Invest in Public Agricultural Research, Development and Extension—Now!

Our food and agriculture systems face profound challenges in the 21st century.

Consumers need more nutritious food that is affordable and safe; producers seek innovation to help them beat climate change and natural resource constraints; and the entire agri-food value chain must rapidly adopt new practices and tools that contribute to a healthy sustainable world.

Technician Carolyn Johnson uses monoclonal antibodies to confirm E. coli presence in cattle fecal samples. USDA/ARS. Photo by Keith Weller.

Due to agriculture's dependence on limited resources like water and land, it may be unique in its reliance on productivity and innovation to meet the rapidly growing demand of consumers by 2050.[1] Agri-food innovation systems rely heavily on public agricultural research and development (R&D) and extension systems as well as regulatory frameworks that incentivize risk-taking innovation and investment.

Such agricultural R&D investments require long gestation periods of more than a decade to realize the full benefits that these investments generate. Over time, they pay large dividends, including higher profits for farmers, more abundant food supply at lower cost for consumers, and more opportunities and a higher quality of life in rural communities.

Yet, investments in public research in agriculture are not keeping up with the need. Without significant increases in R&D investment and partnerships, food and agriculture systems will fall short of a vision for a healthier, more sustainable world.

This chapter is a call to action to reverse the decline in public agriculture research, development and extension we face today.

Public R&D Sparks Innovation

Agricultural R&D along with extension programs are essential public goods and the principal drivers of Total Factor Productivity (TFP) growth. Public sector R&D and extension programs deliver innovation and information to agricultural producers. They provide access to proven techniques such as conservation agriculture and animal care practices to improve the sustainability and resilience of their operations.

While farmers innovate on their farms, experimenting with practices that can boost their own production, individually they do not have the capacity to conduct long-term research and development activities.

Public R&D provides foundational results that the private sector can further develop to improve specific crops, livestock, machinery or food manufacturing industries. R&D and extension services help producers control costs, reduce loss and waste and become resilient to weather challenges and climate change while conserving natural resources.

Countries that build national agricultural research systems (NARS) capable of producing a steady stream of innovations suitable for local farming systems have generally achieved higher growth rates in agricultural productivity than countries that do not make these investments.

Women's empowerment in research is critical to improve women's agricultural success in developing countries. In Tanzania a focus group discussion takes place with vegetable growers and agricultural researchers to improve the vegetable value chain. Credit: Winfrida Mayilla

Low-income countries must prioritize and increase investments, as their R&D spending remains much lower than others as a percentage of their agricultural GDP, a common measure of the commitment to productivity and agricultural innovation. Higher income countries must maintain a commitment to ongoing agricultural R&D to keep pace with ever evolving challenges faced by their producers and consumers.

Out of the Lab, On to the Farm
Case Study

TFP, as measured at the country, regional or global level, increases when there is widespread adoption of an innovative technology or practice.

Agricultural extension systems provide the link between public research and farmers, enabling them to understand and adopt innovation to benefit their business operations, the natural resources they manage, their families and the communities they live in.

In the United States, the cooperative extension program was established by the **Smith-Lever Act in 1914** and has become a model for many other countries. Working cooperatively, the federal government agencies involved in agricultural research, along with land-grant universities across the country and local county governments, built a solid structure for producing and sharing results and new practices.

At the Virginia Tech Shenandoah Valley Agricultural Research and Extension Center, technician Marnie Caldwell (left) and farm manager Dave Cuddy record measurements used to estimate forage yields in cow-calf grazing paddocks. USDA/ARS. Photo by Peggy Greb.

These extension systems serve to keep farmers successfully involved in agriculture, providing advice, training, and support for rural entrepreneurship. A recent study demonstrated that since 1985, some 137,000 farmers would have left farming without the specific services of cooperative extension.[2]

Initially, extension systems were established in the U.S. as a top-down model in which new information, practices and technologies flowed from experts to farmers. But this model has been challenged in recent years by a recession-driven decline in state-level investments for extension.

The twenty-first century needs a fresh, interactive model of partnership for knowledge exchange.

Farmers' social networks — trusted people in their home, community and business circles — play key roles in helping farmers adopt new information, practices and technologies. When it

comes to helping farmers of all sizes and operations adapt to climate change, trusted sources of information combined with practical tools are needed to understand the impacts and opportunities to build resilience at the farm level.

Cooperative extension agents can engage with social networks and develop tools for farmers that help them adapt to climate change and implement conservation agriculture practices. Digital innovation must also become an essential extension tool to reach remote or new farmers, and to reduce the costs of extension programs. Webinars can provide excellent educational resources to remote locations. Online tools and apps developed by extension agents and agriculture departments can help more farmers receive information and best practice advisory services.

Purdue University launched the **Useful to Usable initiative**, a regional level, multi-institutional program offering a suite of online tools to help farmers and agricultural advisors manage the increasingly variable weather and climate conditions across much of the Midwest Corn Belt. Farmers access online historical climate data and many other data sources for production and marketing decision-making throughout the growing season, essentially helping farmers climate-prepare their operations.

Agricultural R&D and extension systems in many **lower-income countries** have not been a priority due to budget constraints and the lack of prioritization. But new approaches and models to extension are emerging and as countries build out their research and extension systems, greater participatory models are evolving to fill the extension gap.

Working with international development institutions such as the **U.S. Agency for International Development (USAID)**, the private sector and non-governmental organizations, novel approaches to sharing technology and practices are being tested.

In the **Republic of Georgia**, decades of underinvestment have left farmers ill equipped and unprepared to take advantage of new market opportunities for their agriculture exports to the European Union. Georgia is committed to developing a robust, innovative public sector extension system.

The **Georgia Ministry of Agriculture** has more than doubled its annual budget with considerable funds for extension and advisory services.

Georgia is linking orchard producers with the information and technologies needed to meet new market demands. Videos on best management practices for orchard management and soil nutrition and training from global extension experts are provided. Credit: Givi Pirtskhalava/World Bank.

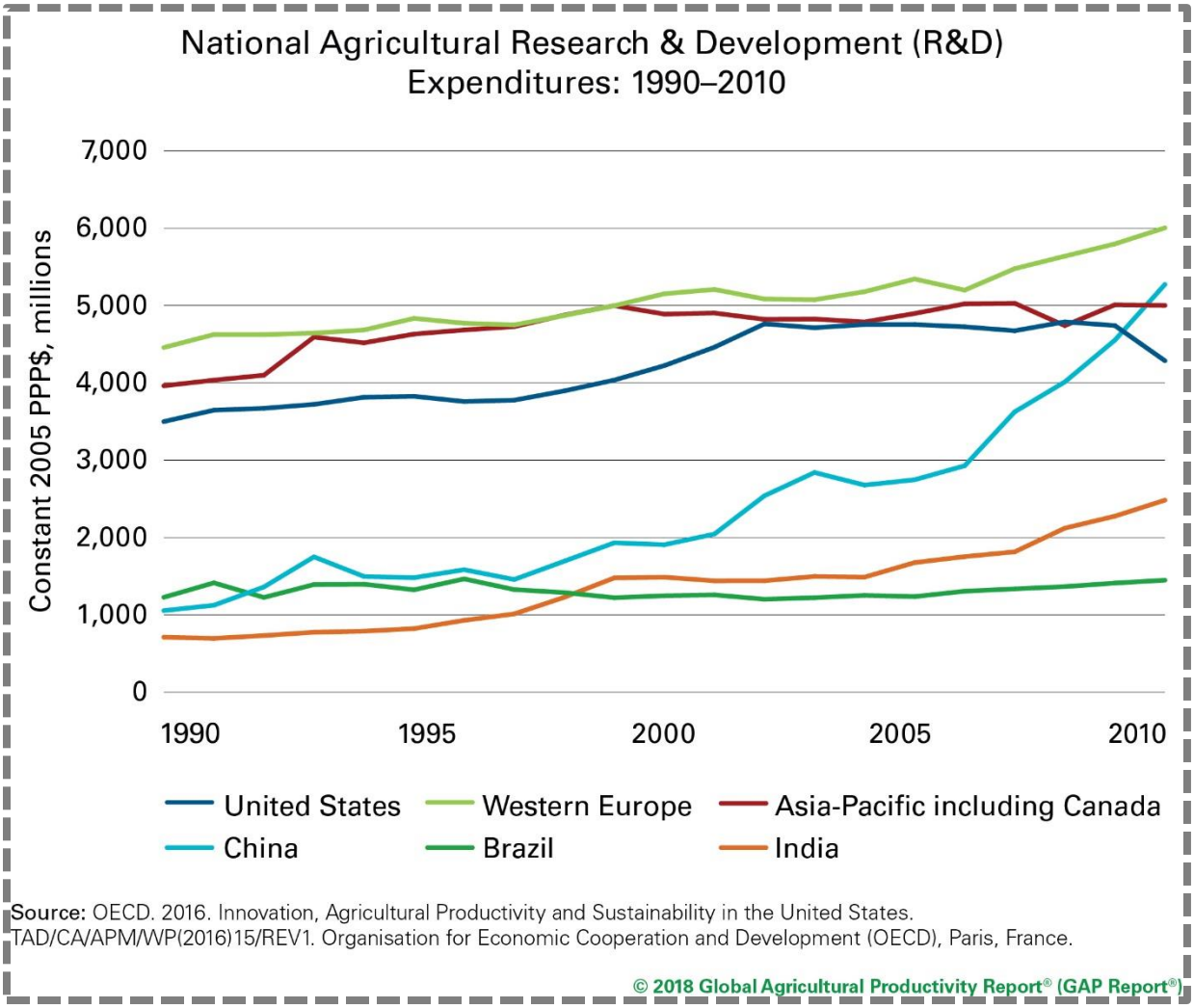
Troublesome Trends in U.S. Public Agricultural R&D

Historically, public funding of agriculture research has been strong and has generated robust TFP growth rates in the United States and other developed countries. These investments have also helped disseminate improved knowledge and technology, conservation practices and higher profitability for producers across additional regions.

Trends for agricultural R&D expenditures among selected countries show that China and India have boosted their commitments in the past decade to research, while expenditures in Brazil and countries in Western Europe have plateaued (Figure 1).

Given its long history as a leading investor in agricultural R&D, and particularly in light of the many challenges faced by U.S. farmers, fishers and ranchers as well as consumers, **the U.S. government must now recommit its support and increase its investments in this critical area.**

Figure 1



Source: OECD. 2016. Innovation, Agricultural Productivity and Sustainability in the United States. TAD/CA/APM/WP(2016)15/REV1. Organisation for Economic Cooperation and Development (OECD), Paris, France.

Understanding and mitigating the impact of climate change, preventing livestock diseases, improving water access and water quality, fighting pests in the crop, horticulture and forest industries, and promoting food safety and good nutrition will all **require that the U.S. invest more in agricultural R&D and sustain those higher funding levels over the next 30 years** to meet the challenge of ensuring global food security through 2050.

U.S. federally-funded national research programs continue to focus on basic issues of national level importance related to crop and livestock production and protection, human nutrition and food safety, rural development and natural resource management and conservation.

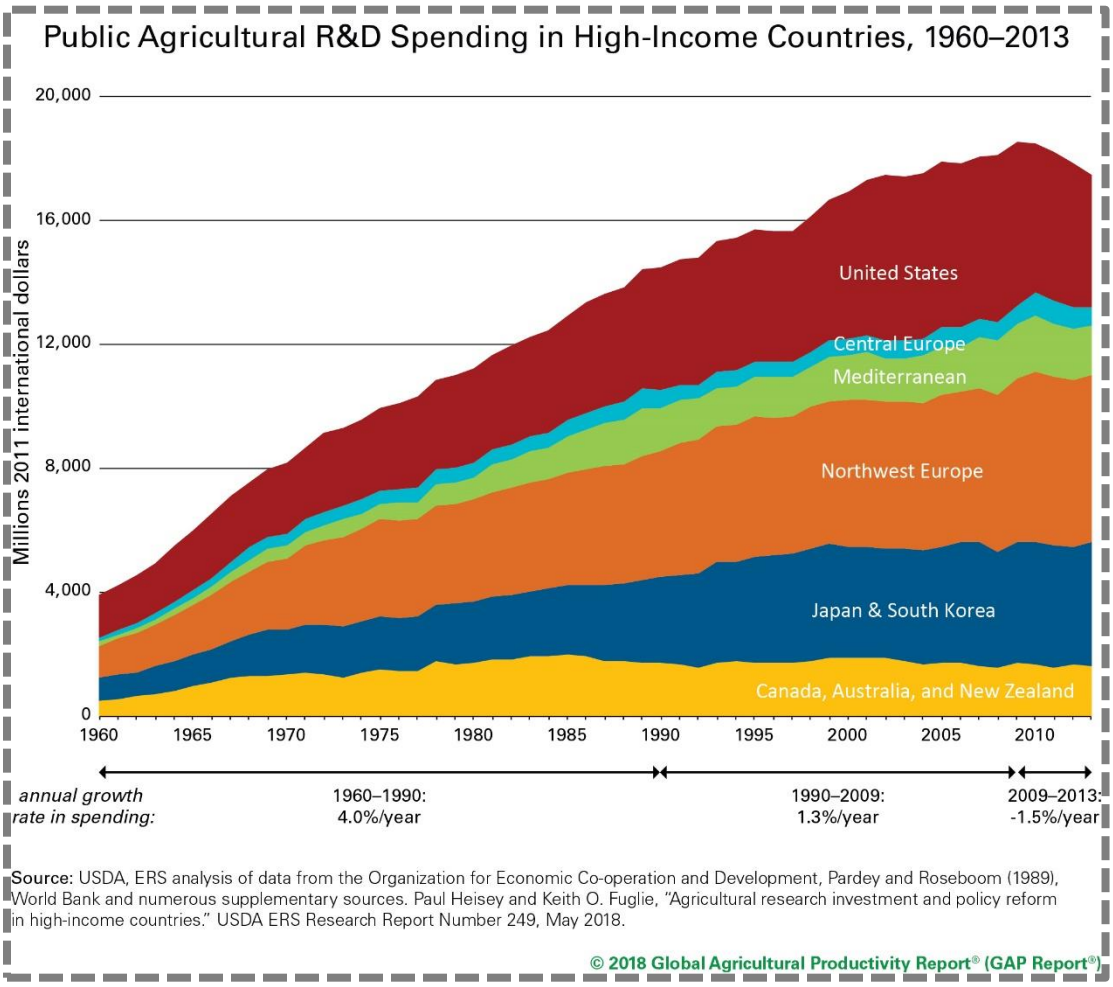
Federal research addresses higher risk and long-term issues, such as unlocking plant and animal genomes, as well as basic research not addressed by the private sector.

In addition to the government's own agricultural R&D programs, the U.S. also funds external research in partnership with land-grant and other universities at the state and local level that is focused on regional or local needs in environment, human health and agriculture systems.

U.S. public agricultural R&D expenditures grew at least 2.6 percent annually in real terms in the years following World War II and this growth continued at a strong pace until levelling off in the early 1980s. **In 2000, the rate of growth in public investment began to slacken, and it has declined 6 percent since then**.

For **high-income countries**, the growth rate in spending for public agricultural R&D averaged four percent annually between 1960 and 1990. Between 1990 and 2009, the growth rate declined to just 1.3 percent annually, and then actually began to contract between 2009 and 2013, declining on average 1.5 percent annually (Figure 2).

Figure 2



Meanwhile, **private sources of funding for R&D** in agriculture production and food manufacturing picked up pace after 2000. However, **research by the private sector does not replace basic foundational research by the public sector**; rather, **it focuses primarily on taking results from public sector research to the next level and creating marketable products** for growers and consumers.

Private-sector research funding is subject to greater volatility and may fluctuate during the more challenging stages in agricultural business cycles, when it may be needed most.

Revving Up Research in the U.S. Farm Bill

In 2018, the reauthorization of the U.S. Farm Bill brings opportunity to rev up the research funding and structure for strengthening the United States global leadership for productive sustainable food systems.

R&D funding levels authorized in the current Farm Bill account for less than one percent of all Farm Bill spending. USDA's annual research budget should be substantially increased to nearly double that of the current level to reinvigorate productivity in American agriculture and to ensure future sustainability of the sector. Current funding levels are inadequate to meet the need.

A promising development was the creation of the **Foundation for Food and Agriculture Research (FFAR)**, established in the 2014 Farm Bill. FFAR is a non-profit corporation that leverages USDA's research investments by mobilizing private-sector and foundation funds, usually at a $1 to $1 match, thereby doubling taxpayer investment. Research areas focus on improving soil health, improving protein production and making it more sustainable, reducing food waste and loss, overcoming water scarcity, and pollinator health and sustainable aquaculture programs. With $200 million authorized for FFAR, the leveraged total could eventually reach $400 million annually.

Exciting examples of FFAR funding that will bring direct benefit to consumers are seen in a recent "**Seeding Solutions: Closing the Gap in Delivery of Fruit and Vegetable Benefits**" grant, awarded to **North Carolina State University** with matching funds from **Dole Foods** and **General Mills**, among others. With a total investment of $2 million, researchers will study how to improve nutrient density of a range of consumer products through use of cutting-edge genetics and phenotyping technologies.

Thanks to research, carrots, onions, garlic and cucumbers taste better and contain more nutrients. And better crop yields and disease resistance make more of these favorite foods available. Photo Credit: USDA ARS/Scott Bauer.

Africa's Research Investment Gap

After the food price crisis of 2007 and 2008, many countries renewed their commitments to put agriculture, and particularly agricultural R&D, at the center of their policy agendas.

In many African nations, national agricultural research systems are highly dependent on funding from donors and development banks — funding that has been less predictable during the past decade. These countries must now mobilize new sources of funding to fill the research investment gap and build national research and extension systems to boost productivity in agriculture.

AWARD (African Women in Agricultural Research and Development) Fellow, Filomena do Anjos, is a senior lecturer and veterinarian at Eduardo Mondlane University, Mozambique. She is developing a more economical poultry feed, as more than 70 percent of rural families in Mozambique raise chickens. The AWARD Fellowship is a career-development program that since 2008 equips top women agricultural scientists across sub-Saharan Africa to accelerate agricultural gains by strengthening their science and leadership skills. (Credit: Carlos Litulo)

After stagnating during the 1990s, Africa's agricultural research spending—excluding the private for-profit sector—increased considerably during 2000–2014, from $1.7 to $2.5 billion in 2011 PPP prices. But **three countries accounted for nearly half of the investments made in 2014: Nigeria** ($434 million), **South Africa** ($417 million), and **Kenya** ($274 million). Ethiopia, Ghana, Tanzania, and Uganda each also spent more than $100 million in 2014.

In contrast, 12 of the 40 countries for which data were available spent less than $10 million on agricultural research, and most of these are in West and Central Africa. Ethiopia, Ghana, Nigeria, South Africa, and Uganda drove about three-quarters of the $800 million growth in agricultural research spending during 2000–2014.[3]

The African Union's New Partnership for Africa's Development (NEPAD) and the **United Nations (UN)** are encouraging governments **to allocate at least one percent of agricultural gross domestic product (AgGDP) to public agricultural R&D**, a generally recognized investment level to sustain and build agricultural productivity. Overall investment levels in most countries are still well below those required, with only Mauritius, Namibia, Botswana, South Africa, Zimbabwe, Senegal and Burkina Faso exceeding the one percent of AgGDP target.[4]

Leveraging Research to Revolutionize Agri-Food Systems

Low-income countries have yet to attract significant levels of private-sector research funds, and a range of commodities (roots and tubers, tree crops, fish and small ruminants) lack investment.

The private sector brings significant resources in terms of investment and talent to the global agricultural research endeavor. **Between 1990 and 2014, private spending on agricultural R&D tripled**, from $5.14 billion to $15.61 billion (or doubled in constant PPP$).[5] In high-income countries, the private-sector research investment constitutes a large portion of total agricultural research funding.

Many low-income countries, however, lack the public policy environment to attract such investment, such as a lack of intellectual property rights protection, adverse regulatory frameworks and poor marketing infrastructure for inputs such as seeds and machinery.

Multi-Stakeholder Partnerships Help Fill the Research Gap

The international community established key research centers in the latter half of the twentieth-century to help developing countries improve crops such as wheat, rice and maize. **CGIAR** (formerly the **Consultative Group for International Agricultural Research**) is today a global research partnership with 15 centers (the CGIAR Consortium of International Agricultural Research Centers) spread around the globe.

CGIAR operates in partnership with national and regional agricultural research institutes, civil society organizations, academia, and the private sector and has expanded its research portfolio to include cassava, chickpea, sorghum, potato, millet and other food crops, as well as livestock, farming systems, the conservation of genetic resources, plant nutrition, water management, policy research, and services to national agricultural research centers in developing countries.

CGIAR also conducts collaborative and cross-cutting research on climate change and food security through its **CGIAR Research Program on Climate Change, Agriculture and Food Security**.

Nepal Climate Smart Villages - A group of farmers involved in participatory rice breeding trials in Pokhara, Nepal. The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) addresses the increasing challenge of global warming and declining food security on agricultural practices, policies and measures through strategic, broad-based global partnerships. Led by the International Center for Tropical Agriculture (CIAT), CCAFS is a collaboration among all 15 CGIAR Research Centers and coordinates with the other CGIAR research programs. Credit-N. Palmer (CIAT: CCAFS).

To begin to fill the research gap in many low-income countries, public-private research partnerships are being formed with CGIAR centers, developing country national agricultural research centers and private-sector companies. Such partnerships improve the nutritional quality and safety of food and leverage funds to tackle environmental and economic challenges faced by producers and consumers.

Research Partnerships for More and Better Maize

Case Study: Corteva Agriscience™

A multi-stakeholder partnership between a CGIAR center, **CIMMYT (The International Maize and Wheat Improvement Center)**, the **U.S. Agency for International Development**, and **Corteva Agriscience™, the Agriculture Division of DowDuPont**, with support from the **Bill and Melinda Gates Foundation** is focused on fighting a deadly virus that destroys maize in developing countries.

Known as **maize lethal necrosis**, the disease is caused by a combination of viruses which can only be treated by developing genetic resistance in the plant. With millions of smallholder farmers dependent on maize in Africa, the disease has destroyed up to 30 percent of some family maize crops and has the potential to disrupt food security and trade.

Maize plants showing maize lethal necrosis (MLN). Infected plants are short and the leaves die at about flowering time. (Credit: CIMMYT).

Together, CIMMYT and Corteva are researching how **CRISPR-Cas9** technology (advanced breeding through gene-editing, relying on natural processes that happen in the genome, but targets those changes more precisely) may help the maize become resistant to the virus. Long-term research partnerships between institutions such as CIMMYT and Corteva help develop trust and collaborative action by bringing private-sector resources and experience to the table.

Maize lethal necrosis technician Janet Kimunye collecting maize leaf samples in the field. The samples will be used to test for MLN-causing viruses. (Credit: George Mahuku/CIMMYT).

Another example of a powerful multi-stakeholder research partnership includes the **Water Efficient Maize for Africa (WEMA)** project, in which drought tolerant maize seed is being developed for the specific needs of African farmers. The WEMA project is the largest tropical white maize breeding program in sub-Saharan Africa. As a leading WEMA partner, **Monsanto Company** (recently acquired by **Bayer AG**) shared 600 elite parental lines of maize seed, along with technical plant breeding know-how and biotech drought-tolerant and insect protection traits. Monsanto also leveraged the expertise of local research partners to develop locally-adapted hybrid maize.

Participatory Research Helps the Chickpea Boom in Ethiopia

In Ethiopia, chickpea is one of the most important foods and the country is considered a secondary center of genetic diversity for the legume. With a near doubling of the population from 92 million today to 160 million in 2050, chickpea demand is expected to boom.

Yet, farm productivity of this nutritious crop has been low; the informal seed sector is dominant in chickpea production and the private sector has been less involved.

Farmer takes chickpea to market. Chickpea is a nutritious crop both consumed and sold for cash by poor rural smallholders (Photo: ICRISAT/A. Paul-Bossuet)

In 2008, government and international efforts were initiated to change this. The effort in Ethiopia is part of the larger multi-phase Tropical Legumes project led by **ICRISAT** **(International Crops Research Institute for the Semi-Arid Tropics)** with support from the **Bill & Melinda Gates Foundation** and strong involvement of national agricultural research centers, such as the **Ethiopian Institute of Agriculture Research**.

The focus in Ethiopia is to develop high quality, reliable and sustainable seed growing and supply systems for chickpea. The program develops improved cultivars of chickpea and delivers seed at scale to smallholder farmers.

Between 2008 and 2014, production of certified and quality seed increased from 632 tons to 3,290 tons, a five-fold increase. During that same time, productivity of chickpea on farms doubled.[6]

A key to the program's success is the inclusion of farmers through participatory research and chickpea variety selection. Farmers' participatory variety selection (FPVS) approaches are used by the Tropical Legumes project to build farmer confidence in the technologies and to provide them with additional training in production and management.

Temengnush Dabi (left) benefits from chickpea cultivation advice from Tsigeredaa Negesu, government agriculture development agent, in Lume district, Ethiopia. (Photo: ICRISAT/A. Paul-Bossuet)

The project started with technical trainings of 3,000 agricultural experts and development agents for management of improved chickpea. They trained 14,000 lead farmers who selected chickpea varieties and grew them in trial field plots and compared them with local unimproved varieties. Farmers nearby were invited to observe the demonstration plot cultivation during organized field days. This approach has enhanced adoption of the new improved varieties along with better production management practices.

A Global Battle to Stop the Fall Armyworm

Fall armyworm caterpillar eats crops in Nigeria, 2017. (Credit: G. Goergen, IITA.)

A global multi-stakeholder research and action alliance has been forged to fight the fall armyworm (FAW), a devastating pest that, in caterpillar stage, devours crops before turning into a moth. The pest eats 80 plant species, including maize, sorghum, rice and sugarcane.

Originating in the Western Hemisphere, FAW has spread to 44 African countries and was confirmed to have reached Karnataka state in the south of India in 2018.[7] Experts have warned that FAW could migrate from Africa to Spain, thereby reaching Europe in coming years.

The pest has caused great destruction in Africa, costing farmers over $12.7 billion since the end of 2016. The pest is difficult to contain and impossible to eradicate completely; scouting for signs of the pest and early action can help stop the spread of FAW to nearby farms.

Farmer fields affected by fall armyworm in Southern Malawi, in Balaka District, 2017.

Rapid and coordinated responses are needed from a broad range of participants, including African governments, farmers, international and national research institutions, donors and the private-sector to halt the horrific consequences of FAW, which threatens millions in Africa and South Asia with hunger from loss of staple crops.

(Photo credit: CIMMYT/C. Thierfelder)

The **United Nations FAO** (Food and Agriculture Organization) and **USAID** (U.S. Agency for International Development) have undertaken major initiatives to coordinate research and action to detect and identify the pest, educate farmers about what steps to take, and to invite private-sector agribusiness companies to develop innovative technologies and proven tools to battle the threat.

Tanzanian farmer scouts for signs of fall armyworm.
Photo credit: Frednand Japhet/IITA

An FAW stakeholders workshop was held in Africa in 2017, and a comprehensive technical guide was produced and disseminated for African farmers. **USDA researchers in Florida** contributed to the technical guide, harnessing research gathered on FAW in the U.S. since the 1920s.[8]

Integrated Pest Management (IPM) is an integrated, science-based approach using a range of techniques that are tailored to local farming and economic and cultural conditions.

IPM uses three coordinated strategies to suppress the pest: **biological controls** (use of conservation agriculture to encourage predators of the FAW such as spiders, ants, fungi and bacteria); **host plant resistance** (developing and growing varieties that are resistant to FAW or using genetically-modified seeds that confer resistance, such as *Bt* corn or *Bt* cotton); and **careful application of safe and innovative pesticides** (both bio-based and synthetic pesticides).

Applying pesticides to kill fall armyworm in Rwanda.

Keeping Farmers Safe in the Battle Against FAW

The African pesticide marketplace is dominated by older, more toxic products that are accompanied with little technical support or training for use. Some of these pesticides pose significant risks to human and livestock health, even when pesticides are used as part of an IPM strategy to fight fall armyworm.

The private-sector crop protection industry plays an important role in the effort to build better farmer education and engagement around pesticide use. Newer, safer and more environmentally beneficial products (green chemistry) can be part of an IPM strategy.

Corteva Agriscience™ has developed and received registration in Kenya for Radiant™, an effective crop protection product recognized as a pesticide with reduced risk. The product was awarded the U.S. Presidential Green Chemistry Challenge Award. Other innovations include use of smaller packet of pesticides for smallholder farmers, allowing them to test and use products with less risk.

Farmers in North and South America currently manage FAW through integrated pest management approaches, combining the use of pesticides, genetically engineered crops, and other technologies and techniques. With large percentages of biotech crops planted in the Americas, harm from FAW is reduced.

No single "silver bullet" exists to manage such widespread pest destruction, but careful IPM practices integrated with improved biotech crops can make a significant difference for farmers of all scales.

The Early App Gets the (Fall Army) Worm

One of the most important stages in the battle to suppress fall armyworm is early detection and early action. Yet, many African farmers are unfamiliar with the pest, especially in the early stages, when it is hard to detect.

The **UN Food and Agriculture Organization (FAO)** and **Pennsylvania State University** are working together to develop and launch a talking app – *Nuru*—that assists with fall armyworm recognition so they can quickly stop its spread across their fields. The app is on an open platform, free to use and "speaks" in several local languages for African farmers.

A Tanzanian cassava farmer, left, learns to use a plant disease mobile app developed as part of the PlantVillage initiative led by Penn State researchers. Photo credit: Penn State

By using Nuru, farmers can register to receive alerts and advice over their phones. The app is part of the **PlantVillage** platform, built at Pennsylvania State University, and collects data for global web-based monitoring and actions to fight FAW.

Endnotes

[1] Keith Fuglie, "R&D Capital, R&D Spillovers, and Productivity Growth in World Agriculture." Applied Economic Perspectives and Policy (2017).

[2] Matt Swayne, "Land Grant University Programs Helped Keep Farmers on the Farm." Penn State News Online, April 19, 2016.

[3] Beintema, Nienke; and Stads, Gert-Jan. 2017. A comprehensive overview of investments and human resource capacity in African agricultural research. ASTI Synthesis Report. Washington, D.C.: International Food Policy Research Institute (IFPRI). http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/131191

[4] Beintema, et al. 2017.

[5] Keith Fuglie, "The growing role of the private sector in agricultural research and development world-wide." *Global Food Security*, Volume 10 (2016), 29-38.

[6] Mekasha Chichaybelu, et al. "Innovative partnership in chickpea seed production and technology dissemination: A decade of lessons in Ethiopia." Ethiopian Journal of Crop Science, Volume 6 (Special Issue), No. 2, 2018.

[7] Carolyn Cowan, CIMMYT. "Fall armyworm reported in India: battle against the pest extends now to Asia." Published online August 13, 2018.

[8] Studies by USDA scientists Robert Meagher and Rodney Nagoshi (Insect Behavior and Biocontrol Research, Gainesville, FL) provided valuable technical insights in the recently released *Fall Armyworm in Africa: A Guide for Integrated Pest Management*. With tips on pest identification, available technologies, and best practices for managing FAW, this guide was jointly produced under the U.S. Government's Feed the Future initiative by USAID, the International Maize and Wheat Improvement Center (CIMMYT) and the CGIAR Research Program on Maize (CRP MAIZE).