Agricultural Science, the First Best Hope for the Future

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I am pleased to be able to weigh in on the theme of NABC 23: global food security. There's no question that we are living in extraordinary times and facing enormous challenges both at home and around the globe. But, to me, the most urgent problem facing us—surpassing even terrorism or nuclear proliferation—is making sure we can provide the safe, nutritious food and clean water needed to support an ever-growing population, and to do that in a sustainable manner.

As a scientist, I know that the research we need to address global food security can't wait. Research takes time, it takes long-term funding, and it takes a work force educated enough to do it. I see a large part of my mission at USDA[1] as moving the ball forward on all of those areas so that our nation can keep its place as a science leader and help the world address the challenges that lie ahead.

The United Nations projections for global population were recently revised upwards—to a global population of 10 billion people by 2100, 3 billion more than today, and they will all need to be fed. Robert Thompson uses a very startling image to illustrate that growth rate:

> *By 2050, the world population will have grown by the equivalent of two Chinas—one by 2020 and the other between 2025 and 2050.*

The challenge of such a population increase is compounded by a larger demand for protein foods in their diets. More meat requires greater inputs to produce. Given all these predictions, food production may need to double by later in this century—and agricultural research is the only way to accomplish that. Science is also essential to making those productivity gains in a sustainable manner—in a way that stewards soil, water, biodiversity, community vitality, and other natural and human resources.

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The other aspect of this challenge is what I call the "preservation gap." Fully 40% of the food that's produced is lost after harvest to insects, rodents and rot. Solving the preservation dilemma will go a long way toward solving our global food-security problem.

Investment in Agricultural Science

In my role at USDA, I am keenly aware of how important the work university and USDA scientists pursue is to addressing these needs. We have focused our work on five priority areas—Food Security, Food Safety, Bioenergy, Climate Change and Nutrition—all of which tie back to making the supply of food more secure here in the United States and around the globe. To meet these priorities, however, will require funding, and that is an over-arching difficulty facing our government today.

A look at our history and at countries around the world shows that increasing our investments in agricultural science, education, and technology is the foundation needed for a strong future. Many economic studies have shown that investments made in publicly-funded research have earned substantial returns to the US economy, with total economic benefits exceeding costs by at least twenty to one. Much of the economic benefit from this research goes to consumers, who gain from more-abundant, lower-cost, better-quality and safer food. In the United States, we've seen the benefits of public research in breakthroughs that improve the productivity of our agricultural producers, giving them the tools they need to produce our food more efficiently and cost-effectively.

Today, the United States enjoys one of the safest, most abundant, high-quality, and diverse food and agricultural systems in the world. We didn't get here by accident. We got here by investing in agricultural science and education and by transferring scientific knowledge and technologies to America's hardworking farmers and businessmen.

Unparalleled Challenges

One of the best things that public investment in science and education has done over the last 149 years is building an agricultural research, education, and extension system that is unequaled and which has contributed greatly to our nation's success.

It's the system that transformed the nation by making higher education not only practical, but accessible to all. It's also the system that faces unparalleled challenges in a time of tight budgets. Budget cuts from the 2011 continuing resolution are already affecting the state experiment stations and Cooperative Extension as well as research that USDA scientists engage in to assure domestic food security and help feed the world. In addition, budget cuts are affecting our standing in the global scientific community. Our 2012 budget is currently being debated in Congress, but the outlook for USDA science is not promising. Unfortunately, USDA science has not been treated in the same manner as that of the other research agencies and has lost substantial ground, whereas others have received only modest reductions in their support.

What's worrisome here at home is also occurring globally. Growth in public research investment has significantly slowed over the course of the last three decades as the world's governments have underinvested in agricultural R&D.

In many developed countries, including the United States, public investment in agricultural science has remained flat or shifted resources away from farm-productivity research and toward other societal concerns like the environment and human-disease treatment. During the 1950s and 1960s, US public sector agricultural R&D spending grew at over 3.6% per year but growth has slowed to less than 1% per year since 1990. Private investment in agricultural research has grown somewhat faster than public R&D, and now accounts for more than half the spending in agricultural R&D in the United States. But the private sector focuses on areas where intellectual property allows it to earn a return on its research investment. It can't do the kinds of fundamental research and scientific training that have traditionally been strengths of government and academic research. And if the fundamental discoveries run out, so will the private avenues for development of new products and processes.

Scientific Successes

USDA science has had some great successes in recent years. Genetic discoveries leading to applications that help farmers, ranchers and agricultural producers, such as the FasTrack Breeding system that accelerates the growth of fruit trees, are excellent success stories. It typically takes at least four generations to develop a new fruit-tree variety. But FasTrack Breeding shortens the breeding time from 16 years to 5 via four steps:

- The continuous flowering gene from poplar (*FT1*) is introduced through genetic engineering into a parent fruit tree.
- The engineered parent tree is then crossed with normal, non-engineered parents. Because the resulting seedlings express *FT1*, advanced selections can be made in less than 1 year. These advanced selections are then used as parents.
- In the last generation, there are four types of trees to choose from: desirable types containing *FT1,* undesirable types containing *FT1,* desirable types NOT containing *FT1,* and undesirable types NOT containing *FT1.*
- The desirable non-*FT1* types are selected for potential release. In this way, genetic engineering is used only to speed up the breeding process in creating non-genetic engineered cultivars.

In another case, USDA research has worked for over 100 years to help dairy farmers breed more productive cows. Since 1940, that research has resulted in a 4-fold increase in milk yield per cow. Today in the United States, 9.1 million dairy cows each average over 21,000 pounds of milk per year. In addition, USDA and collaborators have recently made improvements to the genetic selection program by partnering with the NIH to sequence the cattle genome, and have gone on to develop DNA "chips" for genotyping bulls and cows, with associated computer software for selecting superior parents for breeding. This new technology is dramatically enhancing the dairy industry's genetic selection program for improving milk production.

While these public investments were being made, the private sector was investing in dairy-cow nutrition. Much of the feed analysis and formulation today is still done by private industry, enhancing the production of high-value feedstuffs and supplements that support efficient milk production. It's a case where private investment followed public investment, and the world has reaped the benefits.

It's important to understand that these kinds of breakthroughs require years of public investment in fundamental research before the scientific understanding is advanced enough to move toward practical technologies. Oftentimes, the technological development can be undertaken by the private sector, although even then, some kinds of technologies can't be easily commercialized and may require direct public support. A good example of complementary roles of public and private sectors working together can be seen in crop improvement. Although most new crop varieties sold to farmers today are developed in private seed companies, the steady improvements in crop yields wouldn't be possible without access to better and more diverse sources of plant genetic resources. USDA's investments in plant germplasm conservation, characterization and enhancement underpin the private seed industry. But with some crops—wheat and barley are good examples—the returns private breeders can earn are not sufficient to attract much private R&D. In these cases, the public sector has a role to play in "downstream" technology development.

It's this kind of work that points to the continued and essential need for publicly funded research, because the private sector will always need to answer to shareholders. Scientists funded by USDA—in university labs and intramural labs—aren't constrained by the limits of current commercial demand. They follow the science, and people around the globe end up benefiting. The long-term return on investment—rather than quarterly returns—pays off for everyone.

Developing-World Needs

Public-sector investments are especially critical to the developing world. Private R&D is still very weak in many of these countries and accounts for only 6% of total agricultural research in this part of the world. There is also tremendous potential for many of these countries to raise agricultural productivity by borrowing and adapting technologies developed elsewhere. For example, the research centers that are members to the Consultative Group on International Agricultural Research (CGIAR) have helped developing countries improve their varieties of staple food crops like wheat, rice, sorghum, and cassava, as well as minor but nutritionally important crops like pulses. Almost all of this work has been done by the public sector, and much of it, collaboratively, between international and national agricultural research programs. While many developing nations are stepping up their support of agricultural research, developed countries are stepping back.

The United States, Japan, Australia, Canada, and European countries have cut back on their support of international agricultural research in recent years, and some economists have attributed the decline in the rate of yield growth in major crops like rice and wheat to that underinvestment.

In contrast, a number of developing nations—most notably Brazil and China—have been expanding their agricultural research and development capacities during the last couple of decades. China now has the largest number of agricultural scientists, more than 50,000. Brazil has raised its public R&D investment to over $1 billion per year. China and

Brazil are now achieving some of the highest agricultural productivity growth rates in the world. This productivity growth has enabled China to remain largely self-sufficient in food, despite limited land and rapidly improving diets of its people, while Brazil has transformed itself from a food importer to the second largest food exporter (after the United States). Such successes are not limited to China and Brazil, however. Studies have found a clear link between countries that have invested in agricultural science and technology capacity and the ones that have been most successful at raising their productivity. The poorest and most food-insecure countries of the world today, such as those in sub-Saharan Africa, are also the ones with the least developed scientific capacities in agriculture.

In light of these studies, it's clear that we can't let agricultural research flag here at home, and need to encourage developing countries to put science on their agendas for growth. I applaud the focus and determination of countries such as Brazil and China to invest in developing a well-educated scientific workforce. The investment is paying off for them, and it is important that the United States shouldn't ignore what the competition is doing, but instead, we should pay attention.

Disturbing Trends

One particularly disturbing example, to me, of the effects of our disinvestment in research was in the recent case of the *E. coli* outbreak in Europe. When Germany needed expertise to track down the source of the virus, it turned to Chinese researchers at the Beijing Genomics Institute, not to American scientists. The Chinese researchers then sequenced the DNA of the virus and determined its origin. In the past, this outreach would have been to the United States. This is the kind of development we need to sit up and take notice of—and face the facts about what drying up the well of funding for public research will cost our country and the world.

Since then, USDA science *has* been asked by FDA, the Massachusetts Department of Health and the CDC to analyze the sequence, genes, and antibiotic resistance patterns of the *E. coli* O104:H4 isolate from the outbreak strain in Germany. This is an excellent model of government entities working together for the common good, as they unlock the mysteries of this deadly bacterium and study it to keep our food supply safe.

Other countries are also increasingly more attractive to international students who used to come here to study science, but now can stay in their home countries, or go to Korea, China or Brazil instead. Many of those international students stayed to build extremely successful science-based and technology-based businesses.

There was an opinion piece in the *Washington Post* recently called, "Go to China, Young Scientist," by Matthew Stremlau, a post-doc with Harvard and MIT. He talked about the advice he gives to students and colleagues who ask where they should look to build their careers after graduation:

> *Go to China, I tell them. Or Singapore or Brazil or the Middle East. If the United States can't fund its scientific talent, find a country that will.*

I sincerely hope that young scientists haven't read that article. I do hope that the Congressional appropriations committees did read it.

But it does seem that the United States is already falling behind in the numbers of students graduating with degrees in agriculture. The statistics reveal a "no-growth" trend in graduate enrollment or degrees awarded in the core agricultural disciplines from 2005 to 2009. What little growth there is in graduate enrollment and degrees in colleges of agriculture is coming from related disciplines: family and consumer sciences/human sciences, forestry, and natural resources.

The Educational Landscape

So, our agricultural research system is doubly challenged by underinvestment and by the failure to keep the pipeline filled with the next generation of scientists to keep the research going. And in the near future, we'll have concrete data to help us chart exactly what the status is of that pipeline.

I attended a meeting with the Association of Public and Land-Grant Universities (APLU) in June 2011, and they agreed to work with us on an analysis of the landscape of students and their scientific education. They'll be assessing the flow of students through the "pipeline" of science, K–12, and through undergraduate and graduate education. They will be a valuable partner in determining how prepared we are for the scientific workforce we will need in the future. Their findings will let us know exactly what the situation is, so we can design strategies to shore up the supply of students educated in science and ensure they get the advanced degrees they need. We're working at the president's direction to increase attention and participation in science, technology, engineering and mathematics (STEM) education, which is the foundation needed to go forward into science-related careers.

That meeting with APLU was centered on the Action Plan that I've been working on since I got to USDA 9 months ago, as part of a series of consultations with stakeholders and the National Agricultural Research, Extension, Education, and Economics (NAREEE) Advisory Board. Our Action Plan takes concrete steps to address the strategies laid out in "A New Biology for the 21st Century." We want to strengthen our research by creating both literal and virtual collaborations across agencies, and bring together stakeholders who can add to that equation. We're working through the process of planning a long-term, coordinated strategy that addresses the very real problems that challenge the world right now and in the future. We've built a plan that really is based on action and results—and, as with the New Biology—will need to find ways to determine what those measurable milestones are, so that we know we are moving forward. That's a key part of the heavy lifting we're facing now, and we will continue to use the New Biology framework as a guide.

This vision of working strategically and in coordination is a theme I see across much of the scientific community these days. And it is happening on a global scale to solve global problems.

Malthus Deferred?

I appreciate the interest that this audience has in making sure that agricultural biotechnology advances, and continues to help feed the world. I began by quoting Dr. Thompson and I'd like to end with his encouragement to support agriculture research and the technologies it can offer the world. He was talking about the prediction by British scholar Thomas Malthus, who said that the world would eventually outgrow its capacity to feed itself, saying that Malthus was wrong for more than 200 years because he underestimated the power of agricultural research and technology to increase productivity faster than demand. Dr. Thompson said:

> *There is no more reason for Malthus to be right in the 21st century than he was in the 19th or 20th—but only if we work to support, not impede, continued agricultural research and adoption of new technologies around the world.*

That's a prediction I agree with. By keeping our eye on the goal of feeding the world, doing it in ways that are sustainable, and using our country's scientific abilities in the best of collaboration and coordination, we can ensure that 21st century America is well nourished, that our farmers are prosperous, and that world hunger will one day be an issue we can see in the rear view mirror and say we've beaten. I believe, if we continue supporting agricultural science and educating the next generation of American researchers, we will get there.

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Prior to going to USDA, Dr. Woteki served in the White House Office of Science and Technology Policy as deputy associate director for science from 1994 to1996. She has also held positions in the National Center for Health Statistics of the US Department of Health and Human Services (1983–1990) and the Human Nutrition Information Service at USDA (1981–1983), and was director of the Food and Nutrition Board of the Institute of Medicine at the National Academy of Sciences (1990–1993).