitive, peer-reviewed grants. Although AFRI has been in operation only since 2009, its offerings have changed yearly in response to stakeholder input, the scientific leadership of the National Institute of Food and Agriculture (NIFA), and budget considerations.

PROGRAM AREAS

The Food, Conservation, and Energy Act of 2008 (referred to hereafter as the 2008 Farm Bill) established a complex set of goals for AFRI to broadly address nearly all components of food and agriculture. A review of AFRI will therefore need to include management responses to those goals by assessing whether AFRI:

- Is a source of scientifically merit-based grants in areas related to food and agriculture.
- Broadens the base of scientists who participate in either fundamental or applied research in those areas, attracting proposals from a wide array of public and private institutions.
- Encourages programs that include combinations of research, education, and outreach.
- Supports research activities in both the natural and social sciences.
- Supports research and education efforts at small, mid-size or mi-

nority-serving institutions that have limited institutional success through the Food and Agriculture Science Enhancement grants.

- Supports interdisciplinary research in cross-cutting fields mandated by Congress and that emerge as particularly promising.
- Enables the submission of a wide array of proposals, including
  - Individual fellowships for graduate and postdoctoral students.
  - Small planning and conference grants from individuals.
  - Equipment and small-program grants from Experimental Program to Stimulate Competitive Research institutions.
  - Individual-investigator initiated proposals ("standard" grants).
  - Large, multiyear, multi-investigator projects through Coordinated Agricultural Project (CAP) grants.

As described in Chapter 3, that broad base of support is organized in two program types that address separate but related areas: foundational grants and challenge-area grants. The focus of this chapter is on NIFA's management of those two types of programs.

Foundational Program Grants

The intent of the Foundational Program is to support fundamental and applied research, education, and extension to facilitate advances in food and agriculture. The Farm Bill mandated that 60% of AFRI funding be devoted to fundamental (or basic) research and 40% to applied research. In addition, at least 30% should be made available to fund integrated research, education, and extension programs and at least 30% should be in support of research by multidisciplinary[1] teams.

Two general features of the requests for applications (RFAs) should be noted. First, the general vocabulary and structure of announcements evolved, but the general instructions had the following features:

- Listing of the six priority areas (e.g., plants and animals).
- Stated priorities within each priority area, which vary year by year.
- A set of research focus areas under each priority, which changes in number and degree of specificity.

Second, Foundational Program RFAs have narrowed the scope of proposal submissions by emphasizing the need to focus on organisms of rel-

[1]Although the term "multidisciplinary" was not defined under the 2008 Farm Bill, NIFA has taken a broad and comprehensive approach to incorporating multiple disciplines in addressing complex topics that not only include the biological and physical sciences but also the social, behavioral, education, and economic sciences.

evance to U.S. agriculture. Proposals that include other organisms as model systems have needed to supply special justification to align with AFRI program goals.

Proposals for research, education, and extension in the Farm Bill's six priority areas have been eligible for funding each year since 2009 except in 2012, when no foundational grants were offered.[2] RFAs have changed in program emphasis and focus. In 2009, NIFA had 40 programs listed under the six Farm Bill priority areas, with highly detailed RFAs that range from broad to highly focused program areas in each of the six Farm Bill priority areas. For example, in the plant area alone, there were nine programs, including the wide-ranging field of plant biology with a focused program in arthropod and nematode biology and management. In 2010, it was much simpler, with mostly broad programs listed in the six priority areas. The offerings described in RFAs have since reverted to more detailed, focused programs. Table 5-1 indicates the programs in the six priority areas for 2010, 2011, and 2013 and shows a steadily increasing number of programs in each priority area by year and changes in priorities within the programs. An archive of all AFRI RFAs can be found online (USDA-NIFA, 2013b).

As an example of changing emphases and increased specificities, Table 5-2 shows in more detail the research focus areas specified in the RFAs in the plant priority area over a 3-year period. In Table 5-2, each priority area is numbered (e.g., "Plant Sciences" under 2010), and the research focus areas are labeled with lowercase letters (e.g., "a. Epigenetic regulation" under 2010). The other priority areas had similar modifications over the same interval.

In addition to a changing suite of programs, the areas and specific requirements indicate shifts away from proposal flexibility to more program specificity and away from fundamental research toward more applied objectives. Given the original mandate that 60% of support be for fundamental (or basic) research, the change in emphasis in the RFAs is noteworthy.

Challenge-Area Program Grants

Challenge-area grants were initiated in FY 2010 with tightly focused goals. They were designed to encourage the development of specific tools and responses to current societal problems. The programs have generally encouraged systems approaches, including large, multidisciplinary, multi-institutional, multiyear projects. Specific challenges have been presented in annual RFAs. Each year, a particular set of challenges has been posed for funding; given funding restrictions, AFRI has not funded programs in all

[2]According to NIFA, funds from 2012 were combined with the 2013 RFA.

TABLE 5-1 Programs in Each Priority Area of AFRI Foundational Program

	Programs by Year		
Priority Area	2010	2011	2013
Plants	- Plant Sciences - Pest and Insects	- Biology of Agricultural Plants - Plant-Associated Microbes - Weedy and Invasive Plants - Insects and Nematodes	- Plant Breeding for Production - Bio Mechanisms for Production - Plants and Microbes - Weedy and Invasive Plants - Insects and Nematodes
Animals	- Bioinformatics - Reproduction - Health	- Reproduction - Nutrition, Growth, and Lactation - Health and Disease - Breeding, Genetics, and Genomics	- Reproduction - Nutrition, Growth, and Lactation - Health and Disease - Tools for Breeding, Genetics, Genomics
Food Safety, Nutrition, and Health	- Pathogens in Plants - Practical Approaches to Food Safety - Reducing Food Allergies	- Physical and Molecular Mechanisms of Food Contamination - Function and Efficacy of Nutrients - Processing Technologies	- Physical and Molecular Mechanisms of Food Contamination - Function and Efficacy of Nutrients - Improving Food Quality

challenge areas every year but rather has offered a subset that sometimes deviates from original published schedules, as described below.

Each year's RFAs have identified specific programs for emphasis. Research priorities for the five challenge areas were developed for 3 years of the program (2010, 2011, and 2012). Each RFA deliberately identified the 3-year projected objectives so that applicants could plan, knowing that future-year RFAs would identify related but different priorities (see Table 5-3 for a summary of research priorities in each challenge area). By 2011, priorities and budget constraints had dictated a change, and the crossed-out areas in Table 5-3 were not offered. The year after the missed year offered all the programs that had been proposed for that year and the excluded year. It was not until the FY 2013 RFAs that the research topics for the challenge pro-

TABLE 5-1 Continued

	Programs by Year		
Priority Area	2010	2011	2013
Renewable Energy, Natural Resources, and Environment	- Soil Microbes - Agricultural Water	- Processes and Transformations in Soil, Water, and Air - Ag System Thresholds - Management in Ag Systems	- Soil, Air, and Water in Ag Ecosystems
Ag Systems & Tech	- Animal Management Systems - Nanotech for Safe Food	- Engineering, Products, and Processes - Nanotechnology	- Engineering, Products, and Processes - Nanotechnology
Ag Economics and Rural Communities	- Small and Medium Farms - Economics of Markets and Development	- Small and Medium Farms - Entrepreneurship and Small Business Development - Rural Development - Markets and Trade - Environment	- Small and Medium Farms - Entrepreneurship, Tech, Innovation - Rural Families, Communities, and Regional Development - Markets and Trade -Environment

SOURCE: USDA-NIFA, 2011a, 2012a,b.

gram in 2013, 2014, and 2015 were announced. Food safety was the only area that did not have priorities established for 2014 and 2015.

In summary, AFRI's portfolio can best be understood by reviewing current and past RFAs. Appendix F presents a complete list of the grant types offered in each of the 25 RFAs for foundational and challenge-area programs from 2009 through 2013 and shows a strikingly complex collection of grant offerings with considerable variation year by year.

GRANT TYPES

As described in this chapter and in Chapter 3, AFRI offers various types of grants. Standard project grants mostly involve single principal

TABLE 5-2 Priorities for Proposals in the Plant Priority Area, by Program and Year

2010	2011	2013
1. Plant Sciences a. Epigenetic regulation b. Light and hormone control 2. Pest and beneficial insects a. Abundance and spread b. Plant insect interactions c. Genetic mechanisms	1. Biology of Agricultural Plants in any single or combination of a. Genome structure and function b. Molecular studies and biotech c. Breeding for better plants and resistance d. Responses to pests e. Responses to environment f. Improved nutrition 2. Plant-Associated Microorganisms a. Must be agriculturally relevant 3. Weedy and Invasive Plants 4. Insects and Nematodes, especially a. Signaling b. Interactions with plants c. Management programs d. Transgenics to limit severity	1. Plant Breeding for Agricultural Production in any single or combination of: a. Improving public plant breeding programs b. Enhancing phenomics c. Improved extension to breeding community 2. Biological Mechanisms for Plant Production addressing: a. Growth and development for improved productivity or nutritional content b. Response to abiotic stress 3. Microorganisms in: a. Microbe-microbe or microbe-plant interactions b. Plant molecular responses c. Epidemiology of disease spread 4. Weedy and Invasive Plants a. Ecological processes in IPM b. Ecology and genetics of herbicide resistance c. Ecology and evolution studies for weed management 5. Insects and Nematodes in a. Interaction mechanisms, especially using genomics b. Plant responses especially through signaling mechanisms c. Control through transgenic approaches d. Genomics of vectors

investigator (PIs) although grants with a few co-PIs have been allowed. In general, these standard grants parallel individual-investigator initiated grants typical of other federal granting agencies—such as the National Science Foundation (NSF) and the National Institutes of Health (NIH)—and have been the exclusive type of grant in support of research, extension, or education in the Foundational Program. Grants aimed at strengthening the research infrastructure of small, medium-size, and minority-serving institutions are in this category.

Starting in 2010, and carrying over and extending a practice of the U.S. Department of Agriculture (USDA) National Research Initiative (NRI), AFRI used CAP grants for the challenge-area program. The duration of those grants was typically 5 years, they had total budgets ranging from more than $2 million to almost $40 million, and they involved up to 40 co-PIs and a median of 20 co-PIs (USDA-NIFA, 2013j). Each project involved a complex mixture of research, extension, and education, and all were funded as continuation projects; that is, funding for the years beyond the first year were taken from the succeeding years' budgets. The budgetary effect of the grants is discussed below. The leadership for these large grants was awarded largely (almost 90%) to land-grant universities; this suggests a failure to broaden the base of scientists involved in agriculture-related research, and about 60% of the effort is devoted to applied research (USDA-NIFA, 2009, 2011a, 2012a). The RFAs were highly specific and detailed, and this suggests a top-down design strategy, from AFRI to the research community. A potential downside of these grants was pointed out by a number of CAP grant PIs who provided input to the committee about the complex application process and the major and expensive need for constant communication and grant administration among the PIs in their projects. In contrast, several felt strongly that their projects were uniquely able to connect diverse segments of the research community to address important issues. Chapter 4 of this report presents methods for examining the efficiency and potential return on investment of grant projects of various sizes and identifies possible inefficiencies of large grants that would need to be taken into account in considering the efficacy of this type of grant (Lane, 2010; Wadman, 2010).

In 2010, a decision was made to readjust AFRI's portfolio to reflect 30% for standard grants and 70% for CAP awards for collaborative research. The shift from standard grants aimed at fundamental research to large CAP grants integrating research, extension, and education aimed at specific challenges constituted a strategic change for AFRI. As previously mentioned, even in the Foundational Program, RFAs identified detailed topic areas rather than less directed exploratory efforts. Budget constraints resulting from lack of growth in appropriated budgets compared with initial authorizations and the move to large CAP grants changed the spectrum

TABLE 5-3 Summary of Research Priorities Identified by AFRI for Five Challenge Areas[a]

	RFA		
AFRI Challenge Areas	FY 2010	FY 2011	FY 2012
Agricultural and natural resources science for climate variability and change (RFA actually said climate change only)	- Cropping systems: cereal production systems (e.g., corn, barley, wheat, rice, oats) - Animal systems: swine or poultry production systems - Forest systems: southern conifers	~~- Cropping systems: legume production systems, forage production systems~~ ~~- Animal systems: ruminant livestock production systems, dairy production systems~~ ~~- Forest systems: western conifers~~ ~~- Grassland, pastureland, and rangeland systems~~	- Cropping systems: food and nonfood horticultural production systems, fiber production systems - Animal systems: farmed aquaculture and specialty livestock - Forest systems: deciduous hardwoods and mixed forests - Agroecosystems that provide ecosystem services (e.g., provisioning, regulating, supporting, and cultural services identified under the 2005 Millennium Ecosystem Assessment)
Childhood obesity prevention	Preschool and early elementary school-age children (ages 2-8 years) will be targeted for the following: - Integrated Research, Education, and Extension to Prevent Childhood Obesity - Extension Interventions to Prevent Childhood Obesity - Transdisciplinary Graduate Education and Training in Nutrition and Family Sciences	Same areas as FY 2010 but for older children (ages 9-14)	~~Same areas as FY 2010 but for older children (ages 15-19)~~

	or Child Development or Related Fields to Prevent Childhood Obesity - Methodological Research to Assess the Effectiveness of Obesity Prevention Strategies - Community-Based Childhood Obesity Prevention		
Food safety	- Shiga toxin–producing *Escherichia coli* (STEC) - Food processing technologies - Viruses in food - Food safety education and emerging food safety issues	- *Salmonella* and *Campylobacter* in poultry	~~- Microbial ecology of food-borne pathogens~~ ~~- Control of other food-borne pathogens of concern, *e.g.*, *Listeria monocytogenes*~~

continued

TABLE 5-3 Continued

	RFA		
AFRI Challenge Areas	FY 2010	FY 2011	FY 2012
Food security	- Improving feed efficiency of agriculturally relevant animals - Minimizing losses from one livestock disease with major impact on food production, marketing, and/or trade - Minimizing crop plant losses from oomycete pathosystems - Program delivery and implementation of wide-area pest monitoring - Improving sustainable food systems to reduce hunger and food insecurity domestically and globally	- Translating genomics into practical applications for selection of animals with genetic resistance to diseases - Minimizing losses from a second livestock disease with major impact on food production, marketing, and/or trade - Management of fungal diseases in plants - Management of vector associated pathogens in plants - Enhancing animal welfare in sustainable food systems – a systems approach that evaluates biological, environmental, and societal impacts of different production systems - Evaluating Life Cycle Analysis of sustainable food systems - Determining the impact of use of sustainable food system best practices in communities	- Increasing reproductive fertility in food animals - Minimizing losses from a third livestock disease with major impact on food production, marketing, and/or trade - Management of plant insect pests - Management of plant bacterial diseases - Enhancing the viability of small and mid-sized farms in the context of global food security through - Evaluating trade and sustainable food systems—labor, environment, animal welfare, and related issues in major food-exporting countries to the United States - Determining U.S. consumer willingness to pay for standards that enhance food security - Improving public policies and business strategies that enhance sustainable food systems and global food security

Sustainable bioenergy	- Crop protection for sustainable feedstock production systems - Enhanced-value co-product development - Carbon sequestration and sustainable bioenergy production	~~- Impacts of policy on feedstock production systems~~ ~~- Scalable conversion of feedstock to “drop-in” biofuels~~ ~~- Impacts of feedstock production systems on pollinators and wildlife~~	- Land-use changes resulting from feedstock production and conversion - Socioeconomic impacts of biofuels in rural communities - Logistics of handling feedstocks for biofuels

[a]Areas that are crossed out indicate projected RFAs for 2011 and 2012 that were not issued in those years.

TABLE 5-4 Percentage of Funds for Fundamental vs. Applied Research

Research Focus	2009	2010	2011	2012
Fundamental	60%	54%	33%	42%
Mission-linked applied	40%	46%	67%	58%

SOURCE: USDA-NIFA, 2009, 2011a, 2012a, 2013g.

TABLE 5-5 Percentage of Funds for Multidisciplinary vs. Single-Discipline Research

Research Focus	2009	2010	2011	2012
Multidisciplinary	69%	88%	93%	88%
Single-discipline	31%	12%	7%	12%

SOURCE: USDA-NIFA, 2009, 2011a, 2012a, 2013g.

of research supported by AFRI. Table 5-4 lists the percentage of overall funding of grant research focus areas from 2009 to 2012, as reported in the published AFRI annual synopses. Data for 2012 are from an interim report of February 2013. Table 5-5 tracks the move toward multidisciplinary vs. single-discipline research and shows the trend to support programs that involve multiple investigators in more systems-oriented research.

The move toward large multidisciplinary, multi-institution grants (CAP grants) has also been accompanied by a shift toward so-called integrated projects that fund coordinated efforts in research, education, and extension. Table 5-6 tracks that change. It is striking that although integrated proj-

TABLE 5-6 Percentage of Funds for Integrated vs. Single-Function Grants

	2009	2010	2011	2012
Integrated research, education, and extension	30%	47%	58%	54%
Single-function research	68%	48%	39%	42%
Single-function education	2%	3%	3%	2%
Single-function extension	<1%	2%	0%	2%

SOURCE: USDA-NIFA, 2009, 2011a, 2012a, 2013g.

ects increased substantially, single-function education or extension projects showed no change.

Although AFRI presented RFAs for grant programs each year, the budget available to support new grants varied considerably among the different areas, as is shown in Table 5-7. In 2009, AFRI offered only foundational grants; in 2010, it offered foundational and all the challenge-area grants; in 2011 and 2012, some programs were not offered; and in 2013, all programs were offered again. As mentioned above, AFRI adopted a policy of "continuation funding" for the CAP grants in the challenge-area program. In that scenario, funding of work beyond the year of the initial award is provided by later years' anticipated budgets. AFRI points out that this approach "allows for a much higher level of post-award oversight and quality control since funds are allocated on a year-by-year basis with continued funding provided only if performance has been satisfactory, appropriations are available for this purpose, and continued support would be in the best interests of the Federal government and the public" (USDA-NIFA, 2011b). It is striking to note that because of continuing commitments, 2011 and 2012 witnessed considerable decreases in funds available for new grants. The 2013 available budget for new grants rebounded as a result of the forward-funding approach adopted by AFRI's managers.

The move to large multidisciplinary, multifunction CAP grants and legislative decisions not to fully appropriate authorization funding levels appear to have led to a decline in the number of new grants funded annually from 2009 to 2012 (see Table 5-8).

PRIORITY-SETTING PROCESS

As previously discussed, in addition to the six legislatively mandated priority areas, NIFA scientific leadership identified five challenge areas that are based on societal challenges outlined in the National Research Council's *New Biology* report (NRC, 2009) and the agency goals for the program (see Figure 5-1 for an overview of AFRI priority setting and see Chapter 3).

In each foundational or challenge area, research priorities are driven by National Program Leaders (NPLs). According to NIFA, NPLs take into consideration a variety of

> inputs from any individual and specifically from commodity groups, industry, interagency federal work groups, the National Academy of Sciences, nongovernmental organizations, scientific societies, and university partners. In addition, AFRI obtains input from the Congress, the Department, the NAREEEAB [National Agricultural Research, Extension, Education, and Economics Advisory Board], the REE [Research, Education, and Economics] Mission Area, and NIFA's scientific leadership. Stakeholder input

TABLE 5-7 Budget for New Programs, by Program Area Over Years of Program

Program Area	2009	2010	2011	2012	2013
In millions of dollars					
Foundational	190	64	78	0	136
Challenge					
Climate Change	0	55	0	12	5
Childhood Obesity	0	25	8.5	5	5
Food Safety	0	20	7	0	10
Food Security	0	19	0	19	5
Sustainable Bioenergy	0	40	0	11	10
Subtotal for Challenge	0	159	15.5	47	35
Total for all new	190	223	93.5	47	171
Total for all grants, as announced in RFAs	190	262	262	264	264
% of total for new	100%	85%	36%	18%	65%

SOURCE: USDA-NIFA, 2009, 2011a, 2012a, 2013g.

TABLE 5-8 Number of New Grants Awarded, by Year

FY 2009	FY 2010	FY 2011	FY 2012
470	403	281	254

SOURCE: USDA-NIFA, 2009, 2011a, 2012a, 2013g.

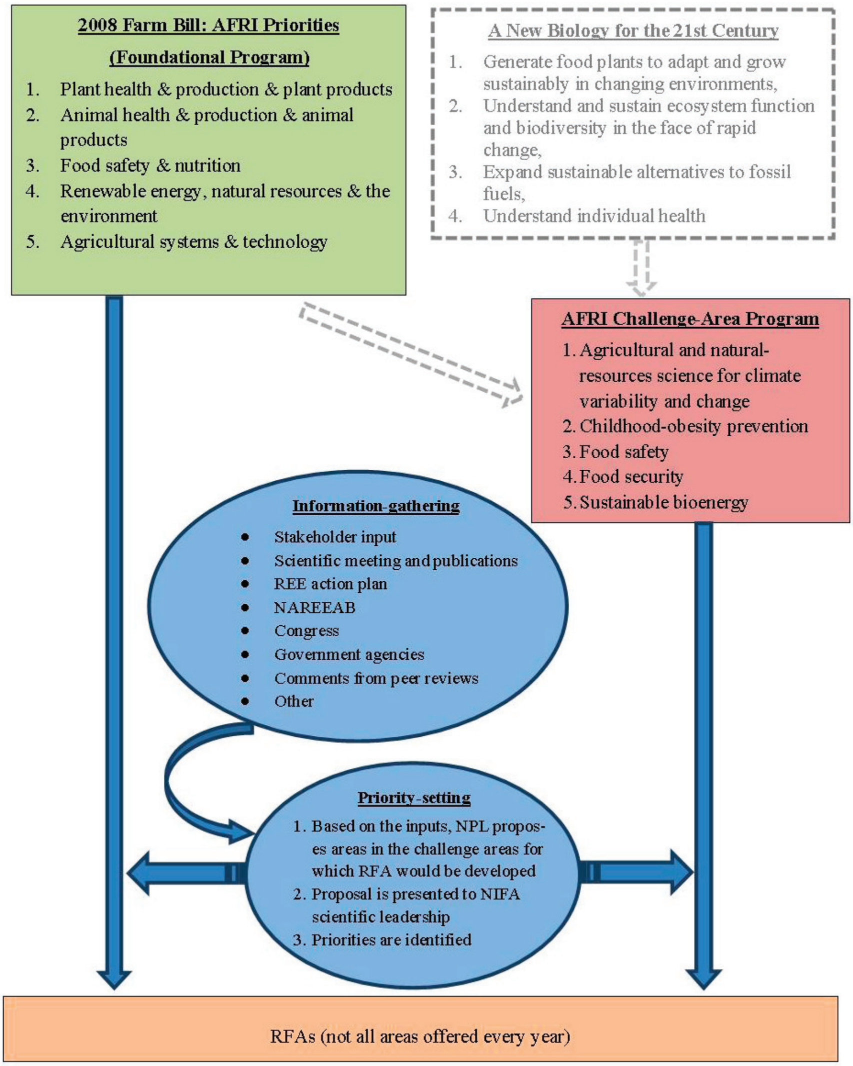

FIGURE 5-1 Setting AFRI's challenge-area program. Dotted lines and items in gray reflect previous inputs for setting priorities.
SOURCE: Based on information provided by NIFA.

is obtained in several ways. Input is solicited in all NIFA RFAs; and NIFA may also conduct stakeholder listening sessions or workshops, some as stand-alone events, some in conjunction with national scientific meetings. There are also webinars organized by NIFA. Stakeholder information from other government and private-sector events and publications are also gathered by NIFA." (USDA-NIFA, 2013i)

Stakeholders can provide input and comments on AFRI's priority setting at any time through NIFA's website (USDA-NIFA, 2012c), and the RFAs have an address for interested parties to use in submitting comments. Stakeholder listening sessions are also posted on the agency's website, published in the *Federal Register*, and disseminated through NIFA's listservs (Lichens-Park and Mirando, 2013; USDA-NIFA, 2013f).

All the information above is considered by the NPLs in developing proposals for future research to be addressed by the foundational and challenge programs. NPLs then present their plans to NIFA scientific leadership, and the topics for the RFAs are defined. However, to judge from the information provided by NIFA, there did not appear to be a systematic approach or a standardized operating procedure for identifying priorities for all NPLs. And there is no external mechanism for validating or conducting concept clearance for decisions by NPLs and NIFA leadership.

Because of the goal of each program, priorities for the challenge areas are specific and target key and immediate issues in food and agriculture; for the foundational areas, they are broader. Challenge-area priorities are identified every 3 years (see Table 5-3), and foundational program priorities are identified annually (see Table 5-2); this makes it difficult for investigators to predict which priority or program areas will be offered and emphasized at any given time.

Allocation of funds for challenge and foundational program RFAs is also determined by "NIFA leadership taking into account stakeholder input, previous year investments, non-AFRI program support from NIFA and other funding agencies, and scientific judgment" (USDA-NIFA, 2013h).

PROGRAM EFFECTIVENESS AND EFFICIENCY

The success of AFRI will be measured according to how well its program is able to attract the best ideas from a broad community of qualified researchers in all areas of science. For AFRI to succeed, there needs to be a well-documented and transparent process in place for managing proposals and awards. AFRI's grant-management process is fundamentally the same as that of its predecessor organization, the NRI, and is patterned after successful models used by such sister agencies such as NSF and NIH. The proposal and award-management process involves a number of steps, which are illustrated in Figure 5-2.

Request for Applications

Program announcements (RFAs) are prepared by the RFA writing group, which comprises a number of NPLs and program specialists, on the basis of the established NIFA proposal and award policy, parts of which are found on the NIFA website and at Grants.gov. The approval chain of AFRI RFAs consists of the leadership of the relevant NIFA institute, NIFA senior executives (the Science Leadership Council), the NIFA Policy Office, and the Office of the Chief Scientist.

RFAs are posted simultaneously to the NIFA website and to Grants.gov as they are released. They are also listed on the NIFA homepage as news items ("In the News") and in the NIFA Update, which are broadly distributed through seven listservs to well over 2,000 organizations, institutions, and individuals. Since FY 2011, NIFA has issued a list of RFAs that it expects to fund in the upcoming fiscal year. The list is developed before or at the start of a fiscal year with an expected date of release of each specific RFA; however, those plans are not always implemented. For example, NIFA announced that it planned to issue seven RFAs for AFRI in FY 2011, but three were actually issued. Because of delays in appropriations, RFAs are

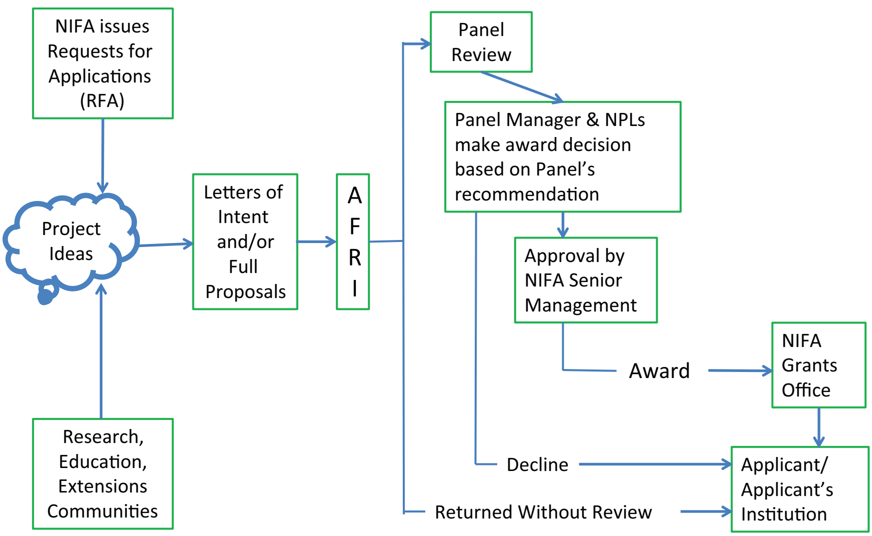

FIGURE 5-2 AFRI proposal and award process.

often issued before the budget for the fiscal year is known. As a result, RFAs are often modified after they are issued; most of the modifications are administrative, such as an extended submission deadline, rather than programmatic, such as priority areas.

Because the priority areas, the date of RFAs issuance, and the submission deadlines change from year to year, potential applicants must wait to start preparing their proposals. Therefore, the time allotted for proposal preparation becomes crucial if AFRI is to receive high-quality proposals. NIFA aims to provide at least 30 days of preparation time for letters of intent from the date of RFA issuance for most standard grant programs and at least 2 months for CAP proposals. Responses to letters of intent are to be provided within 2–3 weeks of the deadline. NIFA's goal for the preparation time for full proposals from the notification on the letters of intent is a minimum of 30 days for most proposals and 4 months for CAP proposals.

RFA activities for FY 2009–2012 are summarized in Appendix F. Individual RFAs can be found online (USDA-NIFA, 2013b). Each RFA contains information specific to the program areas that are soliciting proposals and a description of AFRI policies and procedures that are common to all program areas (with identical text). Program-specific information includes priority areas, submission deadlines, and an upper limit for the budget. If an applicant requests more than that limit, the proposal is returned without review. Most proposals request a budget at the upper limit. For challenge-area programs, which solicit mostly integrated projects or CAPs, many RFAs read like an outline of a proposal rather than like a solicitation document with detailed guidance on research, education, and extension activities that is expected or often required in a proposal. Required documentation outside the project description for CAP proposals (CVs and support documents for up to 40 co-PIs, subaward budgets from a dozen participating institutions, and the like) resulted in proposals that were 400–700 pages long.

Proposals for joint programs with other agencies are solicited separately through a joint solicitation and managed as part of the AFRI portfolio in that funds to support successful proposals come from the AFRI appropriation. The proposal-review process for joint programs varies from program to program, ranging from simple piggy-backing on the partner agencies' process to joint management of the entire process. In all cases, there is no separate scientific review of proposals identified by AFRI, and AFRI funds proposals that are highly rated by the joint review process and are aligned with AFRI's goals and objectives. All joint programs supported by AFRI are listed on NIFA's website.[3]

[3] Available online at http://www.csrees.usda.gov/funding/afri/afri_interagency_programs.html. Accessed December 23, 2013.

Proposal-Review Process

Peer review is the central component of any competitive research-grants program. For a competitive research-grants program to maintain credibility, the review process needs to be well documented and transparent. Furthermore, the system needs to have an appropriate mechanism for preventing actions that may undermine integrity. AFRI continues to follow a well-established, science-based peer-review process that was also in place with the NRI.

Once letters of intent or proposals are submitted in response to RFAs, they are reviewed according to established policies and procedures, parts of which are described on the NIFA homepage, at Grants.gov, and in individual RFAs. Panel managers and NPLs assigned to each program area are responsible for fair and thorough review of proposals. Panel managers are part-time, temporary USDA employees recruited for the sole purpose of managing AFRI proposal review, whereas NPLs are full-time, permanent USDA employees.

The panel-manager system is a modification of the rotator system used at NSF.[4] An advantage of the panel-manager system is that its part-time nature makes it easier to recruit busy active researchers to participate. A disadvantage is that panel managers are not held accountable for their decisions; accountability falls on the NPLs. Moreover, panel managers are not involved in NIFA activities at the policy level, such as strategic planning, priority setting, and portfolio management.

Conflict-of-interest (COI) rules governing the peer-review process are in place. NIFA's COI rules contain both those required by law and those imposed by NIFA. In response to the present committee's request for comments, a concern was expressed about strict adherence to the COI rules because it often requires the most knowledgeable specialists on the review panel to exclude themselves. Several commenters also noted that COI constraints often limit expert review of a particular proposal.

Panel members are identified and recruited on the basis of information obtained from the letters of intent. The panel manager and NPL assigned to each program are responsible for formulating a panel whose members are well balanced in technical expertise, gender, types of institutions, career stages, and other factors. Panels are constituted anew each year. To maintain continuity on panels from year to year, it is the general practice of AFRI programs to invite 30–50% of the previous year's panelists to return (USDA-NIFA, 2013c). AFRI tries not to ask people to serve on a review panel more than 3 years in a row.

[4] Available online at http://www.nsf.gov/about/career_opps/rotators/index.jsp. Accessed December 23, 2013.

The number of panels per program is based on proposal loads. Multiple panels can be held to review proposals submitted to a single program when the number is large. Conversely, a single panel might review proposals submitted to two or more programs that have similar or identical scientific themes when the number submitted to each program is relatively small. Occasionally, ad hoc reviewers are added as needed. Around 2006, the NRI moved away from ad hoc reviews. Continuing that practice, AFRI programs use ad hoc reviewers rarely and only to augment panel reviews when specific expertise that is not found among the panel members is needed.

Reviewers prepare reviews according to published evaluation criteria. Review criteria for the AFRI are scientific merit, qualifications of project personnel and adequacy of facilities, and relevance to program priorities, including importance of the topic for agriculture. Often, additional review criteria are used to review proposals submitted to specific programs; these are usually described in the RFAs.

Panel members submit written reviews before the face-to-face panel meetings, which are usually held in Washington, DC. On the basis of the submitted reviews, panel managers and NPLs prepare a list of proposals that received uniformly poor reviews. At the beginning of a panel meeting, the panel manager presents the list of poorly ranked proposals and asks the entire panel whether any of the listed proposals need to be discussed. If there are no objections, these proposals will not be discussed further by the panel.

For a funding decision, NIFA policy states that at least three independent written reviews are needed, reviewers' comments are advisory, and final funding decisions are made by NIFA. Nevertheless, the current practice is to consider panels' recommendations as governing. AFRI staff will override panels' rankings only to meet congressionally mandated award distributions (e.g., to states that are underrepresented in the AFRI portfolio). Table 5-9 summarizes the scale of proposal-review activities.

Face-to-face panel meetings have been the norm for conducting proposal reviews. However, a new process that combines in-person panel meetings along with virtual panel meetings is worth exploring as it takes advantage of virtual conferencing capabilities. For example, an expert provided input to the committee about his involvement in reviewing 120 nanotechnology applications using a combination of face-to-face and virtual meetings. The first meeting was a virtual panel of 24 reviewers that reduced the number of proposals for consideration in half, and a later meeting was held in-person with a 12-person panel that made the final selection of projects to be funded. This hybrid approach provides a substantial reduction in time and cost while still allowing an in-depth review at a later date that is expected from a seated panel focused on selecting the most outstanding applications.

TABLE 5-9 AFRI Proposal-Review Activities[a]

	Number of RFAs	Number of Programs	Number of Proposals	Number of Panels	Number of Panel Members
FY 2009	1	40	2,335	29	517
FY 2010	7	51	1,571	39	551
FY 2011	3	24	1,904	21	382
FY 2012	5	17	960	12	165

[a]Most data are derived from AFRI's annual synopses (USDA-NIFA, 2009, 2011a, 2012a, 2013g). Numbers of panels for all years and number of panel members for FY 2012 are from information provided by NIFA.

Post-Award Management

NPLs are assigned responsibility for managing programmatic issues that arise from AFRI awards in the post-award stage. Depending on the project type (foundational or challenge area), the size of award (standard or CAP), and the degree of complexity, an NPL may have diverse roles in the management of funded projects.

The budget of any particular AFRI program is established in advance of peer review, so the program can approximate the number of proposals that can be funded when the funding plan is presented to the Division Director and Institute Assistant Director. After peer review, funds are normally not redistributed among programs in a Division or throughout an institute on the basis of the quality or number of fundable proposals or a desired change or to balance portfolios among scientific areas or among types of research. AFRI indicated that there are far more high-quality proposals in all programs than could possibly be funded, so it is reasonable that programmatic budgets are established ahead of time because only high-quality proposals will be funded. Therefore the Division Director and Institute Assistant Director do not seem to play a direct role in determining the final funding recommendations, and the presentation of the funding plan appears to be pro forma.

Most NPLs manage both review of applications and post-award scientific programs. Thus, NPLs have both an application portfolio and an award portfolio that can be so large that it demands more time for review and constrains the time available for program management. AFRI project management includes reviews of annual reports and some direct interactions through site visits, meetings of investigators, phone calls, connections at professional meetings, and so on, depending on the complexity and nature of projects. However, the committee received comments from several grantees that there was much less post-award management of projects compared to that of other agencies.

It is unclear that the types and sizes of grants determine how many grants are in an NPL's portfolio. Based on information provided by NIFA, the workload of any particular NPL appears random. There do not seem to be any established best practices or standard operating procedures (SOPs) for programmatic post-award management, particularly for the larger, more complex awards.

The AFRI program and its predecessors have had a long-standing practice to adhere strictly to the priority ranking established through peer review. That is a laudatory goal, but it is restrictive in that it does not allow for raising proposals to meet programmatic priorities. Peer review is merely one—albeit a critical one—component of the funding decision, and there is a need to provide greater flexibility to meet the mission. Greater flexibility would allow scientific staff (including panel managers, NPLs, and Division and Institute Directors) to play a more integral role in the funding-decision process. It also allows them to use their scientific backgrounds to ensure the success of their own programs and the overall success of AFRI. With such flexibility, however, there need to be defined SOPs for recording funding decisions and establishing clear criteria for altering ranks apart from peer-review order. SOPs are essential for documenting the scientific and programmatic justification of funding decisions. AFRI does not have a second level of review itself, but one could consider the review by the Division and Institute Directors with input by NPLs as serving this purpose.

AFRI's post-award management needs improvement. Effort needs to be made to provide NPLs the necessary time and resources to provide a high level of post-award management to ensure that grants reach successful conclusions. As shown in Figure 5-3, most NPLs are dedicated to AFRI on a part-time basis. Furthermore, both full-time and part-time NPLs are involved in both review and scientific program management, and their portfolios need to be balanced by management to accommodate a baseline level of post-award activities and professional development. That means that projects may need to be redistributed among NPLs for post-award management, depending on the numbers and complexity of foundational, challenge, CAP, and standard grants in any particular portfolio.

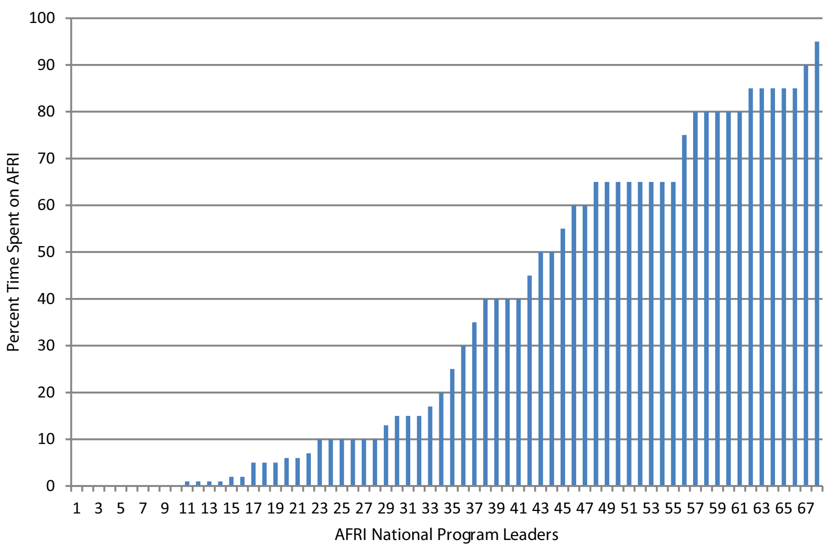

FIGURE 5-3 Time allocation for AFRI by NIFA NPL. The 68 NPLs were ranked and coded according to the percentage of their time spent on AFRI. The numbers have no implicit meaning.

SOPs for programmatic oversight are not well established, and NPLs will need to be evaluated as to their ability to provide a high level of program management.

DIVERSITY

National Institute of Food and Agriculture Policies and Programs

One of the frequently stated goals in all AFRI RFAs is to ensure diversity in the pool of grant recipients (Ramaswamy, 2013). An intended goal of AFRI was to expand the population of researchers, including nontraditional agricultural scientists, from which proposals might come and so improve the quality of the science.[5] To ensure diversity in the pool of participants, AFRI must strive for broad diversity in RFA distribution, proposal applications, review-panel composition, and grant awards.

Distribution of Requests for Applications

A wide distribution of RFAs throughout the research community would presumably maximize the diversity of researchers and organizations applying. As mentioned earlier, all RFAs are posted on the NIFA website and at Grants.gov and distributed to all land-grant universities (LGUs), Hispanic-serving institutions, Native American institutions, and many other related non-LGUs and others through listservs maintained by NIFA NPLs for the communities that they serve. NIFA believes that the entire research community typically monitors such postings and promptly distributes them among their various constituencies and that therefore the availability of the RFA announcements is sufficiently wide to meet the needs of nontraditional agricultural research communities. No data are available for judging the diversity of RFA recipients, but the breadth of distribution probably ensures that widely diverse potential applicants are fully informed.

Review-Panel Composition

NIFA notes that when assembling a review panel, the NPL and panel manager "ensure that all peer panels have a diverse pool of participants" (USDA-NIFA, 2013d). NIFA also states the following:

> **Selection of panelists and proposal review.** The program leader and panel manager aim to assemble a diverse panel active in research, education, and/or extension (as appropriate for the program) related to the subject

[5]Remarks made to the committee by William Danforth, April 1, 2013. Available on request from the Public Access Records Office, National Research Council, Washington, DC.

> matter in question. The goal is to create a balanced panel with the necessary expertise to cover the range of the proposals, while also maintaining diversity in geographical location, institution size and type, professional rank, gender, and ethnicity. Special care is taken to include panelists from minority groups and from minority-serving institutions. (USDA-NIFA, 2013c)

The committee was given summary data on panel composition generated by NIFA for all NRI and AFRI programs in FY 2007–2011 (USDA-NIFA, 2013a). During that 5-year period, an average of 473 panelists per year reviewed an average of 1,945 proposals.

Panel composition by organization is, not surprisingly, skewed toward the university community: 78% of panel members are in academe, 12% in federal agencies, 4% in industry, and 6% other. Although industry representation is low, engagement by industry researchers has always been difficult to obtain in research review panels. The direct benefits of panel membership are hard to justify in a private-sector work environment that generally does not reward public service.

The geographic diversity of the panel was broadly represented as well. According to the FY 2007-2011 summary of panel composition, average representation for the Northeast was 21%, the South 32%, the North Central 27% and the West 20%. Given the difficulty of establishing a panel due to varying demands on potential panel members' time and the need to cover certain specific disciplines, NIFA seems to have achieved reasonable geographic breadth.

An argument could be made that given the outsized need for professional expertise in panel makeup, diversity of geography, race, gender, rank, and institution might be occasionally and necessarily sacrificed, but that does not appear to have happened based on the data provided by NIFA. NIFA has succeeded in diversifying its AFRI panel membership without compromising the scientific quality of the review process.

Grant Awardees

Diversity might be considered in a number of ways in the granting of AFRI funds. Reliable data are available on the relative diversity of institutions and researchers. Those data offer a clear window into participation in AFRI programs and begin to answer the question of whether AFRI has successfully recruited a broad mixture of nontraditional agricultural scientists and nontraditional agricultural institutions.

Researcher Diversity

In AFRI, Food and Agriculture Science Enhancement (FASE) grants are intended to enhance institutional capacity and attract new scientists into agricultural research, especially in underrepresented constituencies, such as the Experimental Program to Stimulate Competitive Research (EPSCoR) states, which are considered underrepresented in federal research, education, and extension funding. NIFA's stated goal is to set aside 10% of AFRI research dollars for "strengthening awards" and predoctoral and postdoctoral fellowships grants. FASE grants, in particular, include predoctoral and postdoctoral fellowships, new investigator grants, and strengthening awards.

According to the AFRI annual synopses (USDA-NIFA, 2009, 2011a, 2012a, 2013g), FASE grants have averaged 16.8% of the total funds available, providing an average of $32 million per year. In light of limited funding, that has been on the average an aggressive response to building agricultural infrastructure. However, the actual number of researchers trained[6] as part of FASE declined by 58% from FY 2007 to FY 2012 (that period includes the last 2 years of the NRI) (Figure 5-4), and this indicates an alarming trend. Moreover, in 2011, the last year for which NIFA provided data, only 13% of predoctoral and postdoctoral applicants received awards (USDA-NIFA, 2012a) compared with 33% in 2010 (USDA-NIFA, 2011a; no other data made available). A number of those who provided testimony and input to the committee expressed that meager rates of funding can be discouraging to new, young researchers.[7] If talented young investigators in agriculture decide to look for higher funding rates outside USDA, they could alter their focus away from agricultural research; some researchers have indicated that is already happening.

A number of organizations have called for a substantial increase in funding for training and supporting the work of new researchers. Concern was expressed by the Tri-Societies (a collaborative association of agronomy, crop science, and soil sciences societies) during committee testimony (February 27, 2013) that young investigators are not being given a sufficient chance to get started and that they might well move to other, nonagricultural investigation (Volenec, 2013). In response, the Tri-Societies have proposed a focused Young Investigators Grant Program to be funded at a level of $50 million.

In the American Society of Plant Biology's survey of its membership, 50% of respondents believed that AFRI was an important source of fund-

[6] *Researchers trained* is defined by NIFA as undergraduate students, graduates, and postdoctoral scientists funded by NRI and AFRI grants. Data were provided in an Excel file titled "Training Data for NRI and AFRI programs from 2000–2012."

[7] AFRI grants are awarded to the institution, not the researcher; therefore, there are no restrictions for submitting proposals based on citizenship.

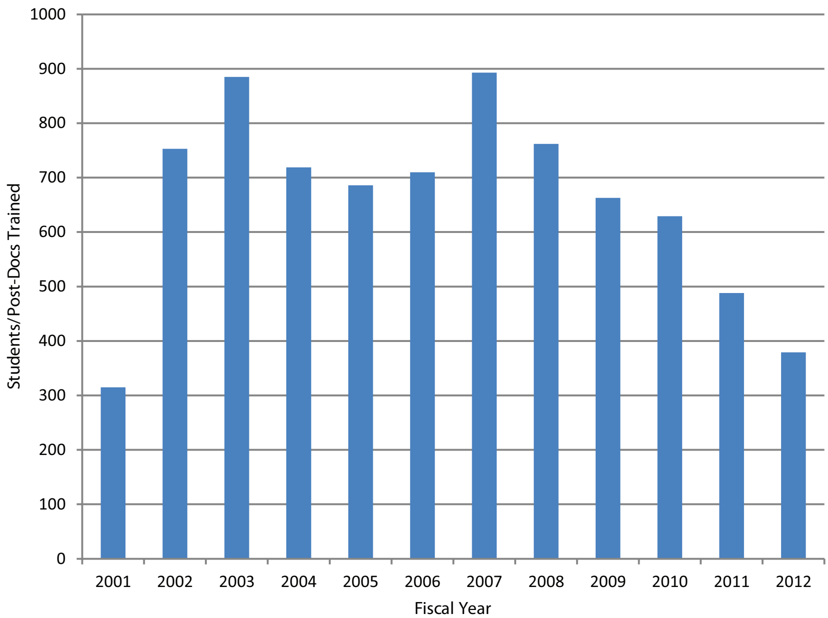

FIGURE 5-4 Number of postdoctoral, graduate, and undergraduate students trained through NRI and AFRI Programs, FY 2001–2012.
SOURCE: USDA-NIFA, 2013e.

ing for graduate students. Their concern was that in light of the history of low levels of PI funding, students would be discouraged from continuing in agriculture. They also believed that by prescribing the research topics in the RFA narrowly, AFRI was disenfranchising the best and brightest researchers.

The President's Council of Advisors on Science and Technology Report to the President (PCAST, 2012) recommended that "the USDA, in collaboration with NSF, expand a national competitive fellowship program for graduate students and postdoctoral researchers." PCAST noted a repeated concern among testifying experts that agriculture is facing a workforce deficit and that the best and brightest students are not interested in agricultural research and instead are flocking to medicine, law, and business. Fellowships for young scientists could greatly improve the talent pipeline and develop an agricultural workforce that produces needed "innovations, technology, and products for the future." PCAST's proposal was for $180 million per year for at least 5 years.

According to the AFRI annual synopses (USDA-NIFA, 2009, 2011a, 2012a, 2013g), new-investigator awards averaged $5.6 million over its

4 years of funding, 2012 being the lowest at $1.16 million. Thus, although AFRI's support in FASE grants has been above the goal on a relative basis (as a percentage of available dollars), the actual amount awarded to new investigators is well short of recommendations from those concerned with the future quality of agricultural research.

Institution Diversity

Respondents to the present committee's Web-based solicitation of input indicated that they believed that AFRI favored large, well-known institutions, especially 1862 land-grant universities (LGUs). They believed not only that the LGUs were favored because of reputation but that the complexity of the grant-application process favored universities that could provide expanded resources and administrative support to handle the paperwork. Some also believed that large institutions were advantaged because they could handle the lower than standard overhead specified for AFRI grants better, but it is clear that these institutions also submit the largest number of proposals.

At first glance, data from the AFRI annual synopses appears to support the perception of advantage enjoyed by LGUs, which on the average submitted 77% of the applications and received 79% of the dollars awarded (Table 5-10). That is not noticeably different from the last 2 years (FY 2007–2008) of the NRI awards, in which on the average 73% of the applications were from and 78% of the dollars were awarded to LGUs (USDA-NIFA, 2013h). Thus, there has not been an appreciable increase in awards to non–1862 LGUs, private universities, private research, or indus-

TABLE 5-10 Percentage of Applications Submitted, Applications Awarded, and Total Funds Awarded to 1862 Land-Grant Institutions by AFRI, 2009–2011

Fiscal Year	Applications Submitted (%)	Applications Awarded (%)	Grant Dollars Awarded (%)
2009	76.2	74.5	74.4
2010	78.3	74.0	83.3
2011	75.2	80.1	80.0
Average	**76.6**	**76.2**	**79.2**

NOTE: Percentages not accounted for include 1890 and 1994 LGUs, non-LGU public and private universities, private research, individuals, and federal institutions. No data were available for 2012.
SOURCES: USDA-NIFA, 2009, 2011a, 2012a, 2013g.

try, despite the expressed desire to expand the population of researchers receiving grants.

Although the 1862 LGUs receive the bulk of the grants, the fact that non-1862 LGUs are awarded grants in proportion to their application rate suggests that new institutions are not unduly discouraged from submitting applications. Expressed concerns range from the complexity of AFRI RFAs to investigators' enjoying a better success rate elsewhere. Some concern has also been expressed that the allowable overhead rate—30% of the federal funds awarded—deters non-LGUs from applying for grants (NRC, 2000). This amount closely approximates the total amount that other agencies allocate for indirect costs using the standard methodology of applying the federally negotiated indirect cost rates (an average of 33.8% of total federal funds) to modified direct costs. Since the two methods produce about the same proportion of funds used for indirect costs, every consideration will need to be given to remove the 30% cap and instead use the negotiated rate.

Diversity in Comparable Programs: NSF and NIH Policies and Programs for Broadening Diversity

NSF and NIH are two large comparable research-grants programs that have implemented clear policies for achieving diversity, assigned staff to establish guidelines, and carried out specific measurable activities to ensure progress. Box 5-1 and Box 5-2 describe those diversity programs.

MANAGEMENT STRUCTURE AND STAFF WORKLOAD

Management of AFRI is an ensemble effort on the part of many of the NPLs at NIFA. All but 10 of the 68 NPLs work on AFRI in some capacity (see Figure 5-3). According to data supplied by NIFA, management of AFRI programs requires 24 full-time equivalents, which are spread out over the 58 NPLs, representing an average time spent on AFRI of about 41%. In fact, one-third of NIFA NPLs spend 30–80% of their time on AFRI management. Thinly spreading the AFRI workload across a host of NIFA NPLs who have other duties seems to lead to a broadly distributed, fragmented management effort. According to both testimony and the present committee members' own knowledge, NSF and NIH use dedicated program officers to manage their grants programs from RFA through project completion.

NIFA's difficulty in answering some of the committee's questions suggested that the diffusion of responsibilities and accountabilities has left a considerable vacuum in knowledge. Such matrix-style management provides cross-functional benefits among disciplines and exploits a broader range of technical expertise, but the customer experience can be severely eroded by the time it takes to navigate the matrix.

BOX 5-1
Diversity Programs in the National Science Foundation

One of NSF's statutory functions is "to strengthen research and education in science and engineering throughout the United States and to avoid undue concentration of such research and education." Hence, broadening participation has always been one of NSF's core principles. Today, NSF has a large portfolio of programs specifically designed to increase participation of groups that are underrepresented in science, technology, engineering, and mathematics (STEM).

Broadening participation is embedded in NSF's current strategic plan.[a] Specific participation-broadening performance goals include the following:

- Preparing a diverse, globally engaged STEM workforce.
- Integrating research with education and building capacity.
- Expanding efforts to broaden participation by underrepresented groups and diverse institutions in all geographic regions in all NSF activities.
- Improving processes to recruit and select highly qualified reviewers and panelists.

Implementation strategies and assessment strategies are outlined in *Framework for Action* and *Framework for Evaluating Impacts of Broadening Participation Projects*, respectively. Both strategies incorporate collecting and analyzing diversity data on all NSF's activities and activities supported by NSF. Broadening participation is also embedded firmly in NSF's two merit-review criteria, "Intellectual Merit" and "Broader Impacts," which have been in effect since 1997. Implicit in the "Broader Impacts" review criterion is increasing the participation of underrepresented groups (e.g., gender, ethnicity, and geography) in STEM.

Details of NSF's efforts to encourage and incorporate diversity, including program portfolio and documents mentioned above, are posted at its broadening-participation website.[b]

---

[a]Available online at http://www.nsf.gov/news/strategicplan/nsfstrategicplan_2011_2016.pdf. Accessed December 23, 2013.

[b]Available online at http://www.nsf.gov/od/broadeningparticipation/bp.jsp. Accessed December 23, 2013.

BOX 5-2
Diversity Programs in the National Institutes of Health

In a study commissioned by NIH, Ginther et al. (2011) found that black applicants for NIH grants were 10% less likely than white applicants to be awarded research funding even when such variables as the applicant's educational background, training, previous research awards, and publication record are controlled for. The report notes NIH's long history of working to increase the diversity of the intramural and extramural research workforce and suggests further research into the review process.

Concurrently with the release of the Ginther et al. study, NIH chartered an internal Working Group on Diversity in the Biomedical Research Workforce (WG) to address the concern about minority-group representation. The WG built on the Ginther et al. data review and determined that, in addition to the black–white disparity, there was a large gap in the number of applications between underrepresented universities and highly funded organizations. Whether the disparity is cause or effect is not clear, but to increase diversity it was clear to the WG that NIH needed to reach out to that underserved community, especially at the young-scientist level. On the basis of the results of its investigation, the WG formulated a broad array of recommendations (referred to at one point as interventions), among them the following:

- Ensure available resources for more systematic tracking and reporting of the outcomes of trainee funding.
- Partner with established minority professional groups to implement mentor networks for underrepresented students to provide career guidance.
- Increase scholarships and fellowships for minority-group members in biomedical research.
- Fund the aggressive improvement of infrastructure in underresourced institutions that have a documented history of supporting underrepresented minority groups.
- Establish a standing working group to identify and combat biases in the NIH peer-review system, and investigate and test internal training programs for diversity awareness.
- Appoint a Chief Diversity Officer and establish an NIH Office of Diversity.

Ultimately, according to Deputy Director Lawrence Tabak in a 2012 presentation, NIH's goal is "to increase the diversity of the NIH-funded workforce because we have compelling evidence that this will help us accomplish our mission, and to ensure that all applicants are treated fairly in the peer review system."

AREAS FOR IMPROVEMENT

The committee identifies several areas for AFRI program improvement and provides recommendations here for overall and specific improvements in program management.

Finding 5-1: AFRI does not have a strategic plan for setting goals and priorities for its overall program. Consequently, AFRI's priority-setting process lacks an overall strategy and results in RFAs that lack predictability, consistency, and continuity. The lack of predictability and consistency makes it difficult for applicants to anticipate the areas and types of grants that AFRI might offer each year. In addition, the topics identified in RFAs have become too narrowly focused and restrict applicants in submitting innovative proposals that take advantage of opportunities at the cutting edge of science. Although funded projects exhibit a variety of foci, the balance has shifted away from fundamental, long-term research and toward applied, short-term research. The balance has also shifted away from individual-investigator–initiated grants toward more large-scale applied research and extension projects.

NIFA does not have an external scientific advisory council to assist in validating decisions made by NPLs and NIFA scientific leadership. For example, AFRI's process for setting priorities lacks transparency. Although requests for comments are conducted through RFAs and listening sessions, it is not clear how NIFA evaluates and uses information sources in establishing priorities. Other program-management processes—such as overall portfolio management, award decision-making, and post-award assessment—are not entirely transparent and would benefit from advice of an external advisory body dedicated to helping AFRI.

Finding 5-2: The AFRI program procedures are not clearly defined or accessible and are difficult to assess. The committee requested information about SOPs and best practices for the proposal-review process and post-award management, and it did not appear that those were available. The entire proposal-review and decision-making process is not clearly articulated in an easily accessible manner. For example, basic program information is scattered among three websites; in other agency's programs, it would typically be found on one. Some procedures (such as post-award management and the proposal-review process) are not defined or described.

Although research priorities for challenge areas are communicated in 3-year cycles, the plans have not always been implemented.

RFAs are voluminous and their content is so dense that potential applicants have difficulty in teasing out the most important information from the boilerplate language. In RFAs, each type of proposal dictates a specified upper limit of budget and award duration. The limits appear to be set arbitrarily. The timing of RFA issuance also needs improvement, and there was not adequate time for applicants to prepare proposals. The time from the announcement of a funding opportunity to the proposal-receipt deadline varies greatly from program to program. Over the course of FY 2009–2012, the time between the issuance of an RFA and the deadline for receipt of letters of intent for all programs ranged from 23 to 109 days, the average being 44 days. The time allotted to applicants between receipt of a response to the letter of intent and submission of a full proposal ranged from less than a month to over 2 months, the majority being around 1.75 months. None of the CAP programs was given 4 months of preparation time (NIFA's goal), the longest being 14 weeks. There appears to be no trend toward longer preparation time over the 4 years.

There do not seem to be any best practices or SOPs for programmatic post-award management, particularly for the larger, more complex awards. Projects may need redistribution to a number of NPLs for post-award management, depending on the numbers and complexity of foundational challenge, CAP, and standard grants in any particular portfolio. SOPs for programmatic oversight need to be well established, and NPLs need to be evaluated for their ability to provide a high level of program management.

Finding 5-3: The overall review process adheres to underlying principles similar to those of NSF and NIH, and the quality of the review process is comparable with that of other federal funding agencies, such as NSF and NIH. As previously mentioned, the peer review process is the only criterion that AFRI uses in making funding decisions. This practice differs from NSF or NIH where funding decisions are made by the agency taking programmatic goals into consideration along with the scientific merit of proposals as determined by reviewers. NPLs and panel managers exhibit a high level of commitment and dedication to conducting fair and thorough review. That panel managers are not involved in NIFA activities at the higher level (such as strategic planning, priority setting, and portfolio management) seems to constitute a missed opportunity for NIFA. NIFA's conflict-of-interest (COI) rules include both those defined by law and those based on NIFA's own policies, and the latter makes them too restrictive. It does not have a process whereby a waiver can be authorized by the NIFA conflict official in connection with rules that are not legally binding if the reviewer's involvement is deemed essential. Both NIH and NSF have well-established policies and processes to deal with such cases.

Finding 5-4: AFRI responsibilities are spread widely among 58 NPLs, and the NPLs are not provided sufficient flexibility in managing and balancing the AFRI portfolio to ensure that funded projects align with overall program goals. Many NPLs are involved in both review and program management, and their portfolios are imbalanced. It is not clear that the complexity of the type and size of grants determines how many grants are in an NPL's portfolio, as the workloads of NPLs appear to vary. Also, funding decisions seem to be based solely on peer-review rankings without consideration of portfolio balance. That occurs despite the fact that it is NIFA policy that reviewers' comments are advisory and not binding. The funding allocation for each program area is set before the award decision-making process, and this prevents AFRI NPLs and panel managers from translating the opportunities and ideas of investigators presented in their proposals into scientific opportunities.

Finding 5-5: AFRI has neither broadened nor reduced institutional participation beyond that achieved by the NRI. AFRI has achieved diverse participation in its review panels and has awarded training and EPSCoR grants on a generous basis relative to available funding. Because of AFRI's emphases in agricultural research and extension, land-grant universities are heavily represented in the pool of applicants and awardees. As NIFA communicates the RFAs and information about the AFRI program widely, the small number of proposals from non–land-grant institutions may relate to past congressional constraint on AFRI's indirect cost recovery. In the past, scientists at some institutions, mostly non–land-grant universities, were discouraged from applying to AFRI programs because of the limit on cost recovery. While this indirect cost limit has increased to a level where it is nearly equal to the average negotiated rates at most institutions, the continued existence of the indirect cost limit discourages some institutions from even considering applying for AFRI funds. If broader institutional participation is a goal, then NIFA will need to work with Congress to allow standard negotiated indirect cost recovery rates on AFRI grants.

AFRI is asked to support training programs, young researchers, new institutions, and a broad array of agricultural disciplines in addition to the traditional areas. AFRI has followed the same pattern of outreach and funding previously followed by the NRI, relying largely on LGUs to propose and conduct research in traditional agricultural sciences. With inadequate funds, that is a difficult balancing act—one in which constituents often find AFRI to be lacking. Concern was expressed by some in the applicant community that the future of agricultural science is being compromised by poor funding support and that young, innovative, nontraditional researchers will probably turn to other disciplines that are more generously funded.

The committee found it difficult to assess diversity issues because of a lack of necessary data. For example, in its request for background documentation, NIFA asks for voluntary submission of researcher ethnicity data. However, according to management's response to committee questions, fewer than 10% supply such data, possibly because it represents one more form to fill out. But committee members note that the same data are obtained by NSF and NIH as part of their background information. In some areas, AFRI has succeeded in supporting underrepresented groups of researchers and broadening review-panel diversity, but diversity policies have not been formalized at the leadership level. NSF and NIH have clear, formal internal mandates to seek out and support underrepresented organizations and scientists. Most important, those two agencies also have robust datasets on their RFA outreach and applications and on their grant recipients. Thus, they have been able to conduct analyses to determine weaknesses and put corrective policies in place. It should be noted that those two organizations are sufficiently well funded and have the necessary critical mass to pursue an aggressive diversity strategy.

REFERENCES

Ginther, D.K., W.T. Schaffer, J. Schnell, B. Masimore, F. Liu, L.L. Haak, and R. Kington. 2011. Race, ethnicity, and NIH research awards. Science 333(6045):1015-1019.

Lane, J. 2010. Let's make science metrics more scientific. Nature 464:1267.

Lichens-Park, A., and M. Mirando. 2013. Agriculture & Food Research Initiative Competitive Grants Program. Presentation made to the NRC Committee to Review AFRI, April 1, 2013, Washington, DC.

NRC (National Research Council). 2000. National Research Initiative. A Vital Competitive Grants Program in Food, Fiber, and Natural-Resources Research. Washington, DC: National Academy Press.

———. 2009. A New Biology for the 21st Century. Washington, DC: The National Academies Press.

PCAST (President's Council of Advisors on Science and Technology). 2012. Report to the President on Agricultural Preparedness and the Agriculture Research Enterprise. Washington, DC: Executive Office of the President.

Ramaswamy, S. 2013. Agriculture and Food Research Initiative (AFRI) Review. Paper read at the Presentation made to the NRC Committee to Review AFRI, February 27, 2013, Washington, DC.

USDA-NIFA (U.S. Department of Agriculture, National Institute of Food and Agriculture). 2009. AFRI. Agriculture and Food Research Initiative. 2009 Annual Synopsis. Washington, DC: U.S. Department of Agriculture.

———. 2011a. AFRI. Agriculture and Food Research Initiative. 2010 Annual Synopsis. Washington, DC: U.S. Department of Agriculture.

———. 2011b. Agriculture and Food Research Initiative Competitive Grants Program. AFRI FY 2011 Request for Applications. Washington, DC: U.S. Department of Agriculture.

———. 2012a. AFRI. Agriculture and Food Research Initiative. 2011 Annual Synopsis. Washington, DC: U.S. Department of Agriculture.

———. 2012b. Program synopsis: Agriculture and Food Research Initiative (AFRI) competitive grants program. Available online at http://www.nifa.usda.gov/funding/afri/afri_synopsis.html. Accessed April 18, 2013.

———. 2012c. Stakeholder Input. Available online at http://www.nifa.usda.gov/nea/stakeholder.html. Accessed December 23, 2013.

———. 2013a. AFRI Panel Composition. Summary for all AFRI Programs. FY07-FY11. Washington, DC: U.S. Department of Agriculture.

———. 2013b. Agriculture and Food Research Initiative (AFRI) Request for Applications (RFA) Archive. Available online at http://www.nifa.usda.gov/funding/rfas/afri_archives.html. Accessed December 21, 2013.

———. 2013c. The Peer Review Process: the National Institute of Food and Agriculture (NIFA). Washington, DC: U.S. Department of Agriculture.

———. 2013d. Synopsis of and Response to AFRI Stakeholder Feedback. Washington, DC: U.S. Department of Agriculture.

———. 2013e. Training Data for NRI and AFRI programs from 2000-2012. Presentation to the committee on April 1, 2013.

———. 2013f. AFRI Stakeholder Listening Session Feedback. Washington, DC: U.S. Department of Agriculture.

———. 2013g. Agriculture and Food Research Initiative (AFRI). 2012 Annual Synopsis—Interim Report. Washington, DC: U.S. Department of Agriculture.

———. 2013h. Analysis of AFRI in Relation to the 2008 Farm Bill Priority Areas. Washington, DC: U.S. Department of Agriculture.

———. 2013i. Developing Program Priorities. Washington, DC: U.S. Department of Agriculture.

———. 2013j. Current AFRI Coordinated Agricultural Projects. Washington, DC: U.S. Department of Agriculture.

Volenec, J.J. 2013. ASA-CSSA-SSSA's expection/view of AFRI. Paper read at the presentation to the NRC Committee to Review AFRI, Washington, DC.

Wadman, M. 2010. Study says middle sized labs do best. Nature 468:356-357.

6

Conclusions and Recommendations

At the beginning of its review process, the committee considered the importance of a national research program specifically targeted to the food and agriculture sector. It asked many questions, including these: What is the unique role, if any, of publicly funded agricultural research? How critical have research and development (R&D) been for increasing and maintaining the productivity and sustainability of the nation's agriculture and food sectors? How does the United States compare with other nations in R&D investment in those sectors, and is this investment sufficient for generating the productivity growth and agricultural knowledge that are needed to meet projected needs? Those questions and others helped to set the context for addressing elements of the committee's Statement of Task (see Chapter 1, Box 1-1) that focused on assessing the Agriculture and Food Research Initiative (AFRI). The committee was mindful of the authorizing language in the Food, Conservation, and Energy Act of 2008 (known as the 2008 Farm Bill), which defined the goals and priorities of the AFRI program. The Agricultural Act of 2014 (known as the 2014 Farm Bill) was passed as the committee was completing its report but did not change AFRI's authority substantively despite including some changes in AFRI activities.

The preceding chapters have concentrated on specific elements of the committee's Statement of Task, many of which concern AFRI program functionality and effectiveness. They each outline findings that address specific questions that are included in the Statement of Task. Taken together, these questions led the committee to a broader discussion about AFRI's importance and about what AFRI needs if it is to succeed as the major competitive grants program of the U.S. Department of Agriculture

(USDA). In keeping with the charge to evaluate AFRI, the present chapter provides overarching conclusions and recommendations that resulted from that broader discussion.

NEED FOR FOOD AND AGRICULTURE RESEARCH

U.S. public investment in food and agricultural R&D has contributed substantially, both domestically and internationally, to the public good. The 2012 *Report to the President on Agricultural Preparedness and the Agriculture Research Enterprise* by the President's Council of Advisors on Science and Technology (PCAST, 2012) independently recognized the value of that investment, the importance of competitive grants to ensure the highest-quality R&D effort, and the growing mismatch between the magnitude of the investment used to fulfill the promise of contemporary scientific opportunities versus the magnitude of investment needed to meet present and projected domestic and global needs in food and agriculture. For instance, the needs of 9.6 billion people by 2050 (World Resources Institute, 2013) and the last decade's steady decline in the U.S. relative share of global agriculture and food system R&D are in sharp contrast with the nation's more appropriate response to opportunities in the biomedical and other basic sciences—a response that has produced substantial public-health benefit. Similarly, investment in defense-related research has led to remarkable returns, for example, in information technologies.

AFRI was created with the ambition of using the nation's most creative minds in research, education, and extension to address issues fundamental to human and social well-being. However, continued weakness in the public commitment to food and agricultural R&D is likely to lead to a steady decline in global competitiveness of U.S. food and agriculture production and an inability to respond adequately to health, sustainability, and environmental challenges in this important sector.

CONCLUSION 1: AFRI plays a critical and unique role in the nation's overall R&D portfolio because its mandated scope, mission, and responsibilities are focused on the most important national and international challenges facing food and agriculture. But it has not been given the adequate resources needed to meet contemporary and likely future challenges. Congress established AFRI to manage and carry out research that would address complex national and multistate issues in agriculture and food. The scope, intensity, complexity, and urgency of those issues have been increasing, and demands on AFRI exceed what can reasonably be expected given AFRI's recent funding levels. When AFRI was launched in 2008, the National Institute of Food and Agriculture (NIFA) made program management decisions on the basis of an assumption that appropriations would grow to authorized levels over the next several years. That assumption was not borne out, and many multiyear grants encumbered future years' appropriations. Although AFRI funding is growing, it has still not reached authorized levels.

RECOMMENDATION 1: The United States should strengthen its public investment in competitive agricultural R&D to ensure that it continues its role of a global leader in the innovations and technologies that are needed to promote health and well-being and to feed growing worldwide populations sustainably. AFRI's prospects for success in meeting stated goals and outcomes would improve if its funding and other support elements (such as reporting structures and monitoring abilities) were commensurate with the program's legislatively mandated scope.

REALIGNMENT OF PROGRAM STRUCTURE TO MATCH MISSION, MANDATE, AND BUDGET

When the 2008 Farm Bill replaced the National Research Initiative (NRI) with AFRI to "make competitive grants for fundamental and applied research, extension, and education to address food and agricultural sciences" (see Appendix C), the scientific community envisioned AFRI as USDA's opportunity to create a scientific grants agency for food and agriculture that would be equivalent in scope and stature to the National Science Foundation (NSF) and the National Institutes of Health (NIH). The 2008 Farm Bill established six priorities for AFRI: plant health and production and plant products; animal health and production and animal products; food safety, nutrition, and health; renewable energy, natural resources, and environment; agriculture systems and technology; and agriculture economics and rural communities. Those priorities formed the basis of AFRI's Foundational Program.

In attempting to understand AFRI's mission and structure, the committee requested a NIFA organization chart of units that were affiliated with AFRI and a diagram that showed AFRI's program structure. After several rounds of correspondence, it remained unclear to the committee how NIFA viewed AFRI's mission, how AFRI was structured, and who had direct reporting responsibilities for grant administration. The committee therefore assumed that AFRI's mission was to follow the 2008 Farm Bill's authorizing language. Later communications with NIFA provided a more explicit basis for understanding AFRI's program structure. The committee determined that AFRI maintains two program areas (challenge and foundational), five challenge priority areas (childhood-obesity prevention, climate change, global food security, food safety, and sustainable bioenergy), six foundation priority areas (plant health and production and plant products; animal health and production and animal products; food safety, nutrition, and health; renewable energy, natural resources, and environment; agriculture systems and technology; and agriculture economics and rural communities), and five grant types (standard project, coordinated agricultural project, planning and coordination, conference, and food and agricultural science enhancement). The committee concluded that the structure was unnecessarily complex.

The USDA competitive grants program was restructured in 2010. As part of the restructuring, NIFA established a new AFRI grant category that was intended to attract a wide array of disciplines and expertise to successfully address the most demanding, complex issues in food and agriculture. The challenge-area program was based on a multidisciplinary approach to problem solving. NIFA used the societal topic categories outlined in the National Research Council's *New Biology* report (NRC, 2009) as a basis for identifying childhood-obesity prevention, climate change, global food security, food safety, and sustainable bioenergy as its challenge areas. It also established a multiyear, large-scale Coordinated Agricultural Project (CAP) grants program funded by substantial investments to address key societal concerns—an approach that USDA had previously taken with only a handful of NRI grants. This high-stakes, potentially high-rewards approach for bringing about grand solutions and the impetus for moving the approach forward were based on the assumption that funding would reach authorization levels outlined in the 2008 Farm Bill.

The goal of AFRI's new challenge-area program is worthy—it answers previous demands for incorporating multidisciplinary approaches to complex, pressing issues, and it brings resources to bear on high-profile problems. But the size of AFRI's budget does not allow a reasonable prospect of satisfying its congressional mandate to focus research on the six discipline areas of the 2008 Farm Bill (those areas remained the same for the 2014 Farm Bill) while adopting an ambitious grand-challenges research approach as other agencies have done, such as NSF and NIH. CAP grants have consumed an exceptionally large portion of AFRI's annual appropriations. Meeting the multiyear commitments has reduced the funds available for smaller-scale, more traditional, investigator-initiated grants—a development that, not surprisingly, is associated with a reduction in the number of applicants for AFRI grants relative to AFRI's predecessor (see Figure 3-3). Emphasis on CAP grants and challenge areas has coincided with a growing year-to-year inconsistency in AFRI's project portfolio (see Appendix F), which is unsustainable in itself and insufficient if the various legislative mandates are to be satisfied. Such inconsistency may be one explanation for the absolute decline in AFRI grant applications. The diversion of a large proportion of resources to CAP grants and challenge areas has impaired the flexibility needed to address emergent issues.

CONCLUSION 2: AFRI is unnecessarily complex, difficult to depict clearly, and characterized by overlapping components that do not clearly align with priorities identified in authorizing legislation. Program complexity impedes the measurement of progress relative to clear goals. The multiplicity of grant types, each with its own priorities that change from year to year, contributes to a sense of programmatic inconsistency and unpredictability. Proliferation of priority areas also has resulted in AFRI's inability to satisfy its congressional mandates.

RECOMMENDATION 2: NIFA should simplify the AFRI program structure by realigning it to more clearly address its specific mission and mandates as defined in authorizing legislation. Simplification of program structure to focus on the six foundation priority areas would improve efficiency, effectiveness, and transparency.

Rebalancing the Portfolio

AFRI's ambitious portfolio of multiple grant types is undercutting its mission to support fundamental research, which generates critical knowledge and tools for future applications. Federal support is essential to increase the storehouse of fundamental knowledge, and AFRI will need to solicit and fund applications that advance basic agricultural sciences. The 2008 Farm Bill specifies that grant funding for fundamental research should amount to 60% of the AFRI portfolio, with the remaining 40% for applied research. With a large proportion of AFRI's budget dedicated to addressing grand challenges, the focus of the program has shifted toward applied science at the expense of fundamental research. Given its limited budget, if AFRI continues with that approach, the scientific workforce available to conduct fundamental research in the agricultural and food sciences may continue to diminish.

Conclusion 2-A: Fundamental research is critical to provide the knowledge base upon which future discoveries will be made, and expanding the stock of fundamental knowledge is AFRI's primary purpose. The balance of fundamental and applied research, however, has shifted toward the applied, with extension and education components mainly

included as supporting elements of research grants. Projects whose principal aim is the development of fundamental innovations in research, education, and extension receive less funding. The request-for-application (RFA) topics specified for foundational grants are increasingly narrow in scope and weighted toward applied research. NIFA will need to rebalance the AFRI portfolio toward the proportions described in the 2008 Farm Bill and broaden its foundational grants areas to encourage investigator-initiated applications in basic science.

Recommendation 2-A: To realign AFRI's portfolio with its legislative mandate, NIFA should renew its priority for fundamental research. That should include an emphasis on proposals that will generate fundamental knowledge to support novel technologies, provide platforms for extension and education, and educate the next generation of food and agricultural scientists. Basic research on topics in the six priority areas will be more effectively communicated to users and students if there is more research conducted directly on extension or educational processes, such as training on the use of new technology, and if there are additional educational programs. Less than 11% of AFRI funding is dedicated to extension and education (see Table 4-1). New grants are needed that are specific to extension and education in order to effectively communicate the research community's findings to user communities, enabling AFRI's fundamental and applied research to become better integrated and knowledge transfer to be more efficient in classroom and field settings.

The Challenge-Area Program

Conclusion 2-B: The current AFRI challenge areas are narrowly focused on specific issues, and the challenge and foundation priority areas are unnecessarily redundant. The challenge areas are focused on five societal challenges determined by NIFA, and the foundation priority areas follow the six outlined priorities that are authorized in the 2008 Farm Bill. The challenge areas are prescriptive and focus on specific problems of interest (such as climate change), which were predetermined at the inception of the program in 2010. For that reason, the challenge areas have been perceived by the committee and the scientific community as lacking flexibility to address newly emerging problems and to incorporate rapid advances in science and technology. That is in contrast with the foundation priority areas (such as plant health and production and plant products) that are categorized by disciplines that span food and agriculture.

Recommendation 2-B: As part of its realignment, AFRI should be simplified by eliminating the challenge-area program, and areas of research within the foundational program should be primarily investigator driven. Rather than dividing resources among two categories of programs (challenge and foundational), NIFA could focus its resources on one program (the foundational program). Redirection of resources to the foundational program, whose priority areas directly reflect priorities aligned with the 2008 Farm Bill, would enable AFRI to address more clearly the six congressionally mandated priorities. The six priority areas are broad enough to allow investigators, teams, and institutions to develop innovative projects that address current and expected needs in food and agriculture (including topics that are the focus of the challenge-area program) and to incorporate advances in science and technology in a timely manner. Such a realignment would enable AFRI to fund the most innovative investigator-driven projects and enable NIFA to take full advantage of the intellectual resources in the U.S. scientific community. Multidisciplinary approaches, championed by the current challenge-area program, are critical for successfully addressing many of the challenges in food and agriculture that the AFRI program is expected to address. Such multidisciplinary approaches, where appropriate, can and should be incorporated into the foundational program.

The Decline in Applicants, Awardees, and Trainees

Conclusion 2-C: The recent decline in the numbers of applicants, awardees, and trainees is a disturbing trend. It raises questions: Are scientists "following the money" and moving away from agricultural research? Are young scientists not being trained in agriculture? Young scientists are trained by principal investigators (PIs) who have grant funds to equip their laboratories and to mentor students and postdoctoral scholars. On the basis of the committee's review of the number of graduate students and postdoctoral trainees supported by AFRI grants, it appears that students are increasingly being trained with funds from other federal agencies that have larger budgets. If sufficient competitive research funds are not available in agriculture for funding research and for training young scientists, researchers will seek out a larger portion of their overall support from agencies whose missions are not directly aligned with the food and agriculture sectors. In the long term, food and agriculture will lose talent to other fields of study that have stronger support.

Recommendation 2-C: AFRI should carefully examine the causes of the decline in the numbers of applicants, awardees, and trainees and adjust its grant programs to ensure that future generations of young scientists are not lost inadvertently from food and agriculture R&D because of funding policies.

Coordinated Agricultural Project Grants

Conclusion 2-D: The current AFRI appropriation cannot sustainably support the current policy of investing a disproportionate percentage of the AFRI budget on large CAP awards and simultaneously sustain a credible program of foundational, training, and Food and Agricultural Science Enhancement grants. The shift to funding fewer, higher-amount, and longer-term CAP grants also appears to have resulted in the early decreased output of scholarly products per dollar of AFRI funds invested. Adjusting for the time since project initiation, there is evidence that the large project scope and complexity of these grants have resulted in fewer scholarly products (publications, papers, and presentations) per fixed amount of funding than was the case with less complex, smaller grants. High intraproject management and transaction costs required for very large projects have likely contributed to this phenomenon. The finding applies to large AFRI grants generally but especially to CAP grants. Early output data suggest that reducing the average project's scale and scope (represented by budget and number of PIs, respectively) would improve the output of scholarly products, at least in early phases. The committee is not saying that large grants are inappropriate, only that its early analyses show that as the scale of grants rises, the marginal output of published papers falls over the period that was examined. The committee recognizes that high transaction costs may in some projects be more than offset by the importance of the contributions in addressing the targeted problems (e.g., multi- and transdisciplinary collaboration in the broad research community).

Recommendation 2-D: AFRI should consider eliminating CAP grants as a grant category and committing more resources to other grant types. A grant's multi-investigator structure should be driven by its underlying science. Unless the net benefits of larger, complex projects can be objectively demonstrated or AFRI's budget is increased substantially, AFRI should consider reducing the proportion of its assets that is devoted to very large projects and instead emphasize a greater simplicity of function and PI structure. NIFA should continue to encourage multi-institution and multi-investigator grants as part of AFRI's foundational program and request that PIs develop budgets and project personnel that are commensurate with the proposed level of effort. Such large-scale proposals should be required to demonstrate how grant administration and transaction costs will be commensurate with the proposed effort. Because developing a multifunction, multi-institutional grant entails a large investment of time and planning, a staged development process (e.g., a planning-grant program) for large grants should be considered.

STRATEGY AND COLLABORATION

AFRI's research, extension, and education portfolio is appropriately targeted to meeting the nation's food and agricultural needs. However, its success depends on the generation of fundamental knowledge and the flow of new knowledge generated by other federally funded and private-sector research. AFRI can maximize its impact and resources by collaborating with other federal agencies and by strategically aligning its research with congressional mandates that target the highest-priority needs of the food and agriculture sectors.

CONCLUSION 3: AFRI does not have clearly articulated plans to guide its priority setting, management processes, and interagency collaboration. To evaluate AFRI's success it is critical to define goals and outcomes and thus enable the assessment of progress in meeting them. NIFA provided the committee with several documents that described a roadmap explaining how the challenge areas were developed to take into consideration the societal challenges outlined in the National Research Council *New Biology* report (NRC, 2009) and pointed to individual RFAs for specific goals in each of the priority areas. But it did not provide a statement of overall goals, time frames for meeting them, or planned outcomes for assessing progress. For the purpose of the present review the committee assumed that the goals of AFRI were synonymous with those stated in the 2008 Farm Bill which were unchanged in the 2014 Farm Bill.

RECOMMENDATION 3: AFRI should develop a strategic plan that identifies priorities for its overall program goals for meeting them and a framework for assessing the program's progress. Such a plan is critical for providing program continuity, consistency, and predictability. A strategic plan would include a clear vision statement and strategies for implementing priorities. To develop a strategic plan NIFA could revisit the intent of AFRI and broadly define acceptable topics so that AFRI programs can achieve greater flexibility. The plan could include less restrictive RFAs for which PIs can propose unconventional ideas and take more flexible approaches to the six broad priority areas mandated by the 2008 and 2014 Farm Bills.

Interagency Collaboration

Conclusion 3-A: Interagency efforts directed at food and agriculture need to be more strategic, more robust, and better coordinated across federal agencies. Several other federal agencies—such as NSF, NIH, and the Department of Energy (DOE)—provide grants and conduct research in subjects tangentially related to food and agriculture, but USDA is the only federal agency whose mission is aimed directly at food and agriculture. To further USDA's mission and to leverage the efforts of sister agencies, USDA will need to take on a greater leadership role in coordinating research efforts across agencies.

Recommendation 3-A: NIFA and USDA should lead interagency efforts to effectively coordinate and collaborate across agencies on food and agricultural research. NIFA has been successful in collaborating with NSF, NIH, DOE, the National Aeronautics and Space Administration, and other agencies to support research on subjects of mutual interest, but the increasingly complex issues that face the food and agricultural sectors require more systematic efforts to ensure that AFRI programs maintain effective collaboration among federal agencies whose research programs are related to food, agriculture, human health and nutrition, and natural-resource systems while continuing to avoid unnecessary duplication. NIFA should take a leadership role in coordinating food and agriculture research throughout the federal R&D funding portfolio and lead an interagency working group to leverage investments that will continue to advance the knowledge base on food and agriculture.

External Advisory Council

Conclusion 3-B: AFRI needs an external advisory council to validate its strategic direction and to provide valuable guidance to national program leaders (NPLs) on programmatic decisions. Unlike NIH and NSF, AFRI does not have a formal, external, and strictly scientific advisory council. Such a council would be highly valuable for the following functions of the AFRI program: to guide, advise on, review, and assess on an ongoing basis priority setting, resource allocation, program policies, and peer-review and award-management processes. NIH and NSF each have advisory groups on which NIFA could model its AFRI Scientific Advisory Council.

Recommendation 3-B: NIFA should form an AFRI Scientific Advisory Council that consists of members who represent the food and agricultural research, education, and extension professional communities. Such a council should provide scientific advice and advisory oversight on all aspects of AFRI's program management and strategic planning, and council members should be selected based on their qualifications to perform these functions. The council would be similar to the scientific advisory councils used by NIH and NSF to help to validate the program's direction (e.g., priority setting for research, education, and extension) and substantial changes in program structure (see Box 6-1). In contrast with the National Agricultural Research, Extension, Education, and Economics (NAREEE) advisory board, which advises the Secretary of the U.S. Department of Agriculture on all four topics (research, extension, education, and economics), the AFRI Scientific Advisory Council would specifically be designed to advise the AFRI program. This proposed AFRI Scientific Advisory Council might be possible within existing authority and funding (e.g., as part of the NAREEE authority); however, the committee does not prescribe how NIFA should seek this scientific advice.

PROGRAM MANAGEMENT

As mentioned in Chapter 5, the committee requested an organization chart and other information in an attempt to understand the structure of AFRI and how it was managed. The committee was unable to get complete information on those matters. On the basis of the responses provided, it appears to the committee that the AFRI structure is unnecessarily complicated and is characterized by an elusive chain of command. This complexity and lack of transparency has led to inefficient program management and operation. Given the goal of setting up the new program, developing program priorities, and balancing its portfolio to satisfy its congressional mandate, the committee expected that NIFA leadership would provide higher visibility for the program. AFRI is a program within NIFA that appears to be orphaned in that there is no clear line of leadership, strategy, and policy. However, the AFRI proposal-review and funding-decision processes that were set up during the National Research Initiative (NRI) and continue with AFRI appear to be rigorous and effective in selecting and funding high-quality science.

BOX 6-1
A Scientific Advisory Council for the Agriculture and Food Research Initiative

Each institute and center of NIH has a scientific advisory body.[a] Members represent professional communities and patient advocacy groups. The National Institute of General Medical Sciences (NIGMS) has a mission similar to that of AFRI: to provide support for foundational research and training of the next generation of a diverse workforce in biomedical sciences. Its Advisory Council consists of leaders in the biologic and medical sciences, education, health care, and public affairs. Members are appointed for 4-year terms and meet three times a year. The council performs a second level of peer review for research and research-training grant applications assigned to NIGMS. Council members also offer advice and recommendations on policy and program development, program implementation, evaluation, and other matters of importance to the mission and goals of NIGMS.

In NSF, each directorate and office has an external scientific advisory body.[b] The advisory committees "provide advice and recommendations to maintain high standards of program support for research, education, and infrastructure; to facilitate policy deliberations, program development, and management; to identify disciplinary needs and opportunities; and to promote openness to the research and education community served by NSF." Unlike NIH's advisory councils, NSF's advisory committees do not have responsibility for second-level review of proposals. However, they provide advice on program management, overall program balance, and other aspects of program performance through subcommittees called "Committee of Visitors."[c] NSF's advisory committees are made up of researchers, administrators, and educators in diverse communities. In the case of the Directorate for Biological Sciences,[d] members constitute a cross-section of biology with representatives of many subdisciplines in the field and other relevant fields, such as informatics and bioengineering; a cross-section of institutions, including industry; a cross-section of geographic areas; and a cross-section of women and underrepresented minorities.

---

[a] See http://www.nigms.nih.gov/About/Council/Pages/default.aspx. Accessed December 23, 2013.

[b] See http://www.nsf.gov/about/performance/dir_advisory.jsp. Accessed December 23, 2013.

[c] See http://www.nsf.gov/about/performance/visitors.jsp. Accessed December 23, 2013.

[d] See http://www.nsf.gov/bio/advisory.jsp. Accessed December 23, 2013.

CONCLUSION 4: AFRI's complex and diffuse management structure has made it difficult to efficiently and effectively manage the program. AFRI has many stakeholders it needs to be responsive to: Congress, the administration, various producer groups and interests, numerous scientific disciplinary interests, and consumers. AFRI also needs to more explicitly track—and track for longer periods—the outcomes and contributions of the research that it funds.

RECOMMENDATION 4: To enhance program accountability and management, AFRI should have a dedicated leader who manages the program on a daily basis. Improved processes and procedures should be created for transparency, and AFRI's NPLs should be granted greater authority and flexibility to meet stated goals.

Agriculture and Food Research Initiative Director

Conclusion 4-A: AFRI is managed collectively by many people. No single administrator is responsible for overall program management or accountable for AFRI's performance. As a result, program goals and internal operating procedures are not clearly articulated.

Recommendation 4-A: NIFA should establish a clearer organizational structure and lines of authority for AFRI, including a designated director to lead, manage, and speak for its program, and NPLs dedicated to AFRI alone. The AFRI entity could be analogous to NIH's National Institute of General Medical Sciences. In such a reorganization, NIFA should concentrate the workload of AFRI on an appropriate number of dedicated NPLs who interact directly with AFRI applicants and are accountable for the grants review and management process, including post-award management and assessment of overall program performance and balance. Concentrating AFRI management functions in the hands of selected NIFA staff should improve management efficiency without necessarily increasing total management effort.

Program Continuity and Transparency

Conclusion 4-B: The AFRI applicant community expressed frustration with the discontinuity of AFRI's program offerings from one year to the next, which has impaired researchers' ability to plan, resubmit unsuccessful proposals, and renew successful projects. For foundational programs, the committee received comments from applicants and panel managers that the highly prescriptive nature of RFAs discourages submission of innovative ideas. Paperwork was also long and burdensome for applicants. Furthermore, research priorities were often not communicated in a timely manner, resulting in unnecessarily extended lags between grant cycles. AFRI's success will be determined in large part by how well the program attracts the best ideas from a broad community of qualified researchers in an array of disciplines.

Recommendation 4-B: NIFA should have a more consistent and predictable program portfolio and funding strategy to enable better planning by the food and agricultural research community. The predictability and continuity of the grants program are critical for the development of the research capacity for food, agriculture, and natural resources, particularly for young faculty seeking to establish effective research programs.

In addition, NIFA should consider publishing a single document that provides clear guidelines and policies for proposal preparation and award management. That would help in streamlining the RFA process and would eliminate confusion and excessive paperwork and thus not only help the applicant community but reduce the burden for AFRI program staff. As part of its plan to increase transparency, NIFA should publish a clear description of the AFRI review process, as NSF does on its merit-review Web site[1] and NIH on its peer-review Web site.[2] NSF's proposal and award policies and procedures guide[3] constitutes an example of the type of guide needed for AFRI.

Data Management

Data are needed to inform management decisions and improve assessments of program efficiency and effectiveness. NIFA was unable to provide the committee with data needed for addressing many aspects of the committee's tasks. Some of the data had not been collected, and some were internally inconsistent or could not be easily interpreted or summarized. One aspect that the committee was specifically tasked to examine was diversity of people and institutions supported by AFRI. AFRI does not collect additional data that would enable a robust assessment of the diversity of program applicants or awardees. On the basis of data on awarded projects, the committee found that AFRI is awarding grants to public and private institutions and to land-grant universities and non–land-grant universities in nearly the same ratios as did the former NRI program and approximately in proportion to the number of proposals emanating from such institutions.

Conclusion 4-C: The AFRI program lacks a sufficiently robust information-management system and metrics for measuring key pro-

[1] See http://www.nsf.gov/about/performance/visitors.jsp. Accessed December 23, 2013.
[2] See http://grants.nih.gov/grants/peer_review_process.htm. Accessed December 23, 2013.
[3] See http://www.nsf.gov/pubs/policydocs/pappguide/nsf13001/index.jsp. Accessed December 23, 2013.

gram impacts. The Current Research Information System (CRIS)[4] used by NIFA was not designed as a tool for managing competitive funds and is an inadequate aid for program-management decisions: it is difficult to navigate and manipulate for programmatic needs and not readily compatible with other systems. AFRI needs an information-management system that can provide the accurate information that is necessary for structured analyses of program activities and for analyzing and assessing project and programmatic outputs and outcomes. Conducting performance analyses will require systematic attention to medium-term and long-term outputs and, more importantly, projection of outcomes in the form of the science influenced, social and individual well-being, and products and incomes generated.

Recommendation 4-C: NIFA should use a more robust information-management system that would provide a basis for AFRI policy and strategic planning. The system should allow detailed assessment and management of the food and agricultural competitive research funding pool. Data collection would need to be comprehensive, and this would require a redesigned and expanded CRIS that would be responsive to AFRI's needs and capable of communicating with other federal research-analysis systems. The system would apprise NIFA management and others of AFRI program and project performance, document the scientific and technological products of AFRI grantees, and respond to congressional and public requests for AFRI information. Such a database is critical for conducting post-award monitoring and enabling managers to measure the outputs and outcomes of AFRI research more effectively. Other funding agencies, such as NIH and NSF, are constantly working to improve their information-management systems, and NIFA should work with them toward a system that would be interoperable across agencies.

Post-Award Management

Conclusion 4-D: NIFA needs clearly defined metrics for measuring program outputs and outcomes that allow program managers to assess the value of AFRI-funded research. Project-output assessment affords only one perspective on the performance of AFRI. Some valuable benefits and contributions of the program cannot be captured by assessments of program outputs alone. Examples of the other benefits are such outcomes as AFRI's role in encouraging graduate students and young

[4] As of the writing of this report, the committee is aware of USDA's plans to retire CRIS and to replace it with another reporting system.

scientists to develop careers in food and agriculture, its role in advancing the quality of agriculture and food science and in increasing the knowledge base, and its contributions to the innovations that underpin economic development. Appropriate changes are needed to give NPLs the time and resources needed to provide a higher level of post-award management (including post-termination monitoring) designed to ensure that grants reach the most successful conclusions and outcomes attainable.

Recommendation 4-D: NIFA should develop the capability to regularly evaluate AFRI projects in terms of their outcomes, which would allow assessment of the economic and social impacts of the research that AFRI supports. In addition to the standard bibliometric measures, quantitative rates-of-return and qualitative outcomes assessments will need to include such information as important scientific advances, concrete economic impacts, patents, young-scientist training, and improvements in processes, products, or productive jobs. Both output analyses and outcome analyses will require NIFA to maintain post-termination relationships with its grantees after projects have ended and allow it to chart, for example, the progress of graduate students and young scientists who were supported by AFRI funds. To facilitate more comprehensive program assessment, AFRI should maintain post-termination relationships with grantees to monitor and document medium-term and longer-term outcome-related information.

Greater Authority for National Program Leaders

Conclusion 4-E: In their project-funding decisions, NPLs are tasked to ensure that a maximum number of high-priority issues are addressed and that funded projects align maximally with program goals. Yet NPLs have been unnecessarily constrained in their efforts to manage and balance the AFRI portfolio. The committee noted several ways in which NPLs were constrained in participating in funding decisions that would allow a better portfolio balance to align with AFRI's mission and goals. For example, funding decisions are typically based solely on peer-reviewed rankings without consideration of the funding portfolio's programmatic balance. That continues to occur despite NIFA's policy that reviewers' comments are advisory and not binding. Funding allocations to program areas are set before the award decision-making process, and this can limit the ability of NPLs to capitalize on innovative ideas presented in proposals and to pursue the most promising scientific opportunities.

Recommendation 4-E: NIFA should establish standard operating procedures (SOPs) that provide greater opportunity for NPLs to contribute to final project-funding decisions. Although peer-review ranking should be a principal factor in guiding the AFRI funding process, AFRI should consider portfolio and programmatic balance and take steps to achieve an appropriate balance when making final funding decisions. Such considerations would include balancing various food and agricultural issues and various scientific disciplines; the types of awards (e.g., high-risk, high-payoff projects); and the diversity of investigators, institution types, and geographical distributions. SOPs governing the process should be transparent, outline the criteria for balancing the portfolio, and include a mechanism for moving an allocation from one program area to another when overall program balance is needed. As mentioned in Chapter 5, AFRI's large awards have taken more time to review and manage than has apparently been allotted, raising post-award administration costs above those in other agencies. The advisory council recommended above (see Box 6-1) could be used in some manner to provide independent assessments of programmatic decisions. NPLs are PhD-level scientists in good standing in their own disciplinary communities who were recruited to manage AFRI grants on the basis of their scientific credentials, and they should be trusted to exercise their professional judgment. With such new responsibilities, the portfolios of AFRI NPLs would need to be rebalanced to allow proper attention to programmatic direction and post-award scientific management. SOPs would also need to include a mechanism for training new NPLs and panel managers.

CONCLUDING REMARKS

During the time the committee was conducting its review, Congress passed the 2014 Farm Bill and appropriated an increase in funding for AFRI in FY 2014. The reauthorization of the Farm Bill did not change the priorities for AFRI, reaffirming the importance of this program to sustain the nation's preeminence in knowledge generation and technology advances in the food and agricultural sectors. However, the 2014 Farm Bill contained a provision requiring non–land-grant universities to match funds for AFRI grants. This approach is counterproductive to the goal of attracting the broadest array of the nation's top scientific talent to research and to bringing nontraditional and novel approaches and solutions for food and agricultural challenges. In the future, NIFA should acquire data to determine the impact of this requirement on non–land-grant entities participating in the AFRI program.

NIFA and its AFRI program are essential elements of USDA and will be critical for enhancing the knowledge base needed to successfully address important issues in agriculture, food, and natural resources. The increase in FY 2014 appropriations for this flagship competitive research program is consistent with this report's findings, conclusions, and recommendations and applauded and suggests that USDA has a window of opportunity to establish NIFA as a strong science agency with AFRI at its core and to reinforce the value and mission of AFRI to the nation's well-being. The committee offers its recommendations in the hope that the suggested programmatic changes will enable NIFA to fulfill its mission of leading the food and agricultural sectors to a better future through research, education, and extension.

REFERENCES

NRC (National Research Council). 2009. A New Biology for the 21st Century. Washington, DC: The National Academies Press.

PCAST (President's Council of Advisors on Science and Technology). 2012. Report to the President on Agricultural Preparedness and the Agriculture Research Enterprise. Washington, DC: Executive Office of the President.

World Resources Institute. 2013. Creating a sustainable food future: A menu of solutions to sustainably feed more than 9 billion people by 2050. World Resources Report 2013-14: Interim Findings. Available online at http://www.wri.org/publication/creating-sustainable-food-future-interim-findings (accessed July 30, 2014).

A

Biographical Sketches of Committee Members

Dr. Victor L. Lechtenberg (*Chair*) is special assistant to the president at Purdue University. Dr. Lechtenberg has served Purdue in several roles, most recently as acting provost from 2012 to 2013. He was vice provost for engagement from 2004 to 2011, interim provost from 2007 to 2008, and interim vice president for governmental relations from 2008 to 2009. Dr. Lechtenberg joined the Purdue faculty as assistant professor of Agronomy in 1971 where he taught crop science and conducted research on forage and biomass crops until 1982. He served as associate director for agricultural research and then as executive associate dean of agriculture from 1982 to 1993. He was dean of agriculture from 1993 to 2004. From 1996 through 2002, Dr. Lechtenberg served as chair of the U.S. Department of Agriculture's National Agricultural Research, Extension, Education and Economics Advisory Board and as a member of the advisory board of the National Academies' Division on Earth and Life Studies. From 2004 to 2011, as vice provost for engagement, Dr. Lechtenberg led Purdue's engagement and outreach efforts to governmental agencies, corporate leaders, schools and community leaders across Indiana and beyond. Dr. Lechtenberg is a fellow of the Crop Science Society of America and of the American Society of Agronomy. He served as president of the Crop Science Society of America and the Council of Agricultural Science and Technology. He received his BS from the University of Nebraska and PhD from Purdue University. Dr. Lechtenberg is a native of Butte, Nebraska, where he grew up on a general livestock farm.

Dr. Steven S. Balling is director of agricultural and analytical services for Del Monte Foods. He is part of a team of scientists responsible for agricultural research, seed operations, and pest management programs supporting 17 crops grown on 110,000 acres. Over the past 20 years, Dr. Balling has been involved with the development and implementation of Del Monte's widely recognized integrated pest management efforts in fruits and vegetables. He also manages Del Monte's agricultural research program, including pest management research, new variety trials, and pea, bean, and corn breeding at six Del Monte locations in the West and Midwest. He directs the seed operations, which annually produce 7 million pounds of corn, pea, and bean seed for Del Monte operations. Dr. Balling received his BS in natural resources and his PhD in entomology from the University of California, Berkeley.

Dr. Keith L. Belli is professor and head of the Department of Forestry, Wildlife, and Fisheries at the University of Tennessee (UT), Knoxville. The department he leads supports undergraduate and graduate programs of study in natural resources, forestry, wildlife, fisheries, forest products, and the environment. Its mission is to advance the science, management, and appreciation of natural resources in Tennessee, the region, and beyond through programs in research, teaching, and extension. He leads one of the largest units in the university's College of Agricultural Sciences and Natural Resources, one of four units in the statewide UT Institute of Agriculture. Prior to his appointment with UT, Dr. Belli worked at Mississippi State University for 18 years, most recently as associate dean of the College of Forest Resources, associate director of the Forest and Wildlife Research Center, and interim head of the Department of Forest Products. Dr. Belli received his BS in forest science from the Pennsylvania State University, his MS in silviculture from Michigan State University, and his PhD in forest biometrics from the University of Minnesota. Dr. Belli currently serves as research chair for the National Association of University Forest Resources Programs.

Dr. Peter J. Bruns is a professor of genetics emeritus at Cornell University and vice president retired from the Howard Hughes Medical Institute (HHMI). From 1969 to 2000 he held the following positions at Cornell University: assistant, associate, and full professor of genetics; faculty fellow; chairman, Section of Genetics and Development; associate director, Cornell Biotechnology Program; director, Division of Biological Sciences; and director, Cornell Presidential Research Scholars. He pioneered methods to genetically manipulate the separate somatic and germinal nuclei of the single-celled organism *Tetrahymena thermophila*. From 2001 to 2010 he was vice president for grants and special programs at HHMI, and oversaw one of the nation's largest private funds in support of science education from precollege through graduate. In addition he directed HHMI's international grants program in support of basic research outside of the United States. In 2011, he received the Elizabeth W. Jones Award for Excellence in Education from the Genetics Society of America and the Bruce Alberts Award for Excellence in Science Education from the American Society for Cell Biology. He recently served on the workforce studying higher education for the U.S. President's Council of Advisors on Science and Technology and currently is on the Technical Advisory Committee on Science, Technology, Engineering, and Mathematics Education for the American Association of Universities. Dr. Bruns received an AB in zoology from Syracuse University and a PhD in cell biology from the University of Illinois.

Dr. Steven T. Buccola is professor and director of the Graduate Program in Applied Economics at Oregon State University. He was an assistant professor at Virginia Tech from 1976 to 1981, joining the Department of Agricultural and Resource Economics (now Applied Economics) at Oregon State University in 1981. His research has concentrated on the economics of productivity. Recently he has focused in particular on the economics of science and technology, authoring articles on the implications of basic research for applied research, on the synergies between research productivity and funding success, and on the dynamics of life-science research investment. Dr. Buccola is a Distinguished Fellow and former president of the Agricultural and Applied Economics Association, is former editor of the *American Journal of Agricultural Economics,* and has served on the editorial boards of four other professional journals. He was the recipient in 2008 of Oregon State University's R.M. Wade Award for Excellence in Teaching, and in both 2004 and 2008 of the Outstanding Journal Article award at the *Review of Agricultural Economics* (now *Applied Economics Policy and Planning*). He received his PhD (1976) from the University of California, Davis.

Dr. James C. Carrington, president of the Danforth Plant Science Center in St. Louis, MO, is internationally recognized for his research on gene silencing, the functions of small RNA, and virus-host interactions. His work in the small RNA field has focused on mechanisms through which plants and other organisms use non-coding RNA to control growth and development and to defend against viruses. His awards include the Presidential Young Investigator Award from the National Science Foundation, the Ruth Allen Award from the American Society for Phytopathology, and the Humboldt Research Award from the Alexander von Humboldt Foundation. He was elected as a member of the National Academy of Sciences in 2008, and is a fellow of the American Academy of Microbiology, the American Phytopathological Society, and the American Association for the Advancement of

Science. Dr. Carrington earned his BS in plant sciences at the University of California, Riverside. After receiving his doctorate from the University of California, Berkeley, he served on the faculties at Texas A&M and Washington State universities. Prior to joining the Danforth Center, he served as director of the Center for Genome Research and Biocomputing, the Stewart Professor for Gene Research, and Distinguished Professor of Botany and Plant Pathology at Oregon State University.

Dr. Machi F. Dilworth is retired director of the Office of International Science and Engineering at the National Science Foundation (NSF). Prior to her retirement in 2012, she served as a research administrator with the federal government for 33 years. During her 24-year career at NSF, she held a variety of positions, including deputy assistant director (acting) for the Mathematical and Physical Sciences; head of NSF's Toyko Regional Office with concurrent appointment as science and technology attaché at the U.S. Embassy in Tokyo; division director for Biological Infrastructure within the Directorate for Biological Sciences (BIO), and program director for a number of programs in BIO. In 2002, Dr. Dilworth received the Presidential Distinguished Rank Award for her leadership in the development and management of a series of major research programs at NSF. She is a fellow of the American Association for the Advancement of Science, and a fellow of the American Society of Plant Biologists. She earned her BA in natural sciences from International Christian University in Tokyo, and MA and PhD in plant biochemistry and physiology from the University of California, Los Angeles.

Dr. Cutberto Garza holds the rank of university professor at Boston College and visiting professor at Johns Hopkins Bloomberg School of Public Health and George Washington University School of Public Health. He served as provost and dean of faculties at Boston College from 2005 to 2013. Previous to 2005 he held the rank of full professor at Baylor College of Medicine (where he served as the associate director of the U.S. Department of Agriculture Children's Nutrition Research Center) and Cornell University (where he served as director of the Division of Nutritional Sciences and vice provost). He received his BS from Baylor University, MD from Baylor College of Medicine, and PhD in nutrition and science from MIT. Dr. Garza is a specialist in pediatric nutrition and has worked on projects sponsored by the United Nations University (as director of the UNU Food and Nutrition Program), World Health Organization (WHO), UNICEF, and other international and national organizations with interests in infant and young child health. He served as chair of the WHO Steering Committee that developed the new WHO growth standards for infants and young children, the Institute of Medicine's (IOM's) Food and Nutrition Board, and the National Research

Council's Board on International Scientific Organizations. He currently serves as chair of the World Food Program's Technical Advisory Group. He is a member of the IOM and was named to the inaugural class of the National Associates of the National Academy of Sciences. He also is a member of the American Society of Clinical Nutrition, the Society for Pediatric Research, and the American Pediatric Society, among other organizations.

Dr. Ronnie D. Green has been the Harlan Vice Chancellor for the Institute of Agriculture and Natural Resources at University of Nebraska–Lincoln since July 2010. His position also serves as University of Nebraska vice president. He previously served as the senior director of Pfizer Animal Health overseeing global technical services for Animal Genetics, a position he held since April of 2008. From 2003 to 2008, Dr. Green served as the national program leader for animal production research for the USDA's Agricultural Research Service and as the executive secretary of the White House's interagency working group on animal genomics within the National Science and Technology Council. In this role, he directed a $45 million annual research portfolio and was one of the principal leaders in the international bovine, porcine, and ovine genome projects. He has served on animal science faculties at Texas Tech University and Colorado State University, and received a number of distinguished local, regional, and national teaching and research awards for the work he led in those positions. Author of numerous refereed and other publications and invited speaker in almost all 50 states and foreign countries that range from Australia to the United Kingdom, Dr. Green was president in 2010–2011 of the American Society of Animal Science and has served as a board member, recording secretary, and member of the executive committee. He has held leadership positions in the Beef Improvement Federation, National Cattlemen's Beef Association, National Pork Board, Discover Conferences, and the National Block and Bridle Club. Raised on a mixed beef, dairy, and cropping farm in southwestern Virginia, Dr. Green received his BS and MS degrees in animal science from the Virginia Polytechnic and State University and Colorado State University, respectively. His PhD, with a focus on animal breeding, was completed jointly in 1988 at the University of Nebraska–Lincoln and the USDA Meat Animal Research Center.

Dr. Rosemary R. Haggett is vice chancellor for Academic Affairs and Student Success at the University of North Texas System (UNTS), where she directs academic planning, reporting, and campus support. As the system's chief academic officer, she provides leadership and consultation in the development of the academic planning process, academic and research policy, and academic personnel policy. Dr. Haggett is also charged with oversight and evaluation of educational programs, professional education, major systemwide academic initiatives, and graduate and undergraduate student affairs. Dr. Haggett served as provost and executive vice president for Academic Affairs at the University of Toledo from 2007 until 2010. Dr. Haggett has extensive experience both in academia and the federal government. Prior to becoming provost at Toledo, Dr. Haggett was acting director of the Division of Graduate Education and senior adviser of the Education and Human Resources Directorate of the National Science Foundation (NSF). Her other positions at the NSF since 2003 include acting deputy assistant director of the Education and Human Resources Directorate and director of the Division of Undergraduate Education. Dr. Haggett was the second woman in the United States to serve as a College of Agriculture dean when she was appointed dean of the West Virginia University College of Agriculture, Forestry and Consumer Sciences in 1994. In addition to her work at the NSF, Dr. Haggett held a professorship in Animal and Veterinary Sciences at West Virginia University (WVU) from 1994 to 2007. Dr. Haggett served as associate provost for academic programs at WVU from 1999 to 2003, and as dean of the WVU College of Agriculture, Forestry and Consumer Sciences from 1994 to 1999. Dr. Haggett also worked at the USDA for more than 6 years as a grant administrator in the Competitive Research Grants Office and the National Research Initiative. Dr. Haggett has published in the areas of reproductive biology and neuroendrocrinology, as well as student learning outcome assessment and undergraduate science education. She received her BS in biology from the University of Bridgeport and PhD in physiology from the University of Virginia, and completed postdoctoral work in reproductive biology at Northwestern University.

Mr. Gene Hugoson is on staff, part-time, at the University of Minnesota's St. Paul campus. He is liaison for external and constituent relations for the deans of the College of Food, Agriculture & Natural Resources as well as the College of Veterinary Medicine. In addition, he does food system policy work for the Center for Animal Health and Food Safety. Prior to joining the university, Mr. Hugoson was commissioner of the Minnesota Department of Agriculture from 1995 to 2011. In addition to the regulatory responsibilities, Mr. Hugoson worked to promote value-added industries and international trade opportunities. While commissioner, he served as chair of the Environmental Quality Board and the Next Gen Energy Board. Mr. Hugoson also served on the board of the National Association of State Departments of Agriculture (NASDA) for more than 8 years including serving as NASDA's president in 2003–2004. Prior to his commissioner's position, Mr. Hugoson was elected five times to the Minnesota House of Representatives beginning in 1986. Mr. Hugoson received a BA degree in social science education from Augsburg College in Minneapolis. He served in the U.S. Army, including a tour of duty in Vietnam after which he did graduate work at Minnesota State University, Mankato. Mr. Hugoson and his family operate a corn and soybean farm in Martin County, located in southern Minnesota.

Dr. Bennie I. Osburn is retired dean of the School of Veterinary Medicine at University of California (UC), Davis and was interim executive director of the Association of American Veterinary Colleges. His scientific career focused on the health and welfare of food animals, particularly cattle and sheep. He has been involved in key discoveries about food animal viruses, developmental immunology, congenital infections, and more recently, food safety. He has published more than 285 peer-reviewed publications. He is a member of the Johns Hopkins Society of Scholars; fellow of the American Association for the Advancement of Science; diplomate of the American College of Veterinary Pathologist (ACVP); and past president of ACVP, the American Association of Veterinary Immunologists, and Association of American Veterinary Medical Colleges; and chair of USDA's Agricultural Biotechnology Research Advisory Committee. Dr. Osburn served as head of the Infectious Disease and Immunology Unit at the California Regional Primate and Research Center from 1975 to 1983 and as associate dean for research and graduate programs at UC Davis from 1975 until he became dean in 1996. Dr. Osburn earned his BS and DVM degrees at Kansas State University and his PhD in comparative pathology at the University of California, Davis. From 1964 to 1968 he served on the faculty at the College of Veterinary Medicine at Oklahoma State University.

Dr. Philip G. Pardey is professor of science and technology policy in the Department of Applied Economics at the University of Minnesota where he also directs the university's International Science and Technology Practice and Policy Center. Previously he was a senior research fellow at the International Food Policy Research Institute, Washington, DC, and prior to 1994 at the International Service for National Agricultural Research in The Hague, Netherlands. He is a fellow of the American Agricultural Economics Association, a distinguished fellow and past president of the Australian Agricultural and Resource Economics Society, and a winner of the Siehl Prize for excellence in agriculture. His research deals with the finance and conduct of research and development globally, methods for assessing the economic impacts of research, and the economic and policy (especially intellectual property) aspects of genetic resources and the biosciences. He currently co-directs a Gates Foundation project, HarvestChoice (www.HarvestChoice.org), designed to inform and guide investments intended to stimulate productivity growth in African agriculture. Dr. Pardey is author of more than 300 books, articles, and papers, including *Ending Hunger in*

Our Lifetime: *Food Security and Globalization* (John Hopkins University Press, 2003), *Saving Seeds*: *The Economics of Conserving Crop Genetic Resources Ex Situ in the Future Harvest Centers of the CGIAR* (CAB International, 2004), *Agricultural R&D in the Developing World: Too Little, Too Late?* (International Food Policy Research Institute, 2006), and *Persistence Pays: U.S. Agricultural Productivity Growth and the Benefits from Public R&D Spending* (Springer, 2010). A native of Australia, he has a BSc in agricultural science from the University of Adelaide (Australia) and obtained a doctoral degree in agricultural economics from the University of Minnesota in 1986.

Dr. Sally J. Rockey, National Institutes of Health (NIH) deputy director for extramural research (DDER), leads the NIH extramural research activities. Her role is to oversee the development and implementation of the critical policies and guidelines central to the successful conduct of NIH-supported biomedical research across the nation and world. Dr. Rockey has a PhD in entomology from the Ohio State University, and has spent the majority of her career in the area of research administration and information technology. In 1986 she joined the U.S. Department of Agriculture, soon becoming the deputy administrator of the Cooperative State Research, Education and Extension Service, overseeing the USDA extramural competitive grants program and serving as the agency's chief information officer. In 2005, Dr. Rockey moved to NIH as deputy to her current position and became the DDER in 2008. Dr. Rockey leads or is active on a number of federal committees related to science, research administration, and electronic government. She works most closely with other federal science and university administrators, small businesses, professional societies and the scientific communities here and around the world. She co-chairs the National Science and Technology Council Committee on Science Research Business Models. In 2012 Dr. Rockey co-led a groundbreaking effort on the biomedical workforce. Dr. Rockey is a skilled public speaker, giving countless presentations on research administration, workforce, and policy. She is the author of the widely read "Rock Talk" blog and has been recognized for her numerous professional accomplishments including receiving the Presidential Rank Award in 2004 and the Joseph F. Carrabino Award in 2013.

Dr. Juliana M. Ruzante is a senior associate for the Food Safety Campaign at the Pew Charitable Trusts. Prior to joining Pew, she was a risk analysis manager for the Joint Institute for Food Safety and Applied Nutrition (JIFSAN), in College Park, MD. She worked for the University of Guelph and Public Health Agency of Canada developing and operationalizing a multifactorial framework to rank foodborne risks using multicriteria decision analysis (MCDA) and at the Western Institute for Food Safety and

Security developing training material on animal health and food safety. She also worked as a quality assurance specialist for one of the largest pork and poultry processing companies in Brazil. She was a member of the Food Safety Research Consortium and has served as an expert on the meeting organized by Food and Agriculture Organization and World Health Organization on the risks associated with *Enterobacter sakazakii* in follow-up formula. Dr. Ruzante received her DVM from the University of São Paulo and master of preventive veterinary medicine (MPVM) and PhD in comparative pathology from the University of California, Davis.

Dr. James J. Zuiches was vice chancellor for the Office of Extension, Engagement and Economic Development at North Carolina State University from 2006 until his retirement in 2011. In this office, he led statewide extension and engagement programs, including the Small Business Technology and Development Center, Industrial Extension Service, Manufacturing Extension Partnership, continuing education, and STEM-related programs. He previously was dean of Washington State University's College of Agriculture and Home Economics from 1995 to 2003, and director of the Agricultural Research Center (1986–1994) and of Cooperative Extension (1995–2000). He was associate director of the agricultural experiment station for New York State at Cornell University from 1982 to1986. He also served as a grant-making program officer for the National Science Foundation in sociology and W.K. Kellogg Foundation in community and rural development, and taught at Michigan State University for 8 years. He serves on the Commission that provides oversight of the Food Systems Leadership Institute. He also served on the USDA's National Agricultural Research, Extension, Education and Economics Advisory Board, the National Research Council (NRC) Board on Agriculture and Natural Resources, and on three NRC committees, most recently, the Framework Committee on the Review of National Institute for Occupational Safety and Health Research Programs. He is a fellow of the American Association for the Advancement of Science. His research and extension specializations include demography, rural sociology, entrepreneurship and community development, leadership, innovation, and organizational processes. His work has been funded by the National Science Foundation, National Institute of Child Health and Human Development, Energy Research and Development Administration (now DOE), Kellogg Foundation, and USDA. He has more than 80 publications, including edited books, journal articles, book chapters, bulletins, and editorials. Dr. Zuiches has an MS and PhD in sociology from the University of Wisconsin–Madison.

B

Presentations to the Committee

FEBRUARY 27, 2013

Motivation for the Study and U.S. Department of Agriculture's (USDA's) Study Objectives
Sonny Ramaswamy, Director, USDA National Institute of Food and Agriculture

Programs at USDA Agricultural Research Service and Their Complementarity with AFRI
Ed Knipling, Administrator, USDA Agricultural Research Service

Programs at the U.S. Department of Energy (DOE) and Their Complementarity with AFRI
Sharlene Weatherwax, DOE Associate Director of Science for Biological and Environmental Research

The Association of Public Land-Grant Universities' (APLU) Expectation/View of AFRI
Ian Maw, APLU Vice President of Food, Agriculture and Natural Resources

The Federation of Animal Science Societies' (FASS) Expectation/View of AFRI
Anthony Pescatore, FASS Board President

American Society of Agronomy (ASA)–Crop Science Society of America (CSSA)–Soil Science Society of America (SSSA)'s Expectation/View of AFRI
Jeffrey Volenec, CSSA President

APRIL 1, 2013

Keynote Address: The Role of Competitive Grants Research at USDA
The Honorable Catherine Woteki, Under Secretary for Research, Education, and Extension, U.S. Department of Agriculture

The 2004 Report: Assessment and Recommendations for the Creation of NIFA and a Competitive Grants Program
William H. Danforth II, Chancellor Emeritus, Washington University in St. Louis

The AFRI Grant-Making and Grant-Management Process
Mark Mirando, National Program Leader for Animal Nutrition, Growth, and Reproduction, NIFA
Ann Lichens-Park, National Program Leader for Microbial Genomics, NIFA

Single Institution AFRI Grant Recipient
Conner Bailey, Professor of Rural Sociology, Auburn University

Multi-Institution CAP Grant Recipient
James Womack, W.P. Luse Endowed & Distinguished Professor in Veterinary Pathobiology, Texas A&M University

Single Investigator AFRI Grant Recipient
Li-Jun Ma, Assistant Professor of Biochemistry and Molecular Biology, University of Massachusetts

APRIL 2, 2013

Multi-Institution CAP Grant Recipient
Lee-Ann Jaykus, William Neal Reynolds Distinguished Professor in Food Science, North Carolina State University

JUNE 3, 2013

The Role and Relevance of the Agriculture and Food Research Initiative (AFRI) to Agricultural Preparedness
Barbara Schaal, Professor, Mary-Dell Chilton Distinguished Professor, Washington University; Co-chair, Report to the President on Agricultural Preparedness and the Agriculture Research Enterprise

CREATE-21 and Its Relation to NIFA and AFRI in the 2008 Farm Bill
Jeffrey Armstrong, President, California Polytechnic University, San Luis Obispo; and Co-chair of CREATE-21

A Vision for AFRI
Roger Beachy, Professor, Washington University; former Director, National Institute of Food and Agriculture

The Role of AFRI in Agricultural Economics and in Rural and Community Development
Scott Loveridge, Professor of Agricultural, Food, and Resource Economics, Michigan State University; Director of the North Central Regional Center for Rural Development

The American Society of Plant Biologists' (ASPB) Expectations and Views of AFRI
Peggy Lemaux, President, ASPB; Cooperative Extension Specialist, University of California, Berkeley

The Institute of Food Technologists' (IFT) Expectations and Views of AFRI
Will Fisher, Vice President of Science and Policy Initiatives, IFT

Views and Expectations of AFRI from the Office of Science and Technology Policy (OSTP)
Kei Koizumi, Assistant Director, Federal Research and Development, OSTP

JUNE 4, 2013

Views and Expectations of AFRI from the Office of Management and Budget (OMB)
Noah Engelberg, Program Examiner, OMB

C

Web-Based Questionnaire

Web-Based Solicitation of Input for the National Research Council Committee on a Review of the USDA Agriculture and Food Research Initiative

Welcome

Purpose of this Solicitation

The National Research Council has appointed the Committee on a Review of the USDA Agriculture and Food Research Initiative (AFRI) to perform an independent assessment, including the quality and value of research funded by the program and the prospects for its success in meeting established goals and outcomes. The study also will examine AFRI's role in advancing science in relation to other research and grant programs inside of USDA as well as how complementary it is to other federal R&D programs. The study committee will prepare a report of its assessment. (Please visit http://www8.nationalacademies.org/cp/projectview.aspx?key=49505 for a complete study description and committee membership.)

The committee would like to solicit your input on the AFRI program whether you are familiar with or have not heard of the program. The committee is soliciting the broadest input in its review from researchers, academic and extension leaders, reviewers, and users and beneficiaries of AFRI. The committee would like input from industry about the role of public-sector agricultural research and from producers and related professional associations about the type of research the federal agencies should be supporting. Please complete the questionnaire to provide the committee with your input. This questionnaire will take approximately 10-20 minutes.

About the Agriculture and Food Research Initiative

AFRI is a competitive grant program charged with "funding research, education, and extension grants and integrated research, extension, and education grants that address key problems of national, regional, and multi-state importance in sustaining all components of agriculture, including farm efficiency and profitability, ranching, renewable energy, forestry (both urban and agroforestry), aquaculture, rural communities and entrepreneurship, human nutrition, food safety, biotechnology, and conventional breeding. Providing this support requires that AFRI advances fundamental sciences in support of agriculture and coordinates opportunities to build on these discoveries. This will necessitate efforts in education and extension that deliver science-based knowledge to people, allowing them to make informed practical decisions." (For a synopsis of the program, please visit http://www.csrees.usda.gov/funding/afri/afri_synopsis.html.)

Treatment of Collected Comments and Information

The information you provide in response to this questionnaire will become part of the formal input submitted to the committee for its consideration. In accordance to Section 15 of the Federal Advisory Committee Act (http://www.nasonline.org/about-nas/leadership/governing-documents/federal-advisory-committee.html), any information you provide to the committee will be placed in the project's public access record and will be made available to the public upon request. Your response will appear in the public access record the way it is submitted, including your name, affiliation and any other identifying information included in your submission.

I have read and understood the information provided above about the treatment of any information I provide in this web-based solicitation of input.*

- Yes
- No

Please provide the following information:*

Name:

Affiliation:

Email:

Qualifying Question

Please select one of the following options that best describes you:*

- Research performer, educator, extension leader, or grant seeker (researcher from academic, government, non-profit, or other institutions)
- Research user from government or industry
- Agricultural or forest producer and related professional society

Research Performer

Please provide information about yourself.

Title/Position:

Type of Institution

- 1862 Land Grant University
- 1890 Land Grant University
- 1994 Land Grant University
- Public Non-Land Grant
- Private University/College
- Private Research
- Federal

- [ ] Other

Area of Research

- [ ] Agronomy
- [ ] Animal science
- [ ] Crop science
- [ ] Economics
- [ ] Food science
- [ ] Nutrition
- [ ] Plant Science
- [ ] Renewable energy, natural resources and environment
- [ ] Sociology
- [ ] Soil science
- [ ] Veterinary science
- [ ] Weed science
- [ ] Other

Principal agencies/organizations (including federal and state agencies, charitable or non-profit organizations, and private corporations) that have supported your research

- [ ] National Institutes of Health (NIH)
- [ ] National Science Foundation (NSF)
- [ ] U.S. Department of Agriculture (USDA)
- [ ] U.S. Department of Energy (DOE)
- [ ] U.S. Environmental Protection Agency (EPA)
- [ ] Charitable Foundation
- [ ] Private Sector
- [ ] Other

Are you a new investigator (less than 5 years of experience on faculty)?

- ○ Yes
- ○ No

Specify number of years since your PhD was received.

Were you familiar with the USDA National Research Initiative Program, the predecessor of AFRI?

- Yes, very familiar
- Somewhat familiar
- Not familiar at all

Are you familiar with the AFRI Program?

- Yes, very familiar
- Somewhat familiar
- Not familiar at all

Was there an AFRI request for applications directly related to your area of research, extension, or academic program in the following years? Please answer "yes", "no", or "not sure".

2008:

2009:

2010:

2011:

2012:

If not, please describe topic areas of research interest to you that are not covered.:

Do you believe the AFRI request for application is fair to all different types of institutions? If not, why?

- Yes
- No
- No opinion

Comments:

Have you applied to the AFRI program?

- Yes
- No

Please provide reasons for why you have not applied to AFRI, check the ones that apply.

- I am not familiar/aware of the AFRI program
- Size of grants are too small compared to grants from other agencies

- Effort required to prepare application is large relative to grant size
- Effort required to prepare application is large relative to the success rate
- Overhead/indirect costs provided by AFRI are smaller than other grant programs
- No RFAs are provided in my area of research
- Other

(AFRI Grant Applicants only) How easy or difficult was the grant application process compared to other grant-funding programs? Please indicate your response on a scale from 1 to 5, with "1" being very easy and "5" being very difficult. If you marked 4 or 5, please provide comments.

1 2 3 4 5

Comments:

(AFRI Grant Applicants only) Do you believe the AFRI panel review process is fair to all different types of institutions? If you indicated "somewhat unfair" or "extremely unfair", please provide comments.

Extremely fair Somewhat fair Indifferent Somewhat unfair Extremely unfair

Comments:

Have you been a recipient of AFRI grant(s)?

Yes

No

(For AFRI grantees only) Was the pre-award and post-award process managed effectively compared to other grant-funding programs? If you indicated "somewhat ineffectively" or "extremely ineffectively", please provide comments.

Extremely effectively Somewhat effectively Indifferent Somewhat ineffectively

Extremely ineffectively

Comments:

(For AFRI Grantees only) Is the reporting requirement a fair and effective method to identify successful projects?

Yes

No

Comments:

(For AFRI grantees only) Please provide the number of students supported by the AFRI grant(s).

Ph.D.:

Masters:

Undergraduates:

Other:

Have you been a reviewer for any AFRI proposals?

- Yes
- No

Did you participate in:

- Virtual grant review panel
- Face-to-face panel

Do you believe the panel review process was effective? If you indicated "somewhat ineffective" or "extremely ineffective", please provide comments on why it was ineffective.

- Extremely effective
- Somewhat effective
- Indifferent
- Somewhat ineffective
- Extremely ineffective

Comments:

Do you believe that it is necessary to integrate agricultural research, extension, and education?

- Yes
- No

Comments:

In your opinion, how well does AFRI facilitate the integration of research, extension, and education? If you indicated "poorly" or "very poorly", please provide comments on why AFRI was not facilitating the integration of research, extension, and education well.

- Extremely well
- Somewhat well
- Satisfactory
- Poorly
- Very poorly

Comments:

Which one of the statements below best represents your opinion:

- AFRI should fund fewer, high-dollar and longer-term grants
- AFRI should fund more, lower-dollar grants
- No opinion
- Other:

How important is the AFRI program for you? Please indicate your response on a scale from 1 to 5, with "1" being very important and "5" being not important at all.

1 2 3 4 5

Other comments that you would like to provide that are not covered by this earlier in this questionnaire.

Research User

Please indicate your views of public-sector agricultural research. Please provide comments.

Very important Somewhat important No opinion Somewhat unimportant Very unimportant

Comments:

Are you familiar with the AFRI program?

Yes, very familiar

Somewhat familiar

Not familiar at all (please visit http://www.nifa.usda.gov/funding/afri/afri_synopsis.html to learn about the program.)

Are there research areas in the AFRI program that duplicate those pursued in your industry?

Yes - Please list the areas

No - Please describe why

No opinion

Comments:

Are there fundamental (basic) research areas that the industry or government needs and that are not covered by the AFRI program areas?

Yes - Please describe the program areas

No

No opinion

Comments:

Are there areas of applied research that the industry or government needs that are not covered by the AFRI program areas?

Yes - Please describe the program areas

- [ ] No
- [ ] No opinion

Comments:

Do you believe AFRI funded research is relevant to the industry and government's needs? If you answered yes, please provide examples.

- [ ] Yes
- [ ] No - Please describe why
- [ ] No opinion

Comments:

How important is the AFRI program for you? Please indicate your response on a scale from 1 to 5, with "1" being very important and "5" being not important at all.

[ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5

Would it be valuable for your industry or government agency to know about AFRI's grants and activities?

- [ ] Yes
- [ ] No
- [ ] No opinion

For industry respondents, please indicate your type of work and field of interest.

Other comments that you would like to provide that are not covered by this earlier in this questionnaire.

Producers and Related

Please indicate your views of public sector agricultural research. Please provide comments.

[ ] Very important [ ] Somewhat important [ ] No opinion [ ] Somewhat unimportant [ ] Very unimportant

Comments:

Are you familiar with the AFRI program?

- [ ] Yes, very familiar
- [ ] Somewhat familiar

- Not familiar at all (please visit http://www.nifa.usda.gov/funding/afri/afri_synopsis.html to learn about the program.)

Do you believe that AFRI-funded research is relevant to producers' needs?

- Yes - Please provide examples
- No - Please describe why not
- No opinion

Comments:

Has your farming or ranching operation benefited from any past research (not limited to AFRI)?

- Yes- Please provide examples of areas where research has been helpful
- No

Comments:

Do you believe that public (government-funded) research is necessary, or is private (industry-funded) research sufficient for your needs? Please select one of the following responses:

- Both public-sector (government) and private-sector (industry) research are relevant for my needs
- Public-sector (government) research is more relevant for my needs than private-sector (industry) research
- Private-sector (industry) research is more relevant for my needs than public-sector (government) research
- Neither public nor private sector research has been relevant for my needs.

Please describe areas of future research topics and areas that can be helpful for addressing your current concerns.

Given that agriculture will continue changing, what are some of the greatest challenges that you believe you will face 10-20 years from now? How can science or technology help you handle these challenges?

Thank You!

Thank you for taking our survey. Your response is very important to us.

D

Summary of Responses to Web-Based Questionnaire[1]

Please select one of the following options that best describes you:

Research performer, educator, extension leader, or grant seeker (researcher from academic, government, non-profit, or other institutions)	524	90.8%
Research user from government or industry	34	5.9%
Agricultural or forest producer and related professional society	19	3.3%
Total Responses	577	

Research Performers - Type of Institution:

1862 Land Grant University	387	75.2%
1890 Land Grant University	39	7.6%
1994 Land Grant University	4	0.8%
Public Non-Land Grant	30	5.8%
Private University/College	12	2.3%
Private Research	7	1.4%
Federal	30	5.8%
		2.3%
Other	12	
Australian Government	(1)	
Botanic Garden	(1)	
M&O for NSF's FFRDC	(1)	

[1]Responses from all respondents are available upon request through the National Academies Public Access Records Office for this study.

Multiple of above	(1)	
Non-profit	(2)	
Public University	(2)	
Scientific Professional Society	(1)	
State Experiment Station	(1)	
Total Responses	**521**	

Area of Research

Agronomy	41	7.9%
Animal science	87	16.8%
Crop science	52	10.1%
Economics	26	5.0%
Food science	48	9.3%
Nutrition	40	7.7%
Plant science	106	20.5%
Renewable energy, natural resources and environment	75	14.5%
Sociology	26	5.0%
Soil science	29	5.6%
Veterinary science	41	7.9%
Weed science	32	6.2%
Other	158	
Agricultural Law	(1)	
Agricultural Literacy	(1)	
Agriculture, Food, and Natural Resources Research	(1)	
Anthropology	(1)	
Aquaculture	(1)	
Atmospheric Sciences	(1)	
Biochemistry and Cell Biology	(1)	
Biologicals	(1)	
Biology	(1)	
Carbohydrate	(1)	
Communication	(1)	
Community/Economic Development	(1)	
Family Science	(1)	
Cropping Systems	(1)	
Demography	(1)	
Ecology	(1)	
Education	(6)	
Adult/Extension Education	(3)	
4-H and Youth Development	(4)	30.6%
Engineering	(3)	
Agricultural	(5)	
Biological	(1)	
Food	(2)	
Food Processing	(1)	
Entomology	(25)	
Pest Management	(3)	
IPM	(2)	

Environmental Risk Assessment	(1)	
Environmental Science	(1)	
Feed Extrusion	(1)	
Food Safety	(4)	
Food System	(1)	
Natural Resources	(2)	
Forestry	(5)	
Policy	(1)	
Products	(1)	
Wildlife Management	(5)	
Genetics	(2)	
GIS	(1)	
Immunology	(1)	
Health and Wellness	(1)	
Public Health	(1)	
Horticulture	(19)	
Hospitality Management	(1)	
Infectious Diseases	(1)	
Meat Science	(1)	
Microbiology	(3)	
Food Microbiology	(1)	
Molecular Biology	(1)	
Pathology	(1)	
Plant	(11)	
Poultry Science	(2)	
Public Administration	(1)	
Remote Sensing	(1)	
Research Administrator	(1)	
Supply Chain Management	(1)	
University Engagement	(1)	
Vector Biology	(1)	
Virology	(1)	
Water	(1)	
Quality	(1)	
Wood Science	(1)	
Fundamental Animal Science	0	0.0%
Fundamental Plant Science	0	0.0%
Total Responses	**517**	

Principal agencies/organizations (including federal and state agencies, charitable or non-profit organizations, and private corporations) that have supported your research

National Institutes of Health (NIH)	74	14.9%
National Science Foundation (NSF)	120	24.1%
U.S. Department of Agriculture (USDA)	421	84.5%
U.S. Department of Energy (DOE)	77	15.5%
U.S. Environmental Protection Agency (EPA)	58	11.7%
Charitable Foundation	92	18.5%
Private Sector	265	53.2%

Other	130	26.1%
All of the above	(1)	
Federal Agencies		
APHIS	(1)	
ARS	(1)	
BARD	(2)	
BLM	(1)	
CAPES (Brazil)	(1)	
CDC	(1)	
Commerce	(1)	
CSREES	(1)	
DAFF (Australia)	(1)	
DHS	(2)	
DOD	(10)	
DOI	(1)	
Education	(1)	
ESTCP	(1)	
DOL	(1)	
DOT	(2)	
FDA	(2)	
FHWA	(1)	
FWS	(2)	
HHS	(1)	
HUD	(1)	
HRSA	(1)	
NASA	(3)	
NOAA	(2)	
OSM	(1)	
SERDP	(1)	
USAID	(1)	
USBR	(1)	
USGS	(1)	
State Agencies	(17)	
Department of Agriculture	(10)	
Natural Resources	(6)	
Military Branches		
U.S. Navy	(1)	
U.S. Army Corps of Engineers	(1)	
Check Off Funds	(4)	
Commodity Organizations	(15)	
Industry	(10)	
International Governments	(2)	
Land-Grant Universities	(3)	
National Academy of Sciences	(1)	
None of the above	(1)	
Nonprofit	(1)	
Private Foundation	(2)	
Public/Private Agency	(1)	
SeaGrant	(1)	
Total Responses	**498**	

SUMMARY OF QUALITATIVE RESPONSES

For researchers that feel the AFRI process is unfair to some institutions, they believe so because:

- Larger institutions have access to more resources and administrative support, which alleviates the burden of managing paperwork and application materials for the researcher.
- The process favors land-grant institutions.
- Scope of RFPs and short turn-around time make it difficult for researchers to fit their proposal into the mold.
- Effort required for application is too burdensome for the amount of money awarded, when comparing to comparable process, such as NSF.

Researchers that thought the AFRI application process was difficult:

- Too lengthy and involved.
- Timing: Solicitation window is too small, and often given around the holidays, when people are busy.
- "Collaborative" requirement/preference makes it difficult to coordinate among team members.

Researchers that thought the pre-award and post-award periods were not handled well:

- Substantial delay between notification of award and disbursement.
- Communication issues between institutions and even among groups within the awarding institution.

Researchers that thought the panel review process was not helpful:

- Very little extension focus.
- Panelists do not always have appropriate expertise to review proposals.
- Panels are composed of experts in and tend to favor basic research instead of applied research.
- Panels can be derailed by strong personalities or researchers with specific agendas.

E

Excerpt from the Food, Conservation, and Energy Act of 2008

SEC. 7406. AGRICULTURE AND FOOD RESEARCH INITIATIVE.

(a) In General.—Subsection (b) of the Competitive, Special, and Facilities Research Grant Act (7 U.S.C. 450i(b)) is amended to read as follows:

``(b) Agriculture and Food Research Initiative.—

``(1) Establishment.—There is established in the Department of Agriculture an Agriculture and Food Research Initiative under which the Secretary of Agriculture (referred to in this subsection as `the Secretary´) may make competitive grants for fundamental and applied research, extension, and education to address food and agricultural sciences (as defined under section 1404 of the National Agricultural Research, Extension, and Teaching Policy Act of 1977 (7 U.S.C. 3103)).

``(2) Priority areas.—The competitive grants program established under this subsection shall address the following areas:

``(A) Plant health and production and plant products.—Plant systems, including—

``(i) plant genome structure and function;

``(ii) molecular and cellular genetics and plant biotechnology;

``(iii) conventional breeding, including cultivar and breed development, selection theory, applied quantitative genetics, breeding for improved food quality, breeding for improved local adaptation to biotic stress and abiotic stress, and participatory breeding;

``(iv) plant-pest interactions and biocontrol systems;

``(v) crop plant response to environmental stresses;

``(vi) unproved nutrient qualities of plant products; and

``(vii) new food and industrial uses of plant products.

``(B) Animal health and production and animal products.—Animal systems, including—

``(i) aquaculture;

``(ii) cellular and molecular basis of animal reproduction, growth, disease, and health;

``(iii) animal biotechnology;

``(iv) conventional breeding, including breed development, selection theory, applied quantitative genetics, breeding for improved food quality, breeding for improved local adaptation to biotic stress and abiotic stress, and participatory breeding;

``(v) identification of genes responsible for improved production traits and resistance to disease;

``(vi) improved nutritional performance of animals;

``(vii) improved nutrient qualities of animal products and uses; and

``(viii) the development of new and improved animal husbandry and production systems that take into account production efficiency, animal well-being, and animal systems applicable to aquaculture.

``(C) Food safety, nutrition, and health.—Nutrition, food safety and quality, and health, including—

``(i) microbial contaminants and pesticides residue relating to human health;

``(ii) links between diet and health;

``(iii) bioavailability of nutrients;

``(iv) postharvest physiology and practices;

and
``(v) improved processing technologies.
``(D) Renewable energy, natural resources, and environment.—Natural resources and the environment, including—
``(i) fundamental structures and functions of ecosystems;
``(ii) biological and physical bases of sustainable production systems;
``(iii) minimizing soil and water losses and sustaining surface water and ground water quality;
``(iv) global climate effects on agriculture;
``(v) forestry; and
``(vi) biological diversity.
``(E) Agriculture systems and technology.—Engineering, products, and processes, including—
``(i) new uses and new products from traditional and nontraditional crops, animals, byproducts, and natural resources;
``(ii) robotics, energy efficiency, computing, and expert systems;
``(iii) new hazard and risk assessment and mitigation measures; and
``(iv) water quality and management.
``(F) Agriculture economics and rural communities.—Markets, trade, and policy, including—
``(i) strategies for entering into and being competitive in domestic and overseas markets;
``(ii) farm efficiency and profitability, including the viability and competitiveness of small and medium-sized dairy, livestock, crop and other commodity operations;
``(iii) new decision tools for farm and market systems;
``(iv) choices and applications of technology;
``(v) technology assessment; and
``(vi) new approaches to rural development, including rural entrepreneurship.
``(3) Term.—The term of a competitive grant made under this subsection may not exceed 10 years.
``(4) <<NOTE: Grants.>> General administration.—In making grants under this subsection, the Secretary shall—
``(A) seek and accept proposals for grants;

``(B) determine the relevance and merit of proposals through a system of peer and merit review in accordance with section 103 of the Agricultural Research, Extension, and Education Reform Act of 1998 (7 U.S.C. 7613);

``(C) award grants on the basis of merit, quality, and relevance;

``(D) solicit and consider input from persons who conduct or use agricultural research, extension, or education in accordance with section 102(b) of the Agricultural Research, Extension, and Education Reform Act of 1998 (7 U.S.C. 7612(b)); and

``(E) in seeking proposals for grants under this subsection and in performing peer review evaluations of such proposals, seek the widest participation of qualified individuals in the Federal Government, colleges and universities, State agricultural experiment stations, and the private sector.

``(5) Allocation of funds.—In making grants under this subsection, the Secretary shall allocate funds to the Agriculture and Food Research Initiative to ensure that, of funds allocated for research activities—

``(A) not less than 60 percent is made available to make grants for fundamental research (as defined in subsection (f)(1) of section 251 of the Department of Agriculture Reorganization Act of 1994 (7 U.S.C. 6971)), of which—

``(i) not less than 30 percent is made available to make grants for research to be conducted by multidisciplinary teams; and

``(ii) not more than 2 percent is used for equipment grants under paragraph (6)(A); and

``(B) not less than 40 percent is made available to make grants for applied research (as defined in subsection (f)(1) of section 251 of the Department of Agriculture Reorganization Act of 1994 (7 U.S.C. 6971)).

``(6) Special considerations.—In making grants under this subsection, the Secretary may assist in the development of capabilities in the agricultural, food, and environmental sciences by providing grants—

``(A) to an institution to allow for the improvement of the research, development, technology transfer, and education capacity of the institution through the acquisition of special research equipment and the improvement of agricultural education and teaching, except that the Secretary shall use not less than 25 percent of the funds made available for grants under this subparagraph to provide fellowships to outstanding pre- and post-doctoral students for research in the agricultural sciences;

``(B) to a single investigator or coinvestigators who are beginning research careers and do not have an extensive research publication record, except that, to be eligible for a grant under this subparagraph, an individual shall be within 5 years of the beginning of the initial career track position of the individual;

``(C) to ensure that the faculty of small, mid-sized, and minority-serving institutions who have not previously been successful in obtaining competitive grants under this subsection receive a portion of the grants; and

``(D) to improve research, extension, and education capabilities in States (as defined in section 1404 of the National Agricultural Research, Extension, and Teaching Policy Act of 1977 (7 U.S.C. 3103)) in which institutions have been less successful in receiving funding under this subsection, based on a 3-year rolling average of funding levels.

``(7) Eligible entities.—The Secretary may make grants to carry out research, extension, and education under this subsection to—

``(A) State agricultural experiment stations;

``(B) colleges and universities;

``(C) university research foundations;

``(D) other research institutions and organizations;

``(E) Federal agencies;

``(F) national laboratories;

``(G) private organizations or corporations;

``(H) individuals; or

``(I) any group consisting of 2 or more of the entities described in subparagraphs (A) through (H).

``(8) Construction prohibited.—Funds made available for grants under this subsection shall not be used for the construction of a new building or facility or the acquisition, expansion, remodeling, or alteration of an existing building or facility (including site grading and improvement, and architect fees).

``(9) Matching funds.—

``(A) Equipment grants.—

``(i) In general.—Except as provided in clause (ii), in the case of a grant made under paragraph (6)(A), the amount provided under this subsection may not exceed 50 percent of the cost of the special research equipment or other equipment acquired using funds from the grant.

``(ii) Waiver.—The Secretary may waive all or part of the match´ing requirement under clause (i) in the case of a college, university, or research foundation maintained by a college or university that ranks in the lowest \1/3\ of such colleges, universities, and research foundations on the basis of Federal research funds received, if the equipment to be acquired using funds from the grant costs not more than $25,000 and has multiple uses within a single research project or is usable in more than 1 research project.

``(B) Applied research.—As a condition of making a grant under paragraph (5)(B), the Secretary shall require the funding of the grant to be matched with equal matching funds from a non-Federal source if the grant is for applied research that is—

``(i) commodity-specific; and

``(ii) not of national scope.

``(10) Program administration.—To the maximum extent practicable, the Director of the National Institute of Food and Agriculture, in coordination with the Under Secretary for Research, Education, and Economics, shall allocate grants under this subsection to high-priority research, taking into consideration, when available, the determinations made by the National Agricultural Research, Extension, Education, and Economics Advisory Board (as established under section 1408 of the National Agricultural Research, Extension, and Teaching Policy Act of 1977 (7 U.S.C. 3123)).

``(11) Authorization of appropriations.—

``(A) In general.—There is authorized to be appropriated to carry out this subsection $700,000,000 for each of fiscal years 2008 through 2012, of which—

``(i) not less than 30 percent shall be made available for integrated research pursuant to section 406 of the Agricultural Research, Extension, and Education Reform Act of 1998 (7 U.S.C. 7626); and

``(ii) not more than 4 percent may be retained by the Secretary to pay administrative costs incurred by the Secretary in carrying out this subsection.

``(B) Availability.—Funds made available under this paragraph shall—

``(i) be available for obligation for a 2-year period beginning on October 1 of the fiscal year for which the funds are first made available; and

``(ii) remain available until expended to pay for obligations incurred during that 2-year period.´´.

(b) Repeals.—

(1) Section 401 of the Agricultural Research, Extension, and Education Reform Act of 1998 (7 U.S.C. 7621) is repealed.

(2) Subsection (d) of the Competitive, Special, and Facilities Research Grant Act (7 U.S.C. 450i(d)) is repealed.

(c) <<NOTE: 7 USC 450i note.>> Effect on Current Solicitations.—The amendments made by this section shall not apply to any solicitation for grant applications issued by the Cooperative State Research, Education, and Extension Service before the date of enactment of this Act.

(d) Conforming Amendments.—

(1) Section 1473 of the National Agricultural Research, Extension, and Teaching Policy Act of 1977 (7 U.S.C. 3319) is amended in the first sentence by striking ``and subsection (d)´´.

(2) Section 1671(d) of the Food, Agriculture, Conservation, and Trade Act of 1990 (7 U.S.C. 5924(d) is amended by striking ``Paragraphs (1), (6), (7), and (11)´´ and inserting ``Paragraphs (4), (7), (8), and (11)(B)´´.

(3) Section 1672B(b) of the Food, Agriculture, Conservation, and Trade Act of 1990 (7 U.S.C. 5925b(b)) is amended by striking ``Paragraphs (1), (6), (7), and (11)´´ and inserting ``Paragraphs (4), (7), (8), and (11)(B)´´.

F

Types of Grants Offered in Each AFRI Program (2009–2013)

Program	Project Function	Grant Type: Standard	CAP	Planning	Conference	Food and Agriculture Science Enhancement (FASE) Grants: New Investigator	Strengthening Grants: Sabbatical	Equipment	Seed	Standard	CAP
2013 Foundational Program	Research	✓			✓	✓	✓	✓	✓	✓	
	Education										
	Extension										
	Integrated	✓			✓	✓	✓	✓	✓	✓	
2013 Challenge-Area Program Agriculture and Natural Resources Science for Climate Variability and Change	Research	✓			✓	✓	✓	✓	✓	✓	
	Education	✓			✓	✓	✓	✓	✓	✓	
	Extension	✓			✓	✓	✓	✓	✓	✓	
	Integrated	✓			✓	✓	✓	✓	✓	✓	
2013 Challenge-Area Program Childhood Obesity Prevention	Research										
	Education										
	Extension										
	Integrated	✓			✓	✓	✓	✓	✓	✓	
2013 Challenge-Area Program Food Safety	Research	✓			✓	✓	✓	✓	✓	✓	
	Education										
	Extension										
	Integrated	✓			✓	✓	✓	✓	✓	✓	

2013 Challenge-Area Program Food Security	Research									
	Education									
	Extension									
	Integrated	✓		✓	✓	✓	✓	✓	✓	
2013 Challenge-Area Program Sustainable Bioenergy	Research	✓		✓	✓	✓	✓	✓	✓	
	Education									
	Extension									
	Integrated		✓	✓	✓	✓	✓	✓		✓
2012 Foundational Program (Not offered this year; combined 2012 and 2013 offered the next year)	Research									
	Education									
	Extension									
	Integrated									
2012 Challenge-Area Program Agriculture and Natural Resources Science for Climate Variability and Change	Research									
	Education									
	Extension									
	Integrated	✓	✓	✓	✓	✓	✓	✓	✓	

continued

Program	Project Function	Grant Type									
						Food and Agriculture Science Enhancement (FASE) Grants					
							Strengthening Grants				
		Standard	CAP	Planning	Conference	New Investigator	Sabbatical	Equipment	Seed	Standard	CAP
2012 Challenge-Area Program Childhood Obesity Prevention (Not offered this year)	Research										
	Education										
	Extension										
	Integrated										
2012 Challenge-Area Program Food Safety (Not offered this year)	Research										
	Education										
	Extension										
	Integrated										
2012 Challenge-Area Program Food Security	Research										
	Education										
	Extension	✓			✓	✓	✓	✓	✓		
	Integrated	✓			✓	✓	✓	✓	✓		
2012 Challenge-Area Program Sustainable Bioenergy	Research	✓			✓	✓	✓	✓	✓		
	Education										
	Extension										
	Integrated		✓		✓	✓	✓	✓		✓	

2011 Foundational Program	Research	✓		✓	✓	✓	✓	✓
	Education							
	Extension							
	Integrated	✓		✓	✓	✓	✓	✓
2011 Challenge-Area Program Agriculture and Natural Resources Science for Climate Variability and Change (Not offered this year)	Research							
	Education							
	Extension							
	Integrated							
2011 Challenge-Area Program Childhood Obesity Prevention	Research							
	Education							
	Extension							
	Integrated	✓		✓	✓	✓	✓	✓
2011 Challenge-Area Program Food Safety	Research	✓		✓	✓	✓	✓	✓
	Education							
	Extension							
	Integrated	✓		✓	✓	✓	✓	✓

continued

Program	Project Function	Grant Type									
						Food and Agriculture Science Enhancement (FASE) Grants					
							Strengthening Grants				
		Standard	CAP	Planning	Conference	New Investigator	Sabbatical	Equipment	Seed	Standard	CAP
2011 Challenge-Area Program Food Security (Not offered this year)	Research Education Extension Integrated										
2011 Challenge-Area Program Sustainable Bioenergy (Not offered this year)	Research Education Extension Integrated										
2010 Foundational Program	Research Education Extension Integrated	✓			✓	✓	✓	✓	✓	✓	

2010 Challenge-Area Program Agriculture and Natural Resources Science for Climate Variability and Change	Research	✓			✓	✓	✓	✓	✓	
	Education	✓			✓	✓	✓	✓	✓	
	Extension	✓			✓	✓	✓	✓	✓	
	Integrated	✓	✓	✓	✓	✓	✓	✓	✓	✓
2010 Challenge-Area Program Childhood Obesity Prevention	Research	✓			✓	✓	✓	✓	✓	
	Education	✓			✓	✓	✓	✓	✓	
	Extension	✓			✓	✓	✓	✓	✓	
	Integrated	✓	✓		✓	✓	✓	✓	✓	✓
2010 Challenge-Area Program Food Safety	Research	✓			✓	✓	✓	✓	✓	
	Education	✓			✓	✓	✓	✓	✓	
	Extension									
	Integrated	✓	✓		✓	✓	✓	✓	✓	✓
2010 Challenge-Area Program Food Security	Research									
	Education									
	Extension		✓		✓	✓	✓	✓		✓
	Integrated	✓	✓		✓	✓	✓	✓	✓	✓
2010 Challenge-Area Program Sustainable Bioenergy	Research	✓	✓		✓	✓	✓	✓	✓	✓
	Education	✓			✓	✓	✓	✓	✓	
	Extension									
	Integrated		✓	✓	✓	✓	✓	✓		✓

continued

Program	Project Function	Grant Type									
						Food and Agriculture Science Enhancement (FASE) Grants					
							Strengthening Grants				
		Standard	CAP	Planning	Conference	New Investigator	Sabbatical	Equipment	Seed	Standard	CAP
2009 Foundational Program	Research	✓	✓		✓	✓	✓	✓	✓	✓	
	Education	✓			✓	✓	✓	✓	✓	✓	
	Extension	✓			✓	✓	✓	✓	✓	✓	
	Integrated	✓	✓			✓			✓	✓	

G

Profile of Average NRI and AFRI Projects (2008–2012)

TABLE G-1 Sample Statistics of NRI Projects, 2008[a]

	Unit	Mean	Standard Deviation
PROJECT OUTPUTS			
Refereed Journal Articles	Number published	2.65	5.29
Citations per Article	Number per article	6.86	14.01
PROJECT SCALE			
Budget	$0,000	39.32	25.98
Project Duration	Months	31.61	9.45
PROJECT SCOPE			
Project Complexity			
Number of Co-PIs	Number	2.92	2.97
Current Support[b]			
Federal Support		0.73	0.44
Non-Federal Support		0.52	0.50
No Other Support		0.10	
Project Functions			
Research	%	93.53	20.95
Extension	%	4.29	12.88
Education	%	2.18	8.59
Project Composition			
Basic Research	%	61.35	34.60
Applied Research	%	32.33	29.51
Extension or Education	%	6.32	
PROJECT LOCUS			
Subject Area			
Plants		0.314	0.465
Animals		0.212	0.409
Food/Nutrition		0.145	0.353
Social Sciences		0.067	0.249
Bio-Products		0.048	0.213
Ecosystems		0.214	0.411
Type of Performing Institution			
Federal		0.045	0.208
Private Research		0.029	0.167
Private University		0.043	0.203
Public Non–Land-Grant Univ		0.083	0.277
Land-Grant University		0.800	0.400

TABLE G-1 Continued

	Unit	Mean	Standard Deviation
Rank of Project Director			
Professor		0.48	0.50
Associate Professor		0.19	0.39
Assistant Professor		0.20	0.40
Federal Scientist or Other		0.09	0.28
Pre- or Postdoctorate		0.04	0.20
Award Type			
Area		0.33	0.47
Conference		0.11	0.31
Standard		0.56	0.50
OTHER FACTORS			
Laboratory Assistance			
Undergraduate	FTE months	7.66	14.84
Graduates	FTE months	18.25	22.29
Postdoctorates	FTE months	13.10	17.34
Project Vintage	Months since start date		
Completed Project	1 if completed, 0 other		

[a]Indicator (0/1) variables. Means shown are percentages of the sample falling into the respective category, expressed in decimal form.
[b]AFRI project directors may receive support from a variety of sources. The sum of the percentages of support sources therefore is greater than unity.

TABLE G-2 Sample Statistics of AFRI Projects, 2009–2010[a]

	Unit	Mean	Standard Deviation
PROJECT OUTPUTS			
Refereed Journal Articles	Number published	1.79	2.90
Citations per Article	Number per article	2.62	6.58
Non-Refereed Communications	Number communicated	1.74	3.25
PROJECT SCALE			
Budget	$0,000	43.9	41.0
Project Duration	Months	41.7	9.7
PROJECT SCOPE			
Project Complexity			
Number of Co-PIs	Number	3.52	3.19
Current Support[b]			
Federal Support		0.66	0.47
Non-Federal Support		0.51	0.50
No Other Support		0.14	0.34
Project Function			
Research	%	89.22	24.79
Extension	%	5.48	16.16
Education	%	5.30	17.73
Project Composition			
Basic Research	%	60.24	35.21
Applied Research	%	28.98	26.22
Extension and Education	%	10.81	22.29
PROJECT LOCUS			
Subject Area			
Plants		0.37	0.48
Animals		0.21	0.40
Food/Nutrition		0.15	0.36
Social Sciences		0.05	0.22
Bio-Products		0.04	0.20
Ecosystems		0.18	0.39
Type of Performing Institution			
Federal		0.05	0.23
Private Research		0.03	0.16
Private University		0.05	0.21
Public Non–Land-Grant Univ		0.10	0.29
Land-Grant University		0.77	0.45

TABLE G-2 Continued

	Unit	Mean	Standard Deviation
Rank of Project Director			
Professor		0.40	0.49
Associate Professor		0.18	0.38
Assistant Professor		0.29	0.46
Federal Scientist		0.05	0.22
Postdoctorate or Other		0.08	
Award Type			
FASE		0.29	0.45
CAP		0.01	0.11
Conference		0.07	0.28
Standard		0.63	0.48
OTHER FACTORS			
Laboratory Assistance			
Undergraduate	FTE months	10.5	52.9
Graduate	FTE months	25.0	33.8
Postdoctorates	FTE months	11.8	19.4
		42.2	3.3
Project Vintage	months since start date		
		0.33	0.47
Completed Project	1 if completed, 0 other		

[a]Indicator (0/1) variables. Means shown are percentages of the sample falling into the respective category, expressed in decimal form.
[b]AFRI project directors may receive support from a variety of sources. The sum of the percentages of support sources therefore is greater than unity.

TABLE G-3 Sample Statistics of AFRI Projects, 2011–2012[a]

	Unit	Mean	Standard Deviation
PROJECT OUTPUTS			
Refereed Journal Articles	Number published	0.88	3.60
Citations per Article	Number per article	0.42	1.76
Non-Refereed Communications	Number communicated	0.73	2.16
PROJECT SCALE			
Budget	$0,000	119.55	346.26
Project Duration	Months	37.79	13.39
PROJECT SCOPE			
Project Complexity			
Number of Co-PIs	Number	4.29	4.76
Current Support[b]			
Federal Support		0.70	0.46
Non-Federal Support		0.45	0.50
No Other Support		0.17	0.38
Project Functions			
Research	%	88.30	23.73
Extension	%	6.10	16.43
Education	%	5.70	15.88
Project Composition			
Basic Research	%	54.85	36.84
Applied Research	%	33.46	35.85
Extension or Education	%	10.80	21.87
PROJECT LOCUS			
Subject Area			
Plants		0.12	0.33
Animals		0.11	0.31
Food/Nutrition		0.05	0.23
Social Sciences		0.08	0.27
Bio-Products		0.07	0.26
Ecosystems		0.03	0.17
Type of Performing Institution			
Federal		0.04	0.18
Private Research		0.02	0.14
Private University		0.06	0.23
Public Non–Land-Grant Univ		0.10	0.30
Land-Grant University		0.78	0.41

TABLE G-3 Continued

	Unit	Mean	Standard Deviation
Rank of Project Director			
Professor		0.32	0.47
Associate Professor		0.18	0.39
Assistant Professor		0.22	0.41
Federal Scientist		0.02	0.16
Postdoctorate or Other		0.26	
Award Type			
FASE		0.39	0.49
CAP		0.03	0.17
Conference		0.05	0.24
Standard		0.53	0.50
Program Area			
Challenge Grant		0.33	0.47
Fellowship Grant		0.21	0.41
Foundational Grant		0.46	0.50
OTHER FACTORS			
Laboratory Assistance			
Undergraduate	FTE	12.86	52.67
Graduates	FTE	33.99	71.40
Postdoctorates	FTE	19.43	43.98
		20.12	7.47
Project Vintage	Months since start date		
		0.08	0.18
Completed Project	1 if completed, 0 other		

[a]Indicator (0/1) variables. Means shown are percentages of the sample falling into the respective category, expressed in decimal form.

[b]AFRI project directors may receive support from a variety of sources. The sum of the percentages of support sources therefore is greater than unity.

TABLE G-4 Budget Regression on Outputs and Inputs, AFRI 2009–2010 and 2011–2012

		2009–2010		2011–2012	
	Variable	Linear	Interactive	Linear	Interactive
OUTPUTS	Intercept	23.15	24.43	–110.22	–92.29
	Number of Journal Articles	1.44	1.14	8.54	–1.91
		(3.24)	(1.90)	(4.08)	(–0.50)
INTERACTIONS	Number of Non–Refereed Articles			16.71	–9.39
				(4.86)	(–0.75)
	Number of Refereed Articles/Number of PIs		0.06		0.54
			(0.73)		(3.30)
	Number of Non–Refereed Articles/Duration				0.58
					(2.30)
SCALE	Project Duration (months)	1.09	1.10	2.06	2.01
		(8.28)	(8.31)	(3.50)	(3.34)
SCOPE	Number of Principal Investigators	2.14	1.97	26.26	24.13
		(4.50)	(3.69)	(12.52)	(11.22)
	Basic Research Proportion of Project	–0.06	–0.06	–0.25	–0.27
		(–1.24)	(–1.26)	(–1.20)	(–1.34)
Award Type	FASE (Base = Standard Grant)	–8.60	–8.63		
		(–3.11)	(–3.12)		
	CAP (Base = Standard Grant)	229.69	227.01	903.64	884.86
		(17.39)	(16.56)	(17.75)	(17.46)

LOCUS	Institution Type				
	Private University	21.07	21.14		
	(Base = all other institutions)	(3.61)	(3.62)		
	Public NLG University			45.27	43.00
	(Base = all other institutions)			(1.91)	(1.83)
Subject Area	Plants	10.45	10.42		
		(2.77)	(2.76)		
	Animals	14.59	14.39		
		(3.46)	(3.41)		
	Food	16.59	16.56		
		(3.99)	(3.98)		
	Bio-Products	8.83	8.71		
		(1.29)	(1.27)		
	Social Science	3.01	2.83		
		(0.49)	(0.46)		
		Base = Ecosystems	Base = Ecosystems	Base = Ecosystems	Base = Ecosystems
OTHER	Project Vintage (months)	–1.00	–1.02		
		(–2.60)	(–2.64)		
Statistics	R^2	0.630	0.630	0.700	0.706
	N	447	447	726	726

NOTES: Dependent variable is Project Budget. Conference and Planning Grants are not included in the dataset. If an input has a positive (negative) output-constant effect on budget, then it has a negative (positive) budget-constant effect on that output.

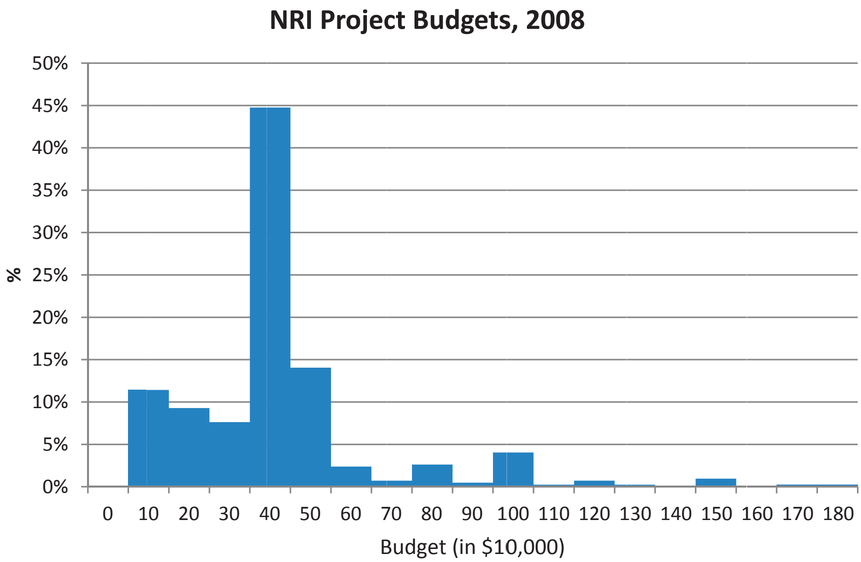

FIGURE G-1 Frequency distributions of project budgets and performance ratios, 2008.

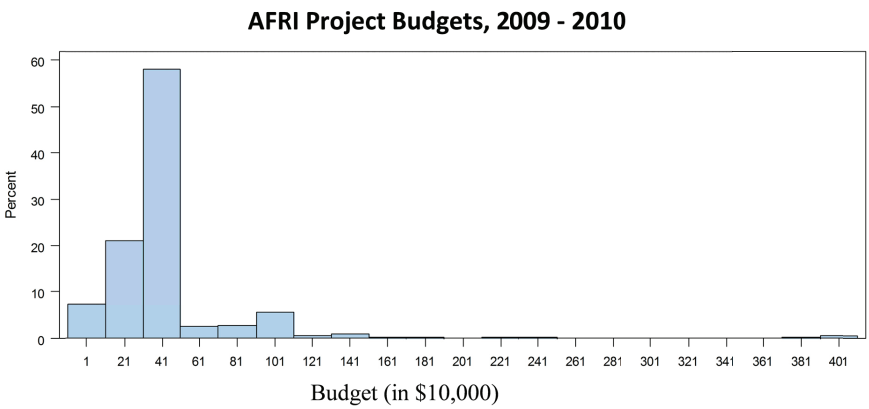

FIGURE G-2 Frequency distributions of project budgets and performance ratios, 2009—2010.

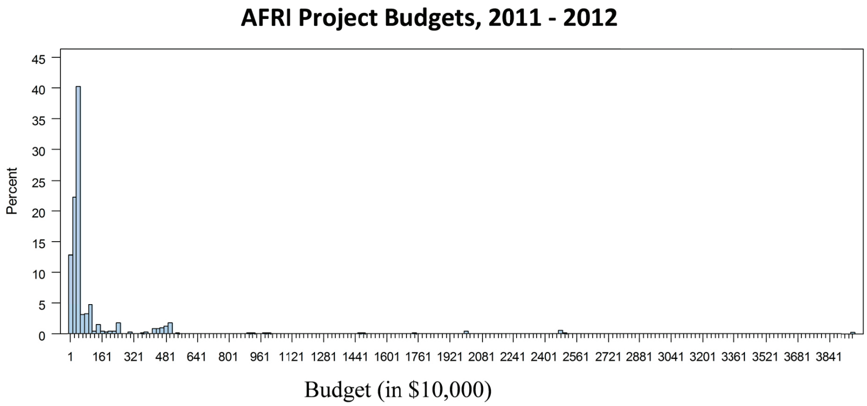

FIGURE G-3 Frequency distributions of project budgets and performance ratios, 2011—2012.

Appendix H

Data Processing for Program Evaluation

The committee solicited data from NIFA to explore the relationship between resource input and the output of AFRI-funded research. Information solicited for the analyses included the following for all new grants funded from 2009 to 2012:

- Title, type, and size of grants (e.g., total value, annual amount, and number of years funded).
- Duration of each award (e.g., start and actual or expected end date).
- Characteristics of each award, such as
    - Program area (e.g., foundation, challenge-area, or fellowship grant).
    - Award type (e.g., standard award, CAP, conference grant, or FASE award).
    - Project function (e.g., research, education, extension, or integrated, that is, integrating at least two of the three functions).
    - Percentage dedicated to research, education, and extension of each award.
    - Program code, which reflects the subject area of the project.
    - Percentage basic and percentage applied research.
    - Awarding institution and type of institution (e.g., 1862 land-grant university, 1890 land-grant university, or public non–land-grant university).

- Demographics of principal investigators (PIs), including
  - Ranks of each PI (e.g., assistant, associate, or full professor).
  - Each PI's current and pending funding.
- Human resources, including
  - Number of co-PIs.
  - Number of undergraduate students and number of months supported.
  - Number of graduate students and number of months supported.
  - Number of postdoctoral researchers and number of months supported.
- Research output as reported in USDA CRIS.

The committee also requested the same data for at least 1 year of the NRI for comparison. NIFA submitted multiple Excel files, each of which consisted of some pieces of the requested data exported from CRIS. The files as submitted were not organized in a way that would allow regression analyses. For example, some files included duplicate entries for a grant (mostly for the continuous grants that require annual reporting). Another example is that the number of undergraduate and graduate students and postdoctoral researchers trained and the number of months trained (also called number of student months) were all grouped together in one column. Those data had to be parsed into separate columns—one for each of the following categories: number of undergraduate students supported, number of undergraduate-student months, number of graduate students supported, number of graduate-student months, number of postdoctoral researchers supported, and number of postdoctoral-researcher months. To render all the submitted data in an analyzable form, National Research Council staff sorted the data, removed duplicate entries, collated data from the various files into one Excel file, and created dummy variables for the regression analyses. In the process of sorting the data, the staff noticed some gaps in data and a few inconsistencies among datasets (e.g., some entries for PI ranks or grant types were missing. In those cases, the staff either sought the information from the Web or sought clarification from NIFA staff.

In addition to the Excel files, the committee received thousands of folders, each of which contained all the files for PIs' and any co-PIs' pending and current funding in pdf. For about 5% of the awards, the staff could not identify the pdf files that contained the pending and current funding information. The committee found the results of the analyses without those data rather robust. Their addition would be unlikely to alter the results of the analyses. In the interest of time and effort spent on the part of the staff and NIFA, the committee decided not to seek those data from NIFA. For those pdf files, the National Research Council staff had to identify the file that corresponded to each grant and manually record the number of pending and current funding that the PI had from various agencies or types of organizations in the Excel file for regression analyses.

The committee did not receive any Excel files that had a column that specified the number of co-PIs on each AFRI award. However, such information was embedded within each folder that had all the pdfs for PIs' and co-PIs' pending support. Under the assumption that all co-PIs completed a form to disclose their current and pending support, the number of those forms completed for each project was used as a proxy for the number of co-PIs on each project. For a sample of projects, the number of co-PIs determined that way was compared with that listed in CRIS in order to confirm that the committee's method of tallying the number of co-PIs in a project was reasonable.

Although CRIS includes data on publications, presentations, and conferences held in connection with each project submitted by PIs, PIs cannot add information to the system after the project terminates. Given the lag time between the conduct of research and the publication of results, it is unlikely that all publications from every project are accounted for by CRIS. Therefore, the committee solicited help from Yunguang Chen, of Oregon State University, to search publications that acknowledge AFRI as a source of funding for the 2009–2012 grants and for the NRI awards initiated in 2008 by using Google Scholar. Written materials submitted to the present committee by external sources, including data submitted by NIFA, are listed in the project's public-access file and can be made available to the public on request.