THE CHICAGO COUNCIL ON GLOBAL AFFAIRS

Reaping the Digital Return: Enhancing Communities through Modern Extension

Authors
Grace Burton
Marcus Glassman

Project director
Alesha Black

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Executive summary

The United States extension system has underpinned the success of American farmers for over a century and has helped bring the benefits of innovation and technology to even the most remote corners of rural America. Agricultural extension, alternatively referred to as rural advisory services, is the formal process of delivering information to farmers, particularly new techniques for production and harvesting, but also other information needed to flourish and compete in a fast-changing world.[1] In the United States extension is the mechanism that turns publicly funded university research and development (R&D) into actionable public goods, ensuring that discoveries at the country's land-grant universities benefit all, particularly those in rural and agricultural communities. This model of tying research, extension, and teaching together in land-grant universities, empowered and shaped by local needs, enabled the United States to become a breadbasket for the world in the 20th century. This structure, combined with the community and youth-driven approach at the heart of agricultural extension, helped bring rural America into the modern age a century ago, and it has since inspired many countries around the world to replicate or adapt this approach.

As extension enters its second century and the digital age, farming and rural landscapes have changed dramatically, and public extension must adapt accordingly. People are connected to information today in ways that were unimaginable at the genesis of the US extension program, and while digital innovations across the public and private sectors are moving ahead, they must go further to serve American agriculture. This will not only enable the US extension system to continue the work that has made US agriculture so successful, but it will create a modern-day model with tools that can be adapted abroad to support low-income countries that continue to struggle with food and nutrition insecurity.

At home and around the world, agricultural extension systems are delivering information through a variety of platforms, including those operated by public, private, nonprofit, and civil society entities. This "pluralistic" system demonstrates that a range of approaches and actors can and should coexist. Indeed, in the United States the private sector plays an important role in disseminating data and information to farmers who can afford it. Innovative companies meet a variety of needs for advanced farming practices, from agronomic advice to farm management and risk mitigation in the face of global market dynamics. However, investment in US public extension continues to be critical for the health of the entire agricultural system as well as for certain segments of farmers and rural people that would otherwise be more marginalized. To ensure that innovations and advances in the research lab reach all those who could benefit, the extension system must comprehensively leverage digital technology.

Among the US extension system's missions is to provide America's diverse farmers with cutting-edge advice, whether to a large family farmer who is weighing a conversion to conservation agriculture practices or to a millennial who is just starting an urban farming operation. The internet, mobile phone applications, and social media platforms are increasingly the first place the general public looks for information, including farmers. The same will be true for poor, small-scale farmers in low-income countries who are increasingly reached by data-enabled smartphones with access to popular search engines and social networking applications. The nature of learning is also shifting: crowd-sourced information, peer-to-peer exchange, and on-demand learning are hallmarks of the current age.

Embracing digital innovation in extension offers three key benefits, whether in the United States or abroad. First, it offers a chance to aggregate vast, complex agricultural information on a scale previously unachievable and then customize it for individual farmers to use at their convenience.

Digital innovation can help contain or reduce overall costs, especially when it comes to reaching new farmers.

Second, digital innovation allows information to reach further—to more remote and marginal areas. In the age of Skype and Twitter, the number of farmers a single agent can reach in the span of a day by car or motorcycle will be a historical constraint.

Third, digital innovation can help contain or reduce overall costs, especially when it comes to reaching new farmers. Not only can digital technology scale at lower costs, it can also provide new and adaptive means of accounting for the time, effort, and success of extension agents and their programs, allowing public resources to be spent more efficiently with better performance data.

The day-to-day work of the rural advisory services will increasingly rely on innovations and good practices in the technology sector to help harness the vast information now available. If farmers are to remain globally competitive, a modern extension agent must remain grounded in local needs while making sense of the best available data and information from around the globe. Rather than "extending" information out from one center of expertise, agents now sit amidst a wide and multi-directional river of information. They are the experts that will help farmers find what they need and decipher increasingly larger volumes of data. Embracing digital innovation allows for a shift in perception of agricultural extension, which may create new appeal among young talent. These "digital natives" entering the workforce are exploring ways to contribute their skills toward critical challenges at home and abroad. Employment as an extension agent could be appealing for both its compelling mission and room to innovate.

American innovation and leadership in digital agricultural advisory services will be critical to continued US agricultural competitiveness. And, innovation in agricultural extension has the potential to serve as a catalyst in ending food insecurity and poverty around the world. But the full power of these services is still being unlocked.

A three-pronged approach to harnessing the power of digital technology can spark great progress at home and contribute to global food security abroad. First, thoughtful review and targeted investments at the national level, paired with incentives that reward innovation across the county, state, and regional tiers, will position the United States to leap forward. Second, new public-private partnerships with a range of technology, data, and agricultural companies as well as with social enterprises at the forefront of digital technology present new opportunities to harness innovations for extension and expand access for underserved populations. And third, greater innovation in domestic extension should be twined with greater emphasis on innovation within US foreign assistance activities, as outlined in the US Global Food Security Strategy. This could be achieved by leveraging existing activities on the ground and within capacity-building exchange programs, while focusing on harmonized data collection and learning across partners.

Ensuring smallholder farmers receive agricultural information is of critical importance for realizing global food security, and the United States Department of Agriculture (USDA) has a prominent role to play in close partnership with USAID. Beyond this, however, the mission of scaling up modern access to agricultural information for food security also creates greater opportunity to rely on the expertise of land-grant universities, the Cochran and Borlaug Fellowships, the John Ogonowski and Doug Bereuter Farmer-to-Farmer program, and returning volunteers from the Peace Corps.

The success of the US extension system

The US extension system dates back to 1908 when President Theodore Roosevelt established the Commission on Country Life to "make rural civilization as effective and satisfying as other civilization."[2] The Commission's recommendation was to create a nationwide extension system: a network that could extend technology and innovation to even the most rural corners of the country so that—through education, community development, and youth engagement—rural agricultural communities could thrive. The extension system was enacted as law through the Smith-Lever Act of 1914.

Historically, extension focused on serving the needs of rural communities, with particular emphasis on providing accurate, scientific advice directly to farmers to improve on-farm practices to enhance productivity, sustainability, and profitability. But from the start, American extension was never exclusively focused on agriculture. It existed to serve the needs of the communities in which extension agents worked, affording states, counties, and individual agents the flexibility to innovate. This flexibility has proved central to extension's development and success. Today agents are as likely to be assisting farmers with organic crop certification or soil conservation as they are to be working on nutrition programs in cities or running youth leadership programs.

The US extension system is coordinated nationally through the USDA's National Institute for Food and Agriculture (NIFA).[4] The system is, however, highly decentralized to allow states, counties, and extension agents significant autonomy to serve the needs of their local communities. Each state administers its own system through its land-grant universities. Land-grant universities arose out of the Morrill Act of 1862 to serve as a state's agricultural education and research hub and later became the natural host for the extension system. Within each state, county-level or regional offices serve as the interface between the extension system and direct community outreach by extension agents.

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The land-grant universities' role as both a state's agricultural research hub and extension host is seen as a key source of extension's success. This deeply embedded co-location of research and practical application in the same institution was designed to allow a rapid and fluid transfer of research and best practices into actionable advice for communities. Without this organizational design, many discoveries may never have left the lab. Extension makes the difference between discoveries that are merely novel, and those that are truly transformative. Moreover, by housing research and extension together under one campus, extension helps to ensure that public research is demand driven and responsive to farmers' needs.

The US extension system has played a vital role in the enormous gains in agriculture seen in the United States over the last century. The introduction of hybrid corn is a key example. Hybrid corn emerged in the 1930s, with yields roughly doubling between 1930 and 1940. As genetic gains were made through improvements in plant breeding, yields continued to rise, jumping sharply again in the 1950s.[5] Historical accounts of the diffusion of this new technology from two communi-

Box 1

Funding for the US extension system is "tripartite"

Funding for local extension programs is considered "tripartite," where funding is provided by the federal, state, and county or regional government. Funding is not evenly shouldered between those three groups, however, and the exact funding structure for each extension office varies, with many offices supplemented by both public and private grants and fee-for-service education provided by the private sector. Specifics vary by location, but it is not uncommon for some offices to draw support from over a dozen sources of funding. USDA-NIFA provides some guidance to the states on best practices and priority issue areas through the structure of the grants it offers, however the priorities and operations of each state's extension system are generally left to the states and local communities to decide.

This purposefully decentralized organizational structure has come with many benefits. Since federal, state, and county governments all share a role supporting local extension agents, they all have a stake in those agents' success. In addition, decentralization allows extension agents to focus on finding solutions to local problems for local farmers rather than concentrating on overarching systemic changes.[3]

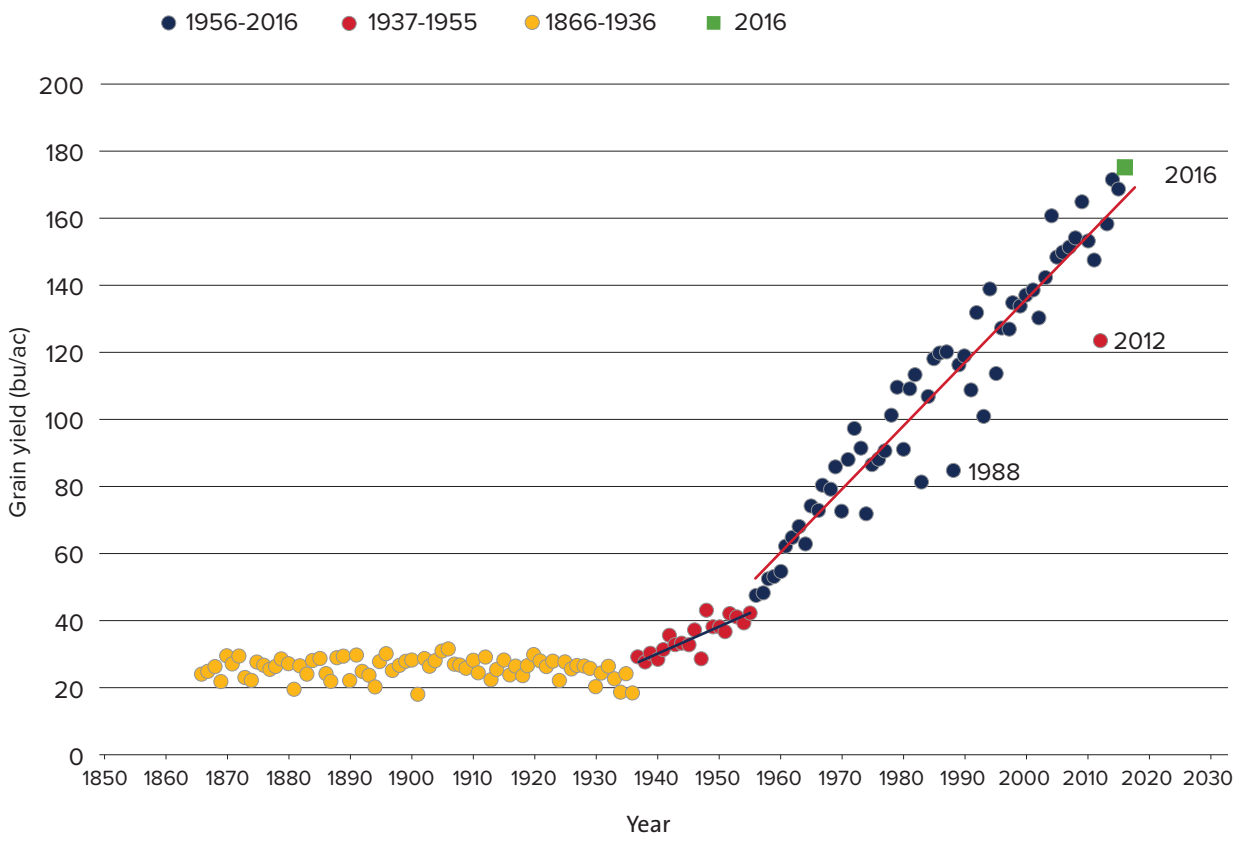
Box 2

Adoption of technologies leads to improved outcomes: US maize yields

Prior to the 1930s, maize yields in the United States were no more remarkable than those seen in Sub-Saharan Africa today. However, starting just before WWII, agricultural scientists began to make considerable gains in output. The production of hybrid corn, new fertilizers, and the development of tractors and other mechanized on-farm tools created a new trajectory for corn production. This upward trend in the United States has continued more or less unabated through the present day, thanks to continued technological progress. While the promotion of these new technologies was handled mostly by the companies that produced them, the adoption of these technologies on farms was significantly aided by extension agents and the person-to-person relationships they maintained with farmers. Today, the United States has a per-acre production rate far ahead of most other countries, and its story of production gains can serve as an instructive model for other countries looking to increase their yields, while recognizing that every model requires local adaptation to be relevant.[6]

Figure 1

US corn yield trends since 1866



Source: USDA-NASS (as of January 2017) in R.L. (Bob) Nielsen, "Historical Corn Grain Yields for the U.S.," May 2017, https://www.agry.purdue.edu/ext/corn/news/timeless/yieldtrends.html.

ties in Iowa indicate that the collaboration between the extension agents and the seed companies was critical to widespread adoption. Given their long-standing relationships with farmers, extension agents lent authority to the technology being provided by the private sector. While neighbors and sales people representing input companies were also influential, extension agents were a crucial piece of the puzzle.[7]

Ultimately, the success of agriculture has been a boon for America. The American economy has been able to thrive because farmers with advanced agricultural techniques have been able to increase production so dramatically that working off the farm was an option for the vast majority of the population. Increases in farm productivity created opportunities in the rural off-farm employment sector, but it also made food affordable for everyone. This increased productivity helped fuel growth in sectors like manufacturing in cities, supporting growth of the American economy as a whole. At the center of this story is the creation, diffusion, and adoption of new technology and extension as a critical piece of that history.

The US extension system has played a vital role in the enormous gains in agriculture seen in the United States over the last century.

The US system has been a model for global agricultural development

The US model of public extension has also contributed to agricultural development globally. Because of its success in the United States, the system has spread around the world in tandem with many modern, US-developed agricultural practices. Partnerships between land-grant universities and their institutional counterparts facilitated the transfer of expertise and models of agricultural research, higher education, and extension. Several nations either borrowed key elements of the system or adopted it as a whole. Many countries that adopted extension models from the United States maintain historical relationships with US land-grant universities.

In India, for example, a 1949 education commission recommended rural universities be replicated after the US land-grant model. The first agricultural university, the G. B. Pant University of Agriculture and Technology, was dedicated in 1960 with support from the University of Illinois, University of Tennessee, Ohio State University, Kansas State University, Pennsylvania State University, and the University of Missouri.[8] Extension was at the core of the university mandate alongside research and education, as it is in the United States. To this day, this university and many others aim to maintain the commitment to extension through training centers for extension agents, linkages to farmer radio, and continuing education, among other methods.[9]

The Ethiopian extension system extends back to 1931. However, this system also has a relationship to the US land-grant model. For example, Haramaya University, which was established with the support of Oklahoma State University in 1954, adopted many aspects of the land-grant model and initially coordinated extension nationally. Today the university continues to offer bachelors and masters degrees focused on rural development and extension, but the national extension system has been scaled up.[10] The Ministry of Agriculture maintains an extension force of over 60,000 agents, available in every kebele (the smallest administrative unit in Ethiopia, similar to a ward) and a new strategy was launched in 2017 to modernize and technologically enable this group.[11]

This is not to suggest that all extension programs were developed based on the American model. Current models are a unique microcosm of each country's political and agricultural history, influenced by the importation of models promoted by colonial powers and by many other exchanges during the Cold War era and beyond. In the past decade, for example, China has begun to provide modernized extension models, training, and technical assistance to some of the world's least developed countries under the "Chinese Agricultural Technical Task Force" model, which emphasizes entrepreneurial thinking and rewarding successful agents. This model was highlighted by the UN Development Program as an emerging approach worthy of spreading.[12] Indeed, China and others from middle-income countries are

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shedding light on alternative models from which to draw inspiration.

Still, the United States remains an important beacon for many around the world as a leader in agriculture, technology, and public-sector-enabled education via the land-grant system, and this leadership continues to have tremendous influence as digital innovation is embraced even further.

The private sector plays a vital role at home and globally

Alongside US public extension, private-sector advisory services have become an integral part of successful agricultural systems around the world. Large-scale trading firms, food companies, and farm input companies are providing more and more direct farming and farm management advice. These are often clustered within business offerings that serve multiple purposes. For instance, a tractor company may help farmers generate specific data automatically from the field such as soil moisture content or precise land productivity information that the farmer can then analyze using software—alone

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or with assistance—to improve farming practices.[13] In fact, tractor companies are some of the leaders in collecting, aggregating, and making use of farmer data given the data requirements needed to advance precision agriculture techniques. However, they are far from the only ones. Traditionally, agricultural input companies provide full support to farmers to ensure they get the best possible yield from the inputs they purchase. But it's not just production support being offered. New crop marketing opportunities are also going digital and can help farmers find the best place to sell their crops by providing powerful data analysis to connect far-flung buyers and sellers.

Individual, private crop consultants have also grown in popularity and numbers over the past 30 years.[14] They are privately hired "extension agents" that provide services for a fee. The National Alliance of Independent Crop Consultants, established in 1978, has over 700 members. The Certified Crop Advisor Program also emerged in the 1990s as an entity that certifies the quality of crop advisors as trained agronomists, whether public or private. Their network boasts more than 13,000 professionals.[17] Such services play a valuable role in helping farmers implement best practices, increase productivity, and improve operations.

Box 3

Public-private partnerships make big data useful to the farmer

On a modern farm most equipment—from the trucks to irrigation systems to tractors—are constantly recording and storing data. But that data isn't always stored in a way that makes it useful to farmers. Thanks to a new collaboration between John Deere and Cornell University, however, big data from the farm is becoming increasingly useful to farmers, agribusiness, and the wider agriculture community. Ag-Analytics, a new data platform from Cornell, integrates with analytics pulled from the John Deere Operations Center as well as with public data like soil and weather information and satellite information on vegetation and real-time field conditions. The platform not only provides useful information to farmers about their farm's performance, but metrics that can be used to project yields and choose which USDA Risk Management insurance a farm needs. The platform has attracted the interest of groups ranging from the Environmental Defense Fund, which sees the platform as a tool to assist farmers with conservation agriculture practices, to corporate buyers, who see the platform as a means to create a more responsive supply chain. Over the long term the platform can help farmers with everything from making market decisions to identifying fertilizer runoff. It's just one way big data is making a difference on farms today.[15, 16]

Public extension is vital

Despite the large and dynamic role that the private sector plays in reaching farmers with the information and inputs they need to make their farms flourish, there is no replacement for the public-sector extension system. Pluralistic models of extension are the key to long-term and broad-based agricultural success. Publicly funded extension remains a vital source of farming information for new farmers, small-scale farmers, or those growing for niche markets where there is limited private-sector support. Public extension also continues to play an

important role as a neutral advisor on science, separate from the promotion of individual products. And, extension remains, as always, an effective outlet to realize the value of publicly funded R&D conducted at land-grant universities, ensuring that these "public goods" are indeed widely available and that farmers can adopt what serves them, as it represents their taxpayer dollars at work.

In the United States, extension is relationship-focused. Indeed, agents play a critical role in the local community as thought partners to farmers and often as mentors and leaders among young people, specifically. County extension agents oversee 4-H programs and contribute strongly to Future Farmers of America (FFA) programs. They also provide overall community-based services, ranging from nutrition and economic advice services to urban agriculture and rural public health, depending on the needs of the community. Thanks to the decentralized nature of the extension system, agents have license to adapt and serve the needs of their communities, agricultural and otherwise. For example, modern day extension agents in the US may support public health programs, advise urban youth programs, help start-up farmers, or offer community nutrition guidance.

The promise of digital technology should not be considered a replacement for extension agents, but as a

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powerful and enabling tool to strengthen the work they are already doing, bringing broader analysis, best practices, information, and exchange to those who need it faster and more efficiently than ever before. Technology will enable these individuals to stretch themselves further, but the agents themselves will always be an essential resource. Indeed, evidence from the e-learning sector reinforces this conviction. Being taught by a skilled professional is a far superior educational experience to simply having access to information. While education can be enhanced and facilitated with technology, studies show there is simply no replacement for interaction and feedback with a real person.[18]

At the same time, models that rely exclusively on in-person contact with an expert may be costc prohibitive or difficult to scale. Technology offers new opportunities to expand learning opportunities using video,

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voice, text, and peer-to-peer exchanges in ways not seen just a few years ago.

The challenges facing extension

Though an exceptional model, US public extension must evolve and make better use of technology to keep up with the rapid pace of change and the new and existing challenges that threaten agriculture and food security globally.

The agricultural landscape continues to change

When the US extension system was founded, over half of Americans lived in rural areas, and farming employed nearly a third of the American workforce. Today, however, less than 2 percent of the population is employed in farming, and only 17 percent live in rural areas.[19] This is partly due to the success of US agriculture and to the research and education model of which extension is part. Dramatic increases in productivity, efficiency gains, and the adoption of new technologies have enabled agriculture to produce much more with fewer people.[20]

Yet despite the success of US agriculture, the average age of the American farmer is steadily rising. There is a real concern over the future of farming, with too few young people entering agricultural careers. For many youth around the world, agriculture appears to be either a difficult-to-enter career or an unclear path to prosperity. In the United States, rural income remains lower than in urban areas, and negative shocks to the economy can be harder felt. In fact, rural poverty rates continued rising during the recent recession two years longer than in urban areas before leveling off.[21]

Over the past few decades public extension has also been shrinking. Many extension offices have large numbers of agents at or near retirement age, while recruit-

ment for new agents—particularly recruitment of young people—has proved challenging. Illinois, for example, had 100 extension specialists in 1980; by 2011 there were just 30 in the state.[22] There has also been a reduction in county-level agents across the board. In 1980 there were 11,441 county agents nationwide; by 2017 that number had fallen to 8,024 full-time equivalent county agents across the country.[23]

Yet while the numbers of farmers and extension agents alike have declined, the needs and the challenges in agriculture have not. Farmers still need, for example, production advice tailored to soils and rainfall, real-time weather updates, market information, and information on emerging pests and diseases. Additionally, the increase in organic and local markets offers farmers new opportunities, yet many find it hard to compete or do not know how to get started and comply with regulations such as food safety certifications. The extension system must be equipped to respond to farmer needs and current agricultural challenges in ways that align with how people access information, communicate, and learn in today's digital world.

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Quick and easy access to the latest knowledge is essential in the digital age

While the US extension system's decentralized operations model has historically been a source of strength and resiliency, it can be a challenge when it comes to the adoption and implementation of modern, digital technology and communication tools. Without a central mechanism to implement best digital practices, states and counties are left to adopt technologies on a state-by-state—or even an agent-by-agent—basis. This creates a digital divide in which those areas served by less tech-savvy agents fall behind the digital curve. In addition, there is no simple, centralized entry point for technology companies to go to both extract widely dispersed, publicly available information or to quickly diffuse new technologies that have broad relevance. This leaves them no choice but to approach state agencies one by one or, as is more typical, to simply bypass the public extension system altogether.

Despite these challenges, there have been public-sector efforts to incorporate digital technology into extension at the national level. For instance, the US extension service has developed the eXtension (pronounced "e-extension") Foundation, an online suite of tools that allows farmers, agents, state agencies, and the general public to access emerging research and tools. For example, the "ask an expert" feature allows anyone from row-crop farmers to household gardeners to ask extension and university agents for advice. The tools available through eXtension are a great starting point, but there is still much more ground to cover before it achieves its full potential for farmers and food security.[24]

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Data analysis is another technology challenge for extension. Whereas the challenge once was getting enough data, the problem now is too much data. An average American farmer now has five seasons worth of data, equivalent to 5 gigabytes.[25] With this volume of data, the potential now exists to analyze trends, spot anomalies, and ultimately provide custom advice. While the private sector is developing a vast amount of data analysis tools, essential public goods like satellite weather information, real-time tracking and identification of pests and diseases, and easy searchability of field trial data need public support to be as accessible and usable as possible. This support could make all the difference for farmers at home and around the world. It is increasingly important that this data feed into predictive modeling and machine learning algorithms that will help farmers respond in real time and proactively plan for the future to maintain a profitable, productive, and sustainable farming operation.

Innovations and knowledge are being ably disseminated by our extension system, land-grant universities, and the private sector. The challenge is to identify the public investments and public-private partnerships that can amplify the existing value of US public investments in research, while keeping pace with rapid technological advancement, especially in the digital realm. US lead-

Figure 2

Digital innovations from across the spectrum

This is a sampling of ditigal platforms and resources and is for illustrative purposes only. It is not intended as a definitive or rank-ordered list of innovations.

Web-based resources	About
eXtension Online www.extension.org	This portal serves the e-learning needs of extension agents and professionals across the country. While many services are provided, perhaps one of the most useful is the "Moodle" e-learning course platform, which aggregates courses and webinars offered across extension programs and is searchable by topic, date, and other criteria.
FarmDoc, University of Illinois Average of 350,000 web hits per month and roughly 30,000 unique users www.farmdoc.illinois.edu/	This web platform is focused on providing real-time, economic decision-making support tools to farmers in the American "cornbelt." It has dozens of web-delivered decision tools to aid farmers with complex economic decision making, eight different newsletters with tailored content, and real-time price and weather data as well as webinars, reports, and help guides available for download. It is funded by user and corporate sponsorships and through core USDA support for the University of Illinois extension program.
Midwest Cover Crop Calculator Hosted by Michigan State University http://mccc.msu.edu/selector-tool/	This cover crop decision-making guide was codeveloped by land-grant universities, private sector crop advisors, and Canadian agriculture experts. Its goal is to consolidate the best information on a promising new production approach that is in the early stages of adoption. Content is locally appropriate down to the county or province level. The decision tools are web-enabled, straightforward, and come with a video tutorial for first-time users. The project was funded by a USDA Conservation Innovation Grant and was completed in partnership with Michigan State University and other partners.
Web-Based Nutrition Education Evaluation and Reporting System (WebNEERS) Hosted by Clemson University https://nifa.usda.gov/tool/webneers	This platform demonstrates how streamlined data collection and reporting can drive accountability across geographies and within a decentralized system. The platform captures the impacts of the Expanded Food and Nutrition Education Program, including SNAP, and can be used to perform diagnostics across the system. As described by the website, the system operates on three levels: • The federal level collects and stores national data that the National Institute of Food and Agriculture (NIFA) leadership uses to manage programs and produce reports. • The institution level allows each land-grant university to define, collect, manage, and report on their programs. • The regional level allows program staff to enter local data and demonstrate results."[26]

ership in digital agriculture is essential, as the goal of achieving food security will be increasingly challenged by changes in the climate and rapid population growth in the coming decades, which will require the best available information to respond accordingly.

Reaching farmers continues to be a challenge in low-income countries

Agricultural extension is a critical dimension of achieving global food security. Without improved agronomy and adoption of new technologies, smallholder farmers in low-income settings around the world will not achieve improvements in their yields. And, while agricultural extension exists in most countries in some form, publicly funded extension often suffers from common problems. Given the human resource-intensive nature of extension, financial resources and sufficient human capacity for full implementation often falls short in low-income countries. In countries that have large populations of smallholder farmers spread over large swaths of land, making contact in person or virtually can be a significant challenge, leaving many without access to the information they need to farm more effectively. In India, for example, data suggests that only 38 percent of smallholder farmers have access to any agricultural information.[27]

While accurate public extension information is challenging to collect at a global level, the best available information suggests that, in general, Asia's public extension systems have the largest numbers of agents in the world. For instance, China tops out at over 600,000, and India comes in at 90,000. Sub-Saharan Africa has notably smaller public-sector agent ranks—with the exception of Ethiopia, which has 60,000 agents and as many as 12,000 training centers.[28]

Traditionally, a farmer-agent ratio determined at the national level provided a guidepost for whether there were "enough" agents to reach farmers. A ratio of one agent to several thousand farmers, quite common in low-income countries, makes it impossible for agents to reasonably reach and support farmers well. The travel to individual farms alone is prohibitive, which means that frequent contact is not possible. The question of the "right" agent-to-farmer ratio is difficult to determine. Yet with the advent of modern technology, agents have many more tools at their disposal for reaching greater numbers of people. Video instruction, for example, allows agents to interact with more farmers more often.

Indeed, the ways in which farmers are likely to access the information they need is evolving dramatically. While the system and constellation of actors providing advisory services varies significantly, there are some common features. In addition to public extension agents, agricultural or "farm" radio has played an important, historical role in reaching farmers, with the United Nations reporting that even in low-income countries, 75 percent of the population have access to a radio. Farm radio programs reach millions of farmers every day in local languages for free. Some are publicly supported, some

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are nonprofit, and some are for-profit radio stations that support their programming with advertising revenue. Many of these programs now also have programs in place to engage listeners in conversation with hosts and guests on their mobile or smartphones. For example, Farm Radio International developed a web-based, participatory application that helps analyze and visualize listener feedback called "Uliza," Swahili for "to ask." The program uses interactive voice response and keypad inputs to rapidly gather information on topics of interest. It also allows farmers to leave messages or ask for specific information.[29]

With the advent of modern smartphone technology, many telecom providers have integrated agricultural services with phone and text offerings to attract and retain customers. Many of these offerings provide the most essential and commonly demanded information, starting with weather forecasting, localized price information, and seasonal crop advice for the most critical staple or high-value crops. For example, Vodafone's Farmers' Club is active in numerous countries, including Ghana, India, Kenya, Tanzania, and Turkey, and has a modified version in New Zealand. The fee-for-service package includes information services, virtual marketplaces, and financial products tailored to farmer-customers.[30] However, telecom offerings are increasingly going beyond this basic package. The Safaricom Spark Venture Fund has invested $1 million in the Kenyan startup Farm Drive, which has developed alternative credit-scoring models that help banks know how much

to lend to whom. The credit scores are generated using data collected by farmers and satellites along with basic market data and a proprietary machine learning algorithm. The goal is to help more farmers access much-needed financial services.[31]

As this last example demonstrates, agricultural information is increasingly bundled with other services such as finance, marketing, input sales, and even information from other sectors. In fact, there is increasingly a joining of health and agricultural information to deliver a better information package more affordably to the most rural populations. This certainly is also true of the US extension system, with the extension service actively involved in nutrition education to combat rising levels of obesity.

To address funding, logistical, and other local needs, pluralistic extension services are now more common around the world. While this provides wide-ranging sources of information and allows for a locally focused approach, it can also make accessing good data through the entirety of the system difficult. Systems that allow not only for transfer of knowledge to farmers but for gathering, sharing, and analyzing data on a broader and more global scale would help speed problem solving, innovation, and response to challenges throughout the food system.

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Communications infrastructure is still inadequate in many rural areas

One limitation of fully leveraging digital technology is internet connectivity and high-speed data coverage. In the United States 34 million Americans lack access to high-speed internet, 68 percent of whom live in rural areas. This equates to nearly 40 percent of rural areas not being reached.[32] Globally, internet connectivity is growing every year, with 3.5 billion people now online, or nearly half the world population. Each year this number grows, with more than 91 countries around the world having more than half their populations online. However, in least developed countries only one in seven has access to the internet. The lowest connectivity rates remain in Sub-Saharan Africa, where some countries still have less than 10 percent access to the internet.[33]

Box 4

Extension is a vehicle for public health success in Ethiopia

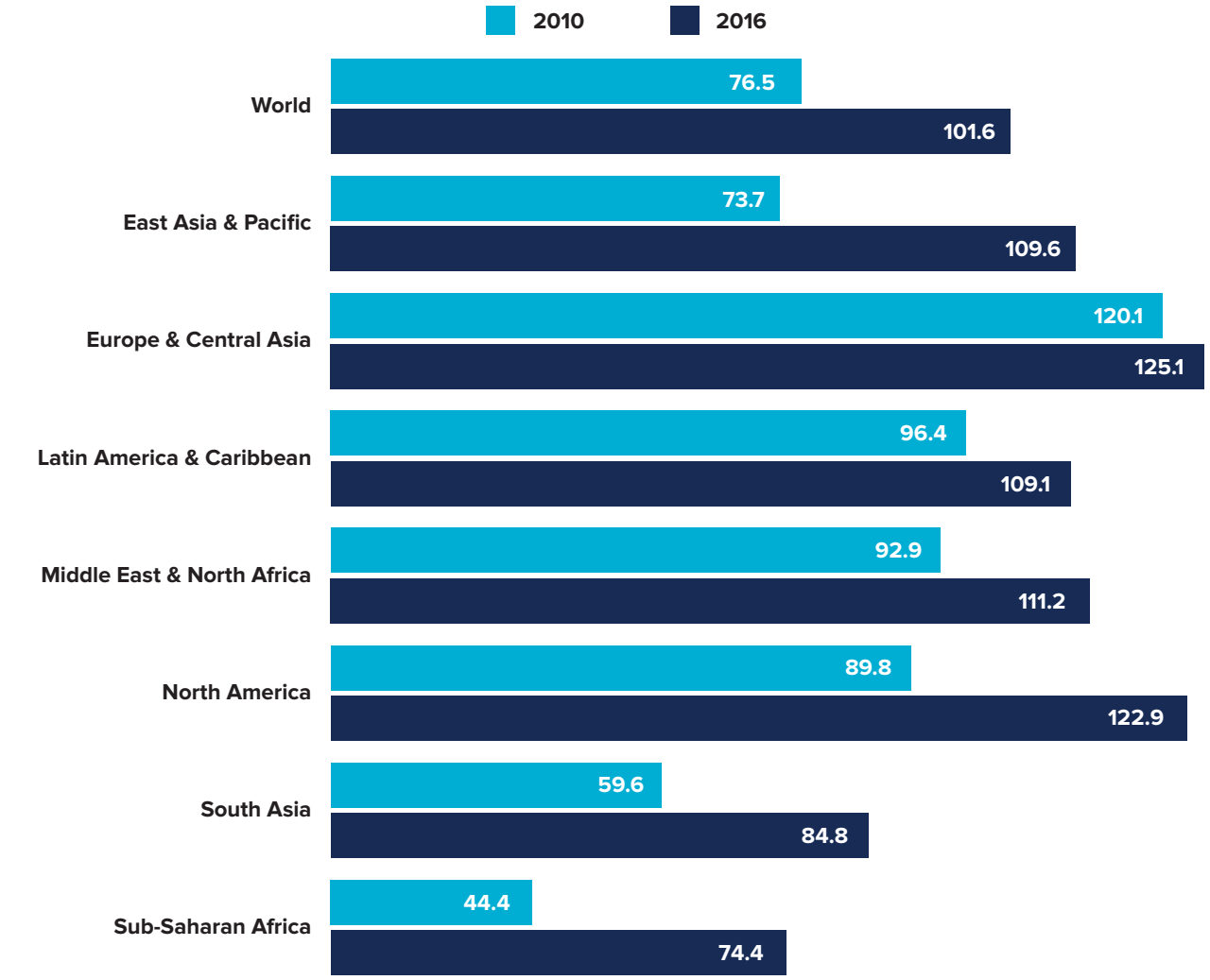
Ethiopia is Africa's second-most populous country and one of its most rural, with 80 percent of the population living in hard-to-reach countryside. Until recently, it had some of the worst health outcomes on the continent. A full 16 percent of children died before their fifth birthday as of 2002. But in 2004, the government launched the Health Extension Program, an army of community health workers who harnessed the model of extension to bring basic public health information to the most remote corners of the country. These extensionists—all government-trained young women, today numbering more than 38,000—are assigned in pairs around the country, about one pair per village of 3,000 to 5,000 people. They work out of the extension system's rural outposts and operate as branches of the country's health centers, which are branches of the country's hospitals. This network has produced enviable success. Child mortality rates have fallen 67 percent since 1990; maternal mortality rates are down 59 percent; and the country achieved Millennium Development Goal 4 (reducing child mortality) three years ahead of schedule. Beyond the Health Extension Program, the government launched the Women's Development Army in 2011. The community-level volunteers of this "army," trained by health extension workers, act as agents of change, working with their peers in the community to promote basic hygiene and public health practices—like proper latrine construction and food handling. Their goal is to help further reduce the country's incidence of preventable, communicable disease.[34, 35]

In general, rural residents have poorer connectivity than their urban counterparts, and women are more likely to be offline and disconnected than men.[36]

In emerging economies, internet connectivity is driven by access to mobile phones. Mobile access is rapidly growing in Sub-Saharan Africa, bringing with it access to information from around the world. It is also bringing smallholder farmers closer into the global market. In 1999 less than 10 percent of the population in Sub-Saharan Africa was covered by mobile phones. Today, it's 90 percent. A full 43 percent of Sub-Saharan Africans have a cell phone subscription, and more than half are expected to have subscriptions by 2020.

Figure 3

Mobile-cellular telephone subscriptions (per 100 people)*



* Subscription rates over 100 reflect more than one mobile subscription per person on average.
Source: International Bank for Reconstruction and Development/The World Bank, The Little Data Book on Information and Communication Technology, (Washington, DC: World Bank, 2018).

Despite these gains, the availability and affordability of mobile data is currently a challenge. Two-thirds of mobile phones (67 percent) are only 2G enabled, and while 27 percent of cell phones are smartphones, that leaves more than 700 million people across the continent without access to these technologies. However, understanding these rapid technological shifts will allow extension agents to take full advantage of technological platforms as they become more prevalent.[37]

Rural communities—with agriculture at the center—will be challenged to thrive without access to the internet and all the inherent opportunities, capabilities, and connections it brings. Prosperous rural areas require smart investments in rural broadband, while public and private-sector innovations that bring the internet to poor and remote regions are desperately needed, in addition to the many agricultural applications.

What is needed

Given the potential inherent in today's digital technologies, the traditional model of extension, which has successfully served the needs of farmers in the United States and abroad for so long, must be updated to keep up with the rapid pace of change and respond to critical agricultural and farming challenges.

Figure 4

Global innovations in extension

Organization	About
Digital Green India and Sub-Saharan Africa 1,500,000 farmers	Locally produced videos are screened using low-cost projectors in small viewing groups mediated by community extension agents and social workers already working with communities. Videos are in local languages and offer short demonstrations and testimonials. Independent evaluation has demonstrated they are 10 times more cost effective than traditional extension and that farmers who have access to them adopt new practices at seven times the rate.
FarmerLine Sub-Saharan Africa 200,000 farmers	FarmerLine connects farmers to production and weather information, markets, and services using short audio messages in local languages delivered directly to basic cell phones (similar to minipodcasts). Given the many languages spoken in the region—and between 1,000 and 3,000 on the continent—this is a powerful innovation. With messages readily available to them, farmers can listen at their convenience. Data is also collected from farmers to enable improvements. Company data suggests using FarmerLine for one season increases per-acre return by 55 percent. [38]
Farmbook Suite by Catholic Refief Services in collaboration with partner NGOs Southern Africa	Farmbook is an integrated package of tools to help extension agents support farmer groups with training, business planning, market analysis, and service delivery. It includes strong accountability metrics to ensure services are being delivered to farmers. The feedback loop between farmer and extension agent helps agents demonstrate their effectiveness and allows accurate quantification of extension's reach. Content focuses on five core skills that all farmers need to succeed. The delivery method was refined in partnership with many NGOs and with University of Illinois Modernizing Extension Advisory Services (MEAS) program, supported by USAID. Each module contains content, quizzes, practice opportunities, and tips for best reaching farmers.
Developing Local Extension Capacity (DLEC) Project Sub-Saharan Africa and South Asia	The DLEC Project is USAID's Feed the Future capacity development program for extension. Operating in countries across Sub-Saharan Africa and South Asia, the project aims to improve extension programs and policies through tailor-made, partnership-based solutions for local farmers and extension agents. DLEC's approach combines global best practices, program analyses, and partnerships that put local needs first. Together, this helps bring the best in global knowledge to farmers most in need of technical assistance. The project is led by Digital Green in partnership with Care International, the International Food Policy Research Institute (IFPRI), and the Global Forum for Rural Advisory Services (GFRAS).

Figure 5

Social media platforms for extension

Platform	About
WhatsApp Groups www.whatsapp.com	Farmer-driven WhatsApp groups, or group chats, have been steadily adopted as a mechanism for networking and aiding farmers affordably in many countries, with India leading the way. In Uttara Kannada the state is now establishing WhatsApp groups with existing cooperatives (now over 200) to enable better service and access to information. In many places, curated groups are also available according to topics of interest such as irrigation, farm equipment, or greenhouses.[39]
Twitter @ISUExtension @NDSUsoilhealth	Twitter now boasts 328 million users, roughly 68 million in the United States, and is a quick way to disseminate and exchange information. Many extension programs host Twitter accounts. Iowa State's account, for example, boasts over 7,000 users. Twitter also allows individual extension agents to improve their reach. For example, Abbey Wick, a Soil Health Specialist with North Dakota State University Extension, has posted over 4,000 tweets about soil health. She posts what she's learning as she visits farmers in the region (including maps on where she is), responses to questions, and help aids for farmers. She has nearly 4,000 followers.
Facebook www.facebook.com/groups	Public and private Facebook groups have taken hold and provide great promise for helping farmers gain access to information. One private group, "Digital Farmers Kenya," had 120,000 users at the time of publication. It provides a platform for farmers to swap photos, ask questions, advertise products for sale, and share other valuable information. Similar groups can be found across regions and crops and may be especially popular given Facebook's "Free Basics" initiative, which gives mobile users access to the site free of data charges in 42 countries.[40]
YouTube www.youtube.com	YouTube, a subsidiary of the tech giant Google, is another example of how popular social technologies can be adapted to the needs of extension and farmer-to-agent information exchange. YouTube has a great deal of content from land-grant university extension programs and similar public and private programs from around the globe. However, integrating entertainment with education is another trend worth building on. One stand-out YouTube channel is the Peterson Brothers Farmers, three brothers from Kansas that post both entertaining, farmer-centric music videos and educational content. The brothers "Gangam-Style" parody went viral, garnering 17 million views. Once there, users can learn about silage, weed control, and hear explanations of new agricultural science delivered in a factual but entertaining way. The success of this channel suggests that entertainment can enhance the reach of agricultural information. At the time of publication, the Peterson brothers had nearly 140,000 subscribers.

Shrinking budgets mean that local extension agents—the highly qualified, resourceful individuals helping farmers learn and solve problems on the ground—must be given the tools and resources they need to improve problem solving, identify and share best practices, exchange knowledge and experience at home and abroad, and increase their ability to reach and help those who need it.

Technology has opened up immense possibilities in the sector, both as a means of reaching farmers and of gathering, storing, analyzing, and sharing data that can help solve agricultural problems more quickly and efficiently than ever before. While there is no substitute for human-to-human learning and problem solving, technological innovations can greatly enhance the value that agents on the ground can bring to their constituents and to others around the world.

Coordination/targeted investments at federal level

While decentralization is at the heart of the US extension system and should remain so, coordination and targeted investments at the federal level are essential to guiding and overseeing the creation of a digital infrastructure and promoting ongoing innovation. While there is minimal oversight of the extension system on the national level, NIFA can and does help direct priorities through its competitive grant offerings and centers of excellence awards. These are among the strongest tools available to increase the extension systems' digital offerings across states.

Information exchange

Extension's traditional operating model needs a deliberate, thoughtful updating for extension's next century. The incorporation of digital tools into extension systems holds enormous possibilities, including a fundamental paradigm shift in the ways information is created, used, and shared. Rather than the traditional top-down, one-way communication of information, digital tools allow for robust exchange of knowledge, where information—and user feedback—integrate to strengthen advice and improve understanding of what is needed to help farmers.

This means far greater accountability to all users of extension: more precise outputs by researchers and agents and more informed governance for the entire system. With unparalleled accuracy about who their constituents are, extension agents will know exactly what piques their interest and can deliver more rapid, tailored advice. Creating transparency across the information supply line—from researchers to extension agents to extension's consumers, farmers and nonfarmers alike—could mean improved decision making and greater resource allocation from the streamlining of duplicative or outdated operational methods.

Public-private partnerships

The private sector has been leading the way in the fast-paced world of digital technology. The public sector should not try to duplicate the work done well by companies. USDA extension should look for ways to leverage the private sector and build public-private partnerships that can make better use of digital platforms to build a stronger system overall. It should take the best practices and identify where digital tools can help to disseminate basic research, allowing access for all farmers. It should also develop partnerships with technology companies that can assess the pieces of the extension system—from county agents to NIFA in Washington—as a cohesive whole to help deliver efficiencies and best practice solutions without compromising the unique and autonomous operations of any part.

The traditional model of extension must be updated to keep up with the rapid pace of change and respond to critical agricultural and farming challenges.

Rethinking agent role to help recruiting

The knowledge and experience of today's cadre of extension agents is immense—and invaluable. Yet without an influx of younger recruits to whom this knowledge can be passed—and without the digital tools to help capture and extend this bank of expertise—the benefits of public extension that have long contributed to US agricultural leadership could languish.

At the same time, there is a great opportunity for young people to contribute to and support a modernized and advancing industry. Born and bred on technology, young leaders can help infuse the system with ideas and innovations that continue to propel extension forward. Reconceiving their roles and rewarding innovation will help attract and retain the talent needed.

Identify global innovations for the betterment of domestic and worldwide extension services

Despite the many differences between the US extension system and those systems in low-income countries, there are many similar systemic challenges that digital technology could address. For example, the United States participates in the Global Soil Map platform, a digital resource that is aiming to use remote sensing to capture soil maps around the world.[41] These maps would enable the tracking of key indicators such as erosion and nutrient content and help with predictive modeling on overall planetary health. This data can be integrated into technological platforms serving farmers around the world, whether through public or private sources. Similarly, digital innovations for tracking pests and diseases could be invaluable to both US agriculture and the global food system.

Beyond such advancements, a focus on incorporating digital tools in extension systems is ultimately necessary in a world with limited extension resources and growing populations to feed. Farmers need good information to make their farms flourish and their incomes rise. With over 500 million smallholder farmers around the world, most of whom grow a multitude of crops and who speak hundreds if not thousands of different languages, the needs and challenges are diverse.[42] The complexity of communication, combined with underdeveloped rural road networks in many countries, poses significant challenges in reaching rural farmers in person. In such cases, digital technologies may be the only way to fill this great need.

Born and bred on technology, young leaders can help infuse the system with ideas and innovations that continue to propel extension forward.

Digital communication technologies offer the opportunity for low-income countries to leapfrog outdated or inefficient technologies, allowing them to adopt the newest technology applications most useful for their given situation. This has the potential not only to transform farmer knowledge and opportunity, but also to help US innovators working to further improve these technologies.

As the United States develops and adopts its own digital solutions for agriculture and extension, collaboration with international partners to transfer best practices and develop global solutions will widen the value of these solutions for the benefit of farmers in the United States and abroad. At the same time, the United States can benefit from solutions adopted in other countries that have already leapfrogged established solutions, offering an opportunity to identify and adopt best practices it has yet to implement.

Policy recommendations

Investing in digital innovation for extension is critical to the continued progress of US agriculture, both in the public and private sector. New technology enables new understanding of how to farm more sustainably through the analysis of vast troves of data, as can be seen with the advent of precision agriculture in recent years. Digital technology can enable greater reach, reduced costs, and improved accountability. It also is the toolkit young farmers and agricultural professionals have come to expect and will continue to use to greater and greater effect. Key opportunities for increasing extension excellence in the United States must be embraced. Doing so will also open the door to opportunity for smallholder farmers around the world struggling with food security. The following recommendations would go a long way toward moving extension toward this digital future.

Make investments to upgrade extension's digital capacity at the national level and create new incentives to reward greater use of digital technology and modernization across county, state, and regional US branches.

- **Action a: Conduct a review of agricultural extension, especially the use of digital technology.** Congress should request that the Government Accountability Office perform an evaluation of USDA's extension efforts and its benefit to US farmers to assess effectiveness and adoption of practices. It should incorporate more than just increased agricultural productivity as an indicator of success. It should also highlight impactful digital technologies in use by extension. The report should also assess the benefits and drawbacks of consolidating the multiple appropriations that support extension under NIFA.

- **Action b: Create a competition to reward digital innovation from the bottom up.** Congress should direct USDA to create an annual competition for the best new digital extension tools. The competition should culminate in a conference for extension agents to expressly showcase their digital and technological work and to have the winners of the competition be the keynote. It should place priority on young and innovative agents.
- **Action c: Build capacity for strong, digitally empowered extension agents and other agricultural professionals by investing in the creation of curricula and degree programs for digital agriculture at the graduate level.** The Foundation for Food and Agriculture Research (FFAR) should create a competitive grant open to land-grant universities or non-land-grant universities to create a new degree program specifically for digital agriculture working closely with USDA.
- **Action d: Create a digital extension advisory group and drive agreement on critical elements of success, including data harmonization and standards.** NIFA should consider creating and leading an extension advisory group that coordinates with relevant agencies, subagencies, land-grant universities, and private and nonprofit groups to advance digital extension practices. This group could work on a number of key issues, but could particularly advance a minimum number of data standards and variables such as GPS reporting and time-stamp protocol, which could be used to foster interoperability across different agricultural data sets. Agreement on the standards of open-data access for publicly funded and voluntary, nonproprietary data sharing from the private sector could also improve farmer access to information. Given the rapidly proliferating nature of data generation from drones, satellites, and sensors, a set of common standards and vision around standards could dramatically improve future outcomes and applications.

Work in greater partnership with the private sector to digitize agricultural information, especially working with land-grant universities, to enable better and broader access (especially for underserved farmers).

- **Action a: Improve searchability, user experience, and public access of existing data, digital extension platforms, and tools by partnering with the private sector to make improvements and consolidate information**. FFAR should create a competitive grant to fund the creation of digital tools that can solve pressing extension problems. It should be in partnership with the private sector with the goal of creating sustainable digital innovations that can generate their own funding. The grant could focus on building common digital platforms that aggregate research outcomes and farmer/industry tools across states and institutions and that improve searchability and access using cutting-edge data analysis tools and user interface.
- **Action b: Explore new financing models to enable greater rural broadband access.** USDA should continue to emphasize the need for rural access to broadband as a key tenant of its infrastructure agenda. It should explore new cost-sharing or innovative financing opportunities with the private sector to help accelerate the timeline for rural access.[43] These funding models could generate new models that could also be used abroad.

Increase the emphasis on digital innovation for agricultural extension in global food security efforts.

Further commit to the highest standards of open data for agriculture and nutrition, consistent with the objectives of the Global Food Security Strategy and the Global Food Security Act. Empower the full breadth of USDA to play a thought leadership role on digital extension in close partnership with USAID, the State Department Office of Global Partnerships, and the Peace Corps.

- **Action a: Make a long-term commitment to digital extension by establishing a university-based innovation lab in addition to other critical efforts.** USAID should build on their support for extension innovation via the Developing Local Extension Capacity (DLEC) initiative by creating a partner innovation lab for

modern extension within a land-grant university and empower the lead institution to lead peer universities in sharing innovations. This would be particularly valuable given the breadth of extension innovation across land-grant universities, the shared history of these universities with many institutions around the world, and role of the American private sector in this space. The lab should formally collaborate with prominent tech colleges and universities in the United States to pair new extension models with digital expertise and innovation. This type of research will greatly elevate land-grant universities and extension, but also have applications globally for extension.

- **Action b: Make geographic information systems/ remote sensing data available to low-income countries and provide technical assistance on data analysis and use.** As governments increasingly look for support to redesign extension systems with digital technology in mind, USDA should continue its commitment to open data by creating a platform to share their geographic information systems-enabled data to Feed the Future target countries, whether collected in-country or remotely through satellites.
- **Action c: Consider requiring common data collection and sharing standards, reporting platforms between implementing partners providing extension services, and an increased focus on accountability.** Such efforts would increase transparency, enable comparisons, and eliminate redundancy in creating platforms and apps. Increasingly, "internet of things" platforms are being developed that create identification of people, places, and activities that could allow for improved tracking of project activities. These platforms can remain anonymous to respect privacy, but can also allow for better understanding of coverage areas if partners shared data. With this information, activities that encourage accountability toward farmers and other key constituents can be made easier. Program-specific innovations can be scaled in the interim. For example, Catholic Relief Services "FarmBook" employs consensual tracking of the laptops used by their extension agents. This helps to document the agents' time spent on farm and can help identify which farms are underserved, including women-headed households that may have less access to information and farm services like extension.
- **Action d: Implement a new exchange program to build extension capacity abroad in partnership with Peace Corps and USDA.**
  - **Subaction 1:** Congress should create a system for US extension agents to support capacity building with their extension counterparts in developing countries similar to the Farmer to Farmer program. Already, the Farmer to Farmer program often includes extension agents as participants, but specifically pairing US agents with agents abroad could improve capacity and interest.
  - **Subaction 2:** The Cochran and Borlaug Fellowships have been critical tools to ensure knowledge transfer and support the development of agricultural professionals. Emphasis should be placed on extension agents in developing countries, allowing them the opportunity to pair with US extension agents at land-grant universities, learn from US extension expertise, and travel to observe US extension. Given the low numbers of female extension agents in low-income countries, special efforts should be made to reach women, perhaps pairing them with female American extension agents, who represent a large share of the US extension workforce.[44]

Conclusion

As the US extension system enters its second century, it is no less foundational to the success of US agriculture—and to agricultural development around the world—than it was when it was established. While the agricultural landscape has changed, challenges to farming are as existential as ever, from shifting weather patterns to threats from pests and diseases to an aging workforce in need of youthful energy, new approaches, and innovation. Indeed, the need for robust extension systems empowered by digital technologies is growing because of increasing populations to feed and continued threats to food security around the world. In a rapidly changing and interconnected world, challenges faced by farmers in any corner of the globe impact everyone. This makes embracing technology to address problems and advance innovation especially urgent.

Investments in research and development remain critical to agriculture, and publicly funded extension remains a key mechanism for knowledge sharing. Applying crosscutting digital tools to extension in the

United States would help ensure that crucial, publicly funded research and other valuable tools and information continue to reach traditional recipients while expanding to a greater numbers of end users, from farmers and extension agents to researchers, entrepreneurs, and global partners. This would dramatically increase the ability of extension to establish robust, two-way communication between local users, researchers, and other stakeholders. Globally, digitally enabled extension systems could transform the world's ability to collect, share, and analyze information to address both long-standing and emerging challenges, quickening the pace of agricultural development and sustainable agricultural intensification. In low-income countries such advancements would broaden the reach of extension significantly, making some smallholders in low-income countries visible to businesses, governments, and NGOs, perhaps for the first time, and helping to move the world toward greater food security.[45]

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Chicago Council on Global Affairs
Two Prudential Plaza
180 North Stetson Avenue
Suite 1400
Chicago, Illinois 60601