USDA
REE

U.S. Department of Agriculture
Research, Education, and Economics

# A Roadmap for *USDA Science*

REE

# A Roadmap for USDA Science

## *Imagine a world in which…*

…Radically improved children's diets and nutrition slash long-term health care costs in the United States;

…Farmers, ranchers, and forest landowners are recognized as significant contributors to large and sustainable reductions in global greenhouse gases;

…Farmers in sub-Saharan Africa have easy, affordable access to new seeds and animal breeds so well adapted to local conditions and so resilient to changing conditions that they feed five times as many people domestically and eliminate persistent hunger;

…Trends in availability of high-quality water and new options for watershed management outpace increasing demand for water even as climate change alters the geography of water resources; and

…Technologically advanced production, processing, and foodborne pathogen detection methods make food product recalls nonexistent.

## *Farfetched?*

No. These goals are achievable, but doing so is powerfully dependent on food, agricultural, and natural resource science. And if such science is to be robust enough to reach these goals, it absolutely requires research and extension education that:

1. Focuses on a reasonable number of **outcome-driven priorities**;

2. Capitalizes on the **strengths of the USDA** and its partners to realize such goals in cooperation with agencies and institutions that bring different missions, mandates, and programs to the table; and

3. **Concentrates resources** in priority areas while maintaining the integrity of the foundational science that underpins all problem solving.

Here we present a roadmap for critical social goals that can best be championed—conducted, overseen, competitively awarded, and/or transferred—by USDA and its partners. The roadmap is conceptual, but implicit in its framework are specific actions over the next several years to reinvigorate and reimagine USDA science, including:

- The implementation of the new National Institute of Food and Agriculture;
- A rejuvenation of the competitive research grant award system; and
- Strategic transformation of USDA's intramural research assets.

The specific strategies for this transformation will evolve through budgetary and program-planning processes; some examples are given later in this document. However, all of our scientific inquiry will be guided by the "Roadmap for USDA Science" presented here.

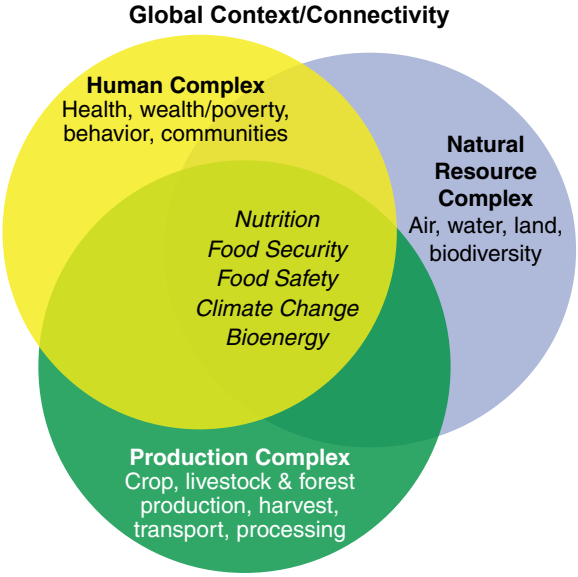
## *The Agricultural Science Imperative*

Investments in food, agricultural, and natural resource science are catalysts for economic growth. Agriculture is a key contributor to productivity growth in the U.S. economy. While production agriculture represents only about 1.8 percent of U.S. gross domestic product, agricultural productivity from 1970 to 2000 made an oversized contribution of 12 percent to overall U.S. productivity growth (Jorgenson et al., 2006). Furthermore, U.S. public agricultural research and development has accounted for about half of that agricultural productivity growth (Shane, 1998). The average social rate of return on investment has been estimated at 45 percent (Fuglie and Heisey, 2007). These figures, while impressive, actually are quite conservative. They do not account for the nonmarket goods—increased water quality, safer food, fertile soils, enhanced wildlife habitat, etc.—that typify such scientific endeavor in more affluent nations.

Societal challenges and opportunities in which agriculture plays a critical role are numerous and varied. These challenges can be viewed in several "complexes"—human, production, and natural resource—which represent areas contributing to and affected by agriculture (Figure 1). In the human complex, issues related to human health and nutrition, poverty and food availability, and food safety and security challenge agriculture as never before. Worldwide, one out of eight people faces starvation, and one of two people is malnourished. Hunger and malnourishment co-exist with widespread obesity in the United States and other countries throughout the world. On local and national scales, changing demographics, consumer preferences, and behavioral norms affect what is produced, how it is produced and marketed, what people choose to consume, and how consumption affects health.

In the production complex, the United Nations Food and Agriculture Organization estimates that farmers will have to produce 30 percent more grain by 2030 than they do now to keep pace with world hunger. Rising standards of living, population increases, and demand for biofuels compound the need for increased productivity. Satisfying these food needs requires integration of crop and livestock genetics; strategic management of nutrients, water, and pests; and efficient processing, distribution, and marketing—all against a backdrop of dynamic and sometimes volatile change. Climate change further challenges

Figure 1
**Society's pressing issues (in italics) all require understanding of the human, production and natural resource complexes and the interactions among issues and complexes**




the agricultural economy, as growing seasons, water availability, pest migration, and carbon markets rapidly evolve.

In the natural resource complex, we currently face serious natural resource and environmental challenges. Globalization has resulted in unprecedented connectivity among the world's ecosystems, facilitating an alarming rate of species invasions that threaten natural and agricultural systems and human and animal health, and cost Americans as much as $120 billion annually (Pimentel et al., 2004). World population growth drives land use changes that affect our climate, imperil our native ecosystems, and place our urban/industrial and rural/agricultural communities in competition not only for space, but for water and other fundamental natural resources as well.

These great challenges and opportunities—food security, human nutrition, energy, climate change, food safety—require an understanding not only of the forces acting within each of the human, production, and natural resource complexes, but also of the interactions *among* the complexes.

## *USDA's Comparative Advantage*

***USDA has a skilled scientific work force, laboratories, data sets, germplasm collections, national forest sites, and scientific transfer and extension systems that make it unique among science agencies.***

Most USDA scientific research and extension takes place in or through five agencies:

- The ***Agricultural Research Service (ARS)*** is the largest intramural research agency of USDA. ARS has a workforce of around 8,000 employees, including 2,500 life and physical scientists who represent a wide range of disciplines and who work at more than 100 locations across the country and at five overseas laboratories. The ARS research agenda is broad, with about 1,200 research projects organized under four major program areas: Nutrition, Food Safety and Food Quality; Animal Production and Protection; Natural Resources and Sustainable Agricultural Systems; and Crop Production and Protection.

- The ***National Institutes of Food and Agriculture (NIFA)*** is USDA's primary extramural research funding agency. Its mission is to advance knowledge for agriculture, the environment, and human health and well-being by funding targeted research, education, and extension projects and programs, some of which are specific to the Land-Grant University System, and others open to participation by other partner organizations.

- The ***Economic Research Service (ERS)*** is USDA's primary source of economic information and economic and social science research. ERS' mission is to anticipate economic and policy issues related to food, agriculture, the environment, and rural development, and conduct research that informs public program and policy decisions.

- ***Forest Service Research and Development*** is the research and development arm of the USDA's Forest Service, devoted to improving the health and use of our Nation's forests and grasslands. Some 500 Forest Service researchers work in a range of biological, physical, and social science fields, with programs in all 50 States, U.S. territories, and commonwealths. The Forest Service focuses on informing policy and land management decisions regarding such issues as invasive species, degraded ecosystems, and sustainable production systems.

- The ***USDA's National Agricultural Statistics Service (NASS)*** conducts hundreds of surveys every year and prepares reports covering virtually every aspect of U.S. agriculture. As the USDA's statistical agency, NASS also conducts statistical science research on survey design, sampling, and other methodological issue areas.

These agencies and many of their scientists are internationally renowned. They are the source of breakthroughs ranging from the first determination of the structure of RNA and the discovery of viroids to participation on the teams that mapped the swine, soybean, and bovine genomes. USDA innovations include the development of an edible coating to keep apple slices fresh, a foodborne illness cost calculator, and the first 100-percent soybean ink.

These agencies are the USDA units dedicated completely to scientific activity. The Food Safety and Inspection Service, Animal and Plant Health Protection Service, and the Food, Nutrition and Consumer Services area are among the USDA agencies or missions with an applied research component.

USDA agencies are not the only science agencies dealing with human well-being, agricultural productivity, and/or natural resource issues. For example, the National Science Foundation (NSF) funds research on basic scientific functions that could enable the coaxing of certain traits out of plants, animals, and food. The National Institutes of Health (NIH) and the other health science agencies of the Department of Health and Human Services conduct wide ranging research on human health. The Department of Energy (DOE) has a large program on biomass as an energy source. And the United States Geological Survey (USGS) conducts outstanding research on natural systems.

While these and other partner agencies' science programs address issues that complement those addressed by USDA, food and agricultural science performed at USDA answers questions and provides perspectives unique in the Federal system.

- **Agricultural and forestry science focus on systems unfamiliar to others.**

  Agricultural and food scientists are trained to understand and design research projects that consider how a change in one factor can result in effects, sometimes counterproductive or counterintuitive, throughout the forestry and food/agricultural systems. For example, genetic improvement in the average yield of a crop must be examined in light of how it and an

array of improvement possibilities affect the need for costly agricultural inputs, crop resilience under abnormal conditions, vulnerability to pests, or nutritional composition of the end product. USDA researchers have to be able to grasp the systemwide scope of effects.

Knowledge of agricultural/forestry systems and infrastructure differentiates USDA's research from that of other science agencies. For example, USDA and DOE each can make valuable contributions to the scientific basis for a viable biofuels industry. Agricultural scientists are deeply familiar with the processes of producing biofuel feedstock—the grown biological materials that can be converted into biofuels. Their understanding of plant physiology, crop genetics, agronomy, and agricultural and forest production systems gives them a strong comparative advantage in researching the production of biomass. DOE has a strong comparative advantage in investigating the physical processes involved in the efficient conversion of produced biofeedstocks to fuel. Since these different functions are linked, USDA and DOE work hard to coordinate their research programs, each benefiting from the collaboration.

- **Agricultural science lends itself to practical applications.**

The history of USDA as "The People's Department" and the establishment of a Land-Grant University system to serve the public good—back when most of the public farmed—reinforce the unique qualities of agricultural science. Even the basic science performed at USDA is done with a specific goal in mind.

Food scientists perform experiments—based on a combination of microbiology, chemistry, physics, and genetics—on how microbes survive in commodities or products, leading to new ways to prevent foodborne diseases. Nutritionists study biochemistry and human physiology to improve health related to food consumption. Agricultural engineers examine physical forces interacting between soil, water, and air to solve complex problems in erosion control and watershed management. Plant physiologists study photosynthesis, respiration, plant nutrition, plant hormone functions, environmental stress physiology, seed germination, and dormancy to develop superior new crop varieties and production systems to maximize genetic potential. Every day, improved scientific understanding makes more transparent the response of agricultural and forest production systems to changes in the environment or production practices, and

this enables producers, consumers, agribusiness, and policymakers to better anticipate problems and make informed decisions.

- **USDA's intramural research agencies have unique capacity and science-critical resources.**

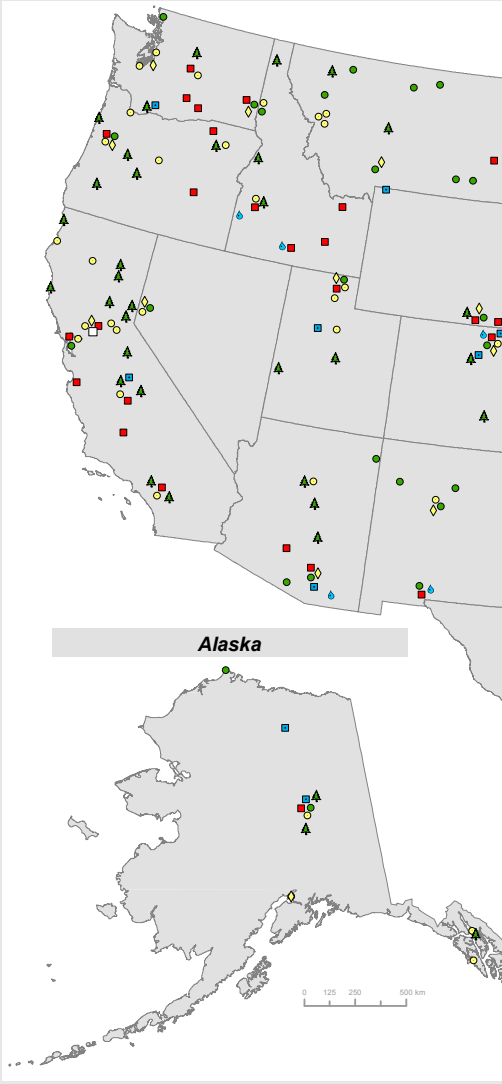
ARS and the Forest Service maintain and continuously add to critical germplasm collections that form the very basis for breeding programs. USDA administers the agricultural census and other farm, ranch, and household surveys that provide data for national-scale models to project agricultural water use, land use, soil erosion, food prices, and other variables under alternative scenarios. ARS houses the Nation's agricultural library. ARS administers technology transfer and NIFA transfers knowledge into action through extension programs that are the envy of the world in their translation of knowledge into communities.

Long-term research is facilitated by unique resources such as the Forest Service's 81 Experimental Forests and Ranges across the United States. These valuable sites incorporate a broad range of climates, forest types, research emphases, and history. They serve as living laboratories for scientists to conduct long-term studies, learn about ecosystems, and share results with partners and stakeholders.

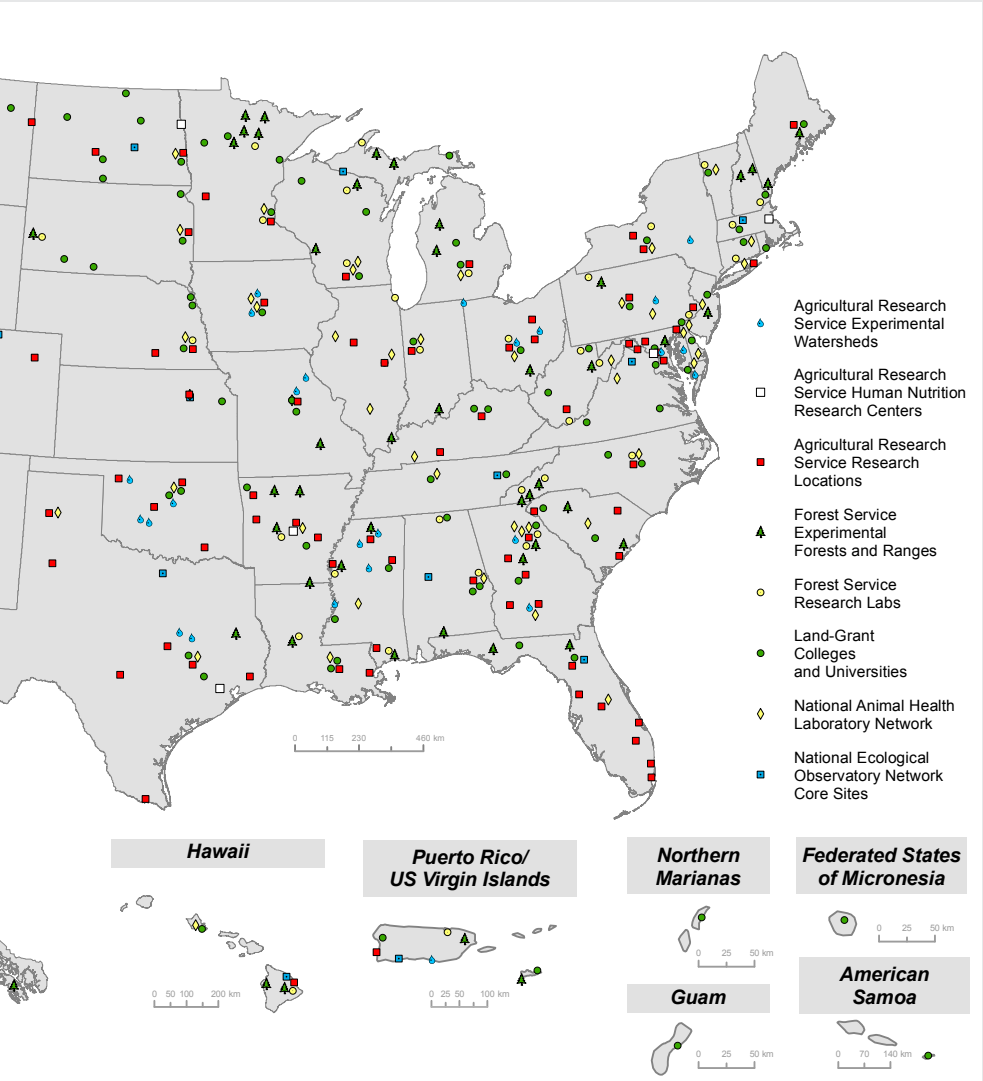
Figure 2 shows the breadth and reach of USDA science across the country.

Figure 2

**USDA research sites**



Quick-turnaround research depends on flexible capacity in laboratory facilities, collections, and personnel. These geographically disperse resources enable USDA to nimbly respond with scientific intensity to new and emerging problems. For example, ARS developed diagnostic tests within a week to differentiate the H1N1 virus from other swine and avian influenza viruses circulating in the United States.



The vast Cooperative Extension System supported by USDA ensures that applied research and new technology reaches the people most likely to benefit from them—from consumers and rural residents to farmers, community leaders, families, schoolchildren, and food assistance recipients.

## *Impact-Driven Science*

***USDA science needs to be focused, leverage other resources, and concentrate on select priorities at a large scale to produce valued results.***

USDA has embraced program prioritization and planning based on the impact of an activity—on what USDA programs will achieve. This model works particularly well for science planning, not because one can predict the ultimate outcome of a scientific endeavor, but because resources can be concentrated and leveraged to ensure that the scientific goal is achieved.

With input from dozens of stakeholder groups and individuals, USDA's Research, Education, and Economics (REE) mission area has designated the following five priority areas:

**Bioenergy**. USDA aims to correct the current trajectory of research to thoroughly account for biomass, the basic building block of biofuel. Among the challenges that must be met for a sustainable biobased-fuel economy: plant improvement for biofuel crop and woody mass production; the analytical capacity to understand the social, economic, and environmental repercussions of biofuel production; and development of technologies suitable to farm scale.

Impact: Increase community prosperity and create energy independence through the development of sustainable new bioenergy systems.

**Climate Change.** Agricultural and forestry ecosystems are climate dependent and could be affected in myriad ways by a changing climate. At the same time, agricultural and forestry practices can provide valuable greenhouse gas offsets under regulation-induced markets to mitigate greenhouse gases. Research aimed at improving crop, animal, and forest management in light of climate change, and at quantifying the potential for agriculture and forestry to serve as carbon sinks, can turn a liability into an asset.

Impact: Anticipate and accommodate climate change effects such that agriculture, forestry, and U.S. producers realize net benefits.

**Food Safety**. Public health can be substantially improved by developing technologies that protect food from pathogens, toxins, and chemical contamination during food production, processing, and preparation. USDA oversees all three processes.

Impact: Improve public health through a U.S. food supply free of foodborne pathogens.

**International Food Security**. In developing countries with largely agrarian populations, a vibrant and sustainable agricultural system is the very basis for broad economic development and stability. Until a nation has the capacity to feed, clothe, and shelter its rural and native populations, labor and capital cannot be freed for the pursuit of growth in other economic sectors. Agricultural development hinges on access to affordable, appropriate, and sustainable technologies that can improve food production, harvesting, storage, and distribution, and advance the health and safety of all citizens.

Impact: Significantly reduce agriculture-dependent poverty and hunger in low-income countries.

**Child Nutrition**. USDA science is in a unique position to enhance the health-supportive traits of food sources, make discoveries about basic food traits, and develop behavioral cues for healthy eating, all in relation to USDA's delivery of nutrition assistance to those who need it.

Impact: Reduce health care costs and raise the productivity of America's future workforce by meaningfully reducing malnutrition and obesity, with a focus on low- and middle-income children.

***REE priorities rely heavily on crop, animal, and production systems research.***

What we produce, how we produce it, and with what productivity outcome determine the availability and, to some degree, cost of food, fiber, and fuel. Intramural as well as extramural research on crops, animals, and production systems is essential for the accomplishment of REE priorities. For example, climate change adaptation requires research on crops, animals, and biotic and abiotic production stress. Bioenergy goals for USDA include the development of targeted plant and production systems. And providing greater food security

through enhanced production capabilities around the world requires contemporary research along the very path blazed by the late Norman Borlaug.

These are some destinations of the roadmap. More detail on the routes and means of travel will allow REE and its agencies to plan research and extension activities—the roads—to get us there. These goal areas do not encompass everything that USDA science will address. They represent priorities among many goals of intramural and extramural research in USDA.

Furthermore, USDA will not try to accomplish these and other goals by itself, but will partner with universities and other Federal agencies to leverage effort. USDA will focus on those things for which it has a comparative advantage (Figure 3).

Figure 3
**NIFA should seek to double its effective grant-making through matching grants from better funded Federal partners**

| | |
|---|---|
| Bioenergy |  |
| Climate change |  |
| International food security |  |
| Food safety |  |
| Child nutrition/ health |  |

## *Strategy*

USDA has a multi-faceted strategy to improve the chances that goals for our five priority areas will be realized.

**Invest funds to recruit the best and brightest in solving food and agriculture problems**.

The accomplishment of critical outcomes requires that we marshal the most innovative, creative, and forward-looking scientists to work toward each outcome goal. Engaging the best and brightest requires investment in education, competitive hiring in USDA intramural research agencies, and the use of sufficiently attractive competitive funding awards to interest research superstars. Thus, USDA is exploring new approaches to grow and leverage the competitive granting programs that exist within the Research, Education and Economics (REE) mission area.

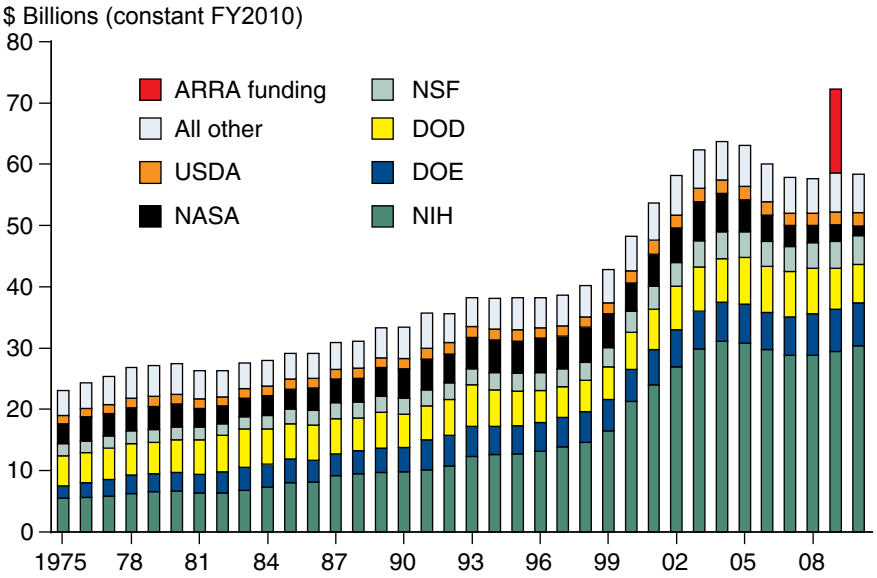
In FY 2010, USDA ranks sixth among Federal agencies in total Federal R&D investment, not including investments in education or extension/outreach (Figure 4). Over the past two decades USDA's share of Federal research has declined from about 5 percent to 3.5-4 percent (3.3 percent of Federal basic research and 4.3 percent of Federal applied research) (NSF, 2008, and U.S. Budget, Analytical Perspectives, Table 21-1). The availability of increased R&D funding would make it possible to attract the best and brightest scientists.

USDA's largest research competitive grants program is the Agriculture and Food Research Initiative (AFRI). AFRI will be the focus of growth in REE. ARS, Forest Service R&D, and ERS scientists are expected to compete for AFRI funding. Because these intramural agencies contain ideal candidates for various researchable issues, their programs likely will be bolstered legitimately with some AFRI funds.

**Reinvigorate USDA's intramural assets.**

Although competitive grants are central to our strategy, intramural research capacity needs to be sustained to undergird and complement competitively funded extramural research. Competitive programs build upon and extend

Figure 4
**Trends in research investments by agency**




FY 2010 are the latest estimates. Research includes basic research and applied research. 1976-1994 figures are NSF data on obligations in the Federal Funds survey.

Source: AAAS Report: Research & Development series.

base funded programs, exploit new opportunities and approaches, and fill gaps not addressed by intramural programs.

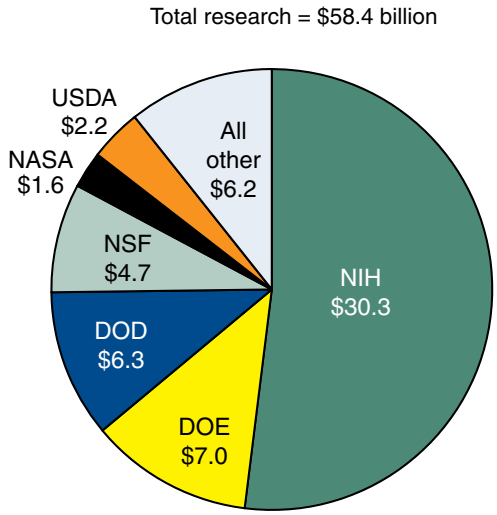
Intramural research programs fulfill a number of inherently governmental roles that do not meet the criteria for competitive funding. The types of research that lend themselves to intramural programs include:

- Research that directly addresses the scientific needs of USDA program delivery agencies whose characteristics may appear arcane outside of government.
- Research that builds on unique or confidential data sources, collections, or special infrastructure unavailable outside of USDA.
- Research that provides coordination for a national perspective or framework, setting a single standard for use by others.
- Research addressing questions with shortrun payoff or requiring immediate response to a health, safety, or policy development.

REE is launching a review of its intramural research capacity, with the goal of initiating a new strategy for strengthening it in 2010.

Data suggest that recruiting and maintaining scientific expertise to address complex issues of food and agriculture will be one of the challenges facing USDA intramural science. More than half of USDA's scientific workforce is eligible to retire between 2009 and 2014. The science agencies compete for talent with the private sector, other Federal agencies, and academe. Attracting, mentoring, and retaining future generations of scientists will be critical to addressing staffing gaps.

Figure 5
**Research by Agency**
*Budget authority in billions of dollars*




Source: OMB R&D data, agency budget justifications, and other agency documents.
Research includes basic research and applied research.

**Elevate science and science-based decisionmaking in USDA.**

The launch of the new National Institutes of Food and Agriculture is a giant step in this direction. Given the complex issues facing agricultural science and the need for efficient use of resources, knowledge sharing and cooperation across agencies within USDA and with science agencies outside USDA is essential. This is true not just among science agencies but also among the agencies that run non-research programs. USDA action agencies (e.g., Food Safety and Inspection) depend on the science generated in the REE mission area to ground their work. Systematic, transparent, and systemwide joint planning, prioritization, and communication are critical to the overall strategy.

Outstanding coordination already is evident. ARS and NIFA conduct joint planning at the headquarters level. ARS scientists and extramural funding recipients work closely at the field and project levels, as is true for Forest Service R&D. ERS provides input to ARS planning. ARS and ERS both hold periodic meetings with USDA action agencies to identify upcoming economic, science, and technology issues.

Nevertheless, improvements can be made in the comprehensiveness, breadth, and accountability of systemwide program coordination.

The USDA Chief Scientist's office is being given this responsibility. A council of representatives from each USDA agency that can use research to meet programmatic needs will meet periodically to help the Department and its agencies prioritize and plan programs.

Among USDA's science agencies, institutional changes will be made to ensure that science programs fit hand-in-glove with one another, avoiding duplication of effort and creating research synergies.

**Recognize the globalization of food, agricultural, and resource problems.**

Agricultural issues no longer have political and geographical borders. Many problems in the developing world are either shared through globalization (e.g., H1N1 virus, wheat stem rust) or are common symptomatically to problems already familiar to USDA scientists.

For example, reducing agriculture-dependent poverty and hunger in low income countries will require more outcome-driven focus on the food and agricultural systems of other countries. This can be best accomplished by the concerted allegiance of USDA scientists with their foreign counterparts. Such engagement allows colleagues from different nations to recognize important contributions from other cultures and science traditions. This in itself encourages a strengthening of science research, the expansion of strategic partnerships, and more open communication with the world's science community. Sharing scientific knowledge among scientists, stakeholders, and decisionmakers contributes to sound policies and on-the-ground management practices that ultimately benefit the global population. USDA envisions scientific exchanges with global peers of suitable duration to develop significant scientific findings.

## *The Road Ahead*

Solutions to the many of modern society's most intractable problems demand a scientific renaissance. The renaissance begins with broader thinking about the physical, biomedical, and curiosity-driven fundamental sciences (*A New Biology for the 21st Century*). Applied food and agricultural sciences need to join together. Land use, agriculture, and food availability have major implications for climate, the natural environment, energy solutions, rural and international economic development, human health, and food security. Better use and availability of competitive research funding, broader thinking about food and agricultural science, and an outcome-driven strategy for research prioritization and targeting are essential elements of a required scientific renaissance.

USDA will embrace this renaissance by:

- **Listening to the needs of the users of its research findings and stakeholders in its research direction**. Stakeholders played an important role in the development of this roadmap, and will continue to be valued. Numerous meetings were held with industry, government, nongovernmental organizations, universities, professional societies, and a variety of individuals to seek their input into what constitutes the major challenges ahead. And USDA issued a *Federal Register* notice to: (1) explore critical issues and identify opportunities to enhance USDA research, education, and extension; and (2) ensure that a broad range of individuals had an opportunity to provide input to the roadmap.

  Looking ahead, the structure of the National Institutes of Food and Agriculture will include new, standing councils that will, along with stakeholder forums currently utilized, solicit input from stakeholders on USDA science policy and program decisions. Further, an internal USDA agency council will ensure that the research agencies of USDA know their sister agencies' science needs.

- **Recognizing the value and unique needs of all USDA partners in agriculture**—including first-time farmers, small farmers, tribal and ethnic communities, community-based organizations, and low-tech farmers.

- **Institutionalizing outcome-driven scientific program planning and implementation**. It is appropriate for USDA to focus on what its scientific

endeavors are aimed at achieving. Quantified outcome goals for specified periods of time will make it easy to judge their success.

- **Focusing research program growth in competitive granting programs, particularly the Agriculture and Food Research Initiative**. While not all funding requests or discretionary allocations will go to AFRI, the Initiative provides the flexibility needed to make awards sufficient to attract the best and the brightest scientists to food, agricultural, and natural resource research, to switch gears to new priorities as new issues emerge, and to accommodate methods of grant proposal solicitation that are not so burdensome as to deter researchers. The Director of the National Institutes of Food and Agriculture will lead an effort to renew and revitalize USDA competitive research granting.

- **Better coordinating its science planning, both among REE science agencies and between those agencies and other Federal science agencies**. Each unit performing research, education, or extension will capitalize on its own advantages, preventing redundancy and making the best possible choices for complementarity and synergy among science agendas. This will be accomplished through structural changes and new coordination responsibilities.

- **Leveraging USDA and others research funding through joint activities.** For example, the State Department's renewed emphasis on international food security can be advanced by coordinating with USDA. Such partnerships will become increasingly commonplace.

- **Communicating about USDA science in new ways.** A new position for Science Communications has been established to raise the level and volume of communication about USDA scientific accomplishment.

We invite all of our constituents, users, stakeholders, and science partners to join us on the exciting journey that begins with the issuance of this general roadmap of destinations, and will evolve as we build the institutional roads to get there.

## *References*


Committee on a New Biology for the 21st Century. *A New Biology for the 21st Century: Ensuring the United States Leads the Coming Biology Revolution.* National Academies Press. 2009.

Fuglie, Keith O., and Paul W. Heisey. 2007. *Economic Returns to Public Agricultural Research*. Economic Brief No. 10, Sept.

Jorgenson, Dale W., Mun S. Ho, Jon D. Samuels, and Kevin J. Stiroh. 2006. "Industry Origins of the American Productivity Resurgence," Working Paper, Department of Economics, Harvard University, Cambridge, MA.

National Science Foundation. Division of Science Resources Statistics. 2009. *FY 2008 Data Show Downward Trend in Federal R&D Funding*. Arlington, VA (NSF 09-309). Jan.

Pimentel, D., R. Zuniga, and D. Morrison. 2005. "Update on the environmental and economic costs associated with alien-invasive species in the United States," *Ecological Economics*. Volume 52, Issue 3.

Shane, M.D., T.L. Roe, and M. Gopinath. 1998. *Agricultural Growth and Productivity*. U.S. Department of Agriculture. Economic Research Service.

United Nations, 2009. "The Millennium Development Goals Report." http://mdgs.un.org/unsd/mdg/Resources/Static/Products/Progress2009/MDG_Report_2009_En.pd. (visited September 10, 2009).

Executive Office of the President, Office of Management and Budget. *Analytical Perspectives*. Budget of the United States Government, Fiscal Year 2011.