THE CHICAGO COUNCIL ON GLOBAL AFFAIRS

# New solutions for a changing climate

## The policy imperative for public investment in agriculture R&D

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## Executive summary

- US public investment in agricultural research in the 20th and 21st centuries has resulted in unprecedented worldwide production of a few staple crops and the improvement of dozens more. Increased crop yields and animal production have drastically reduced famine compared to previous centuries and supported an overall increase in global affluence.
- Today, agricultural producers around the world are facing new challenges as global climate changes become increasingly unpredictable. Inconsistent rain, extreme temperatures, droughts, flooding, wildfires, and shifting pest and disease patterns are just a few of the obstacles farmers face as they try to feed their families and produce enough food to feed the world.
- In spite of these dire challenges, US public agricultural research funding has been decreasing over the past several decades. This has allowed competitors such as China and Brazil to outpace American ingenuity, take over American markets, and put American farmers at a disadvantage.
- The lack of investment in agricultural research and development is a critical national security concern. Historical US agricultural strength has contributed to US hard and soft power around the world. As the US food system is beset by increasing climate, economic, financial, and security threats, US rural communities have been left behind, undermining US power and domestic well-being. Increasing global food insecurity, which has been amplified by increasing weather extremes, will lead to economic and political instability in many areas of the world, further threatening US national security.
- Although the private sector plays a crucial role in the development of new agricultural techniques and products, public funding has been the backbone of many agriculture and food system advances.
- While agricultural research and development has historically focused primarily on increasing yields, this narrow focus does not adequately support the food requirements of today's growing global population.
- There must be a revitalization of public investment in agricultural research, American food systems, and international agricultural development that focuses on the challenges of the future. US leadership is vital to ensuring the global research agenda does not leave farmers behind.
- Opportunities to build upon and enhance existing US agricultural research infrastructure across many diverse government entities abound. The US government should recognize these investment opportunities to address current and future climate challenges.

## The need for agricultural research in a rapidly changing world

Agricultural research fuels discovery that advances the food systems upon which we all depend. For more than 150 years, public investments in agricultural research in the United States and around the world have revolutionized agriculture and rural life, driven economic development, advanced globalized food systems, improved human health, and transformed the human condition. In the 20th century, as the human population increased from 1.6 billion in 1900 to approximately 6 billion in 2000, the impact of public investment in the sciences and engineering was dramatic.[1] Investment in research generally focused on increasing and protecting crop and livestock yields by improving efficiency through intensified inputs, nutrients, mechanization, water, and irrigation technology. These efforts came together toward the goal of maximizing local, short-term productivity.

The magnitude of the increases in agricultural yields as a result of these investments is truly staggering.[2] Corn yields in the United States have increased more than fivefold since 1866.[3] Corn production, the top crop produced globally, topped 1 billion metric tons in 2018–19.[4] Soybeans, used in rotation with corn as a nitrogen-fixing crop, have also steadily gained acreage with marked increases in yield, from below 35 bushels per acre on average in the United States in 1989 to over 50 bushels per acre by the mid-2010s.[5] Even in dry regions where sorghum, wheat, and other small grains have been traditionally grown, corn/soybean rotations have spread, resulting in intensive use of fertilizer for the corn crop and intensive irrigation.[6]

*For more than 150 years, public investments in agricultural research in the United States and around the world have revolutionized agriculture.*

This avalanche of agricultural production resulted in the dramatic reduction of life-threatening famine during the 20th century relative to previous centuries. Alex de Waal describes this as "one of the greatest unacknowledged triumphs of our lifetime."[7] The International Food Policy Research Institute (IFPRI) did not even have a famine program until recently, as famine was considered a thing of the past when the institute was founded in 1975. The geographic areas where famine may occur now are much more highly constricted. While not eliminated as previously thought, famines over the last four decades have also been far less deadly.[8]

Public investments in agricultural research by the United States and other high-income countries have improved famine monitoring systems. The Famine Early Warning System Network (FEWSNET), the Group on Earth Observations Global Agricultural Monitor (GEOGLAM), and the G7's Agricultural Markets Information Service (AMIS) have enabled better emergency relief and reduced future famine risk.[9]

### Growing challenges for farmers and food systems

After decades of decline in famines worldwide, 2017 was the worst year for famine since World War II.[10] There were major concerns in four regions simultaneously: South Sudan, Somalia, the Lake Chad region, and Yemen.[11] The possibility that these famines could grow into a conflagration of complex, intersecting humanitarian crises rooted in conflict, poverty, and drought posed an unprecedented threat to global food security and to US national security. As was clear after 2008, food crises can snowball into political and civil instability.[12] These cascading effects can thrust regions previously perceived stable into turmoil.

Beyond the risks of famine, chronic food insecurity still haunts a quarter of the 4.1 billion people in Asia. An estimated one in four people remains undernourished in Sub-Saharan Africa, while over half of the continent's population has insufficient access to food.[13] Nearly 9 percent of the world's population continues to suffer from hunger, and over 20 percent of all children under five are stunted due to malnutrition.[14] While this number had declined for 30 years, it went up by almost 60 million people in the past five years due to natural disasters and growing conflict. The COVID-19 pandemic could add up to 132 million more hungry people in the world. An estimated 2 billion people suffer from food insecurity around the world, a number that has grown by 400 million since 2014. Moreover, the global population continues to grow. In 2020 an increasingly affluent 7.8 billion people—the COVID pandemic notwithstanding—are soon to be an estimated 9 or 10 billion people by midcentury.[15]

Women are at a particular disadvantage. Women are 10 percent more likely to experience food insecurity regardless of education, income, and location.[16] When conflict or major disaster affects access to food, women

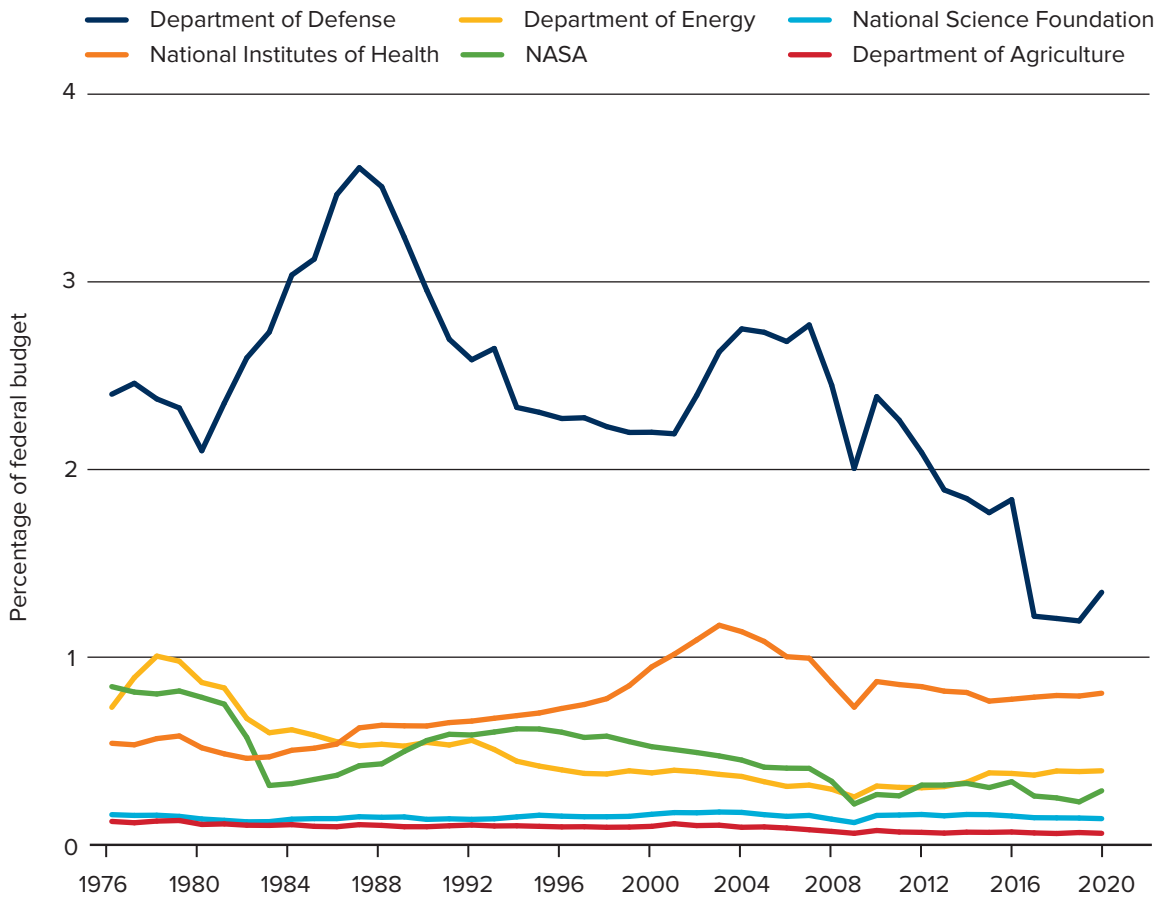
are more likely to experience food insecurity than men.[17] This gender gap in food access has only increased in recent years, and this trend is likely to continue absent intervention.[18]

Climate change, now very real on the American landscape, adds further stress through increasingly frequent, complex, lengthy, and disastrous weather-related losses of crops, property, and life.[19] Extreme weather events include sudden shifts in rainfall and temperature patterns, stronger storms and sustained weather events, and the increasing emergence of pests and disease that can have long-term effects.[20] The COVID-19 crisis has illuminated the weak points in our global food systems and has also revealed their fragility and complexity.[21]

At the same time, food supply chains around the world are being profoundly reshaped. Before 2018 China was one of the top two markets for US agricultural exports every year since 2008.[22] Beginning in 2018, however, trade disputes between the United States and China have resulted in steep drops in US agricultural exports.[23] Overall agricultural exports in 2019 were down 4 percent relative to 2018, but corn exports dropped nearly 40 percent.[24] There is general concern now that even if the trade disputes fully resolve, those markets have found other suppliers and will not rebound for US producers. In 2019, Canada, the European Union (EU), Japan, and Mexico surged ahead of China as leading US trade partners.[25] Given China's increasing affluence and roaring demand, there may be significant implications for US agriculture and the communities sustained by agriculture if China more permanently pulls away from the United States as a major trading partner.

Figure 1

**Research and development funding by federal agency as a share of the total federal budget (1976–2020)**




Source: American Association for the Advancement of Science

## The time for big change is now

This is the moment for the United States to recognize the strategic importance of our agricultural infrastructure to the future of our nation. Agricultural production as we know it in the United States and other high-income countries was born from public investment and is now sustained by public, and more recently, significant private investment in research, education, and outreach. Both public and private investments have generated the technology, institutions, and talent that define US agriculture today.[26]

While great advances in maximizing local agricultural outputs have been made, sustained prosperity and stability for agricultural producers, especially women, ethnic minority, beginning farmers, and their communities, remains an elusive goal. The historical focus of agricultural research on commodity crop yield and protection and input and management regimes may no longer reflect the highest priority needs of farmers in the United States and abroad.

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The focus on productivity has also often come at the expense of longer-term resource stewardship, including maintaining the condition of soils to protect arable land globally and protecting water resources. Concern about the impact of our current agricultural production systems developed as an afterthought with the publication of Rachel Carson's *Silent Spring*.[27] Carson's insights about the unintended consequences of the use of toxic chemicals in agriculture are now far better understood.[28] Yet current production practices and performance assessments do not fully take environmental as well as public health outcomes into account.[29] Innovation is largely focused on tweaks to the same systems. It is not surprising that progress on critical dimensions of the food system that have been discounted or ignored under the pressure of ever-increasing yields, efficiency, globalization, and short-term economic returns has stagnated or even moved in undesirable directions.[30]

Today, the imperative must be to better manage these so-called "externalities" of agriculture, effects that are eminently foreseeable but unintended and consequential, and to better support farmers who are on the front lines in facing the challenges of a changing planet on behalf of all of us. Their livelihoods, our country's future, and our lives hang in the balance.

The retrenching of support for public investment in agricultural research and development has come at a time when all these dynamics—including climate change, political instability, economic, environmental and resource strain, and now severe disruptions in agricultural supply chains as a result of the COVID-19 pandemic—are undermining global food systems and the livelihoods of farmers. These developments threaten the remarkable, life-saving achievements of the past several decades and pose significant immediate and long-term risks for US agricultural producers and the farm economy.

How should we invest in research to support a future for a global food system that manages the resources for the long term, creates steady improvements in the lives and communities who depend on agriculture for their livelihoods, *and* meets the physical and financial needs of our nation?

To ensure that farmers everywhere have the tools they need to prosper now and in the future—regardless of race, gender, age, location, or nationality—a new agenda needs to be created, one that addresses the impact of climate change on agriculture, the need for more diverse and sustainable crop production, and the interconnected nature of our global food system. Building on our traditional agricultural research capacity, which has achieved so much, we must now redouble support for public investment in agricultural research and aim it at the most significant strategic US priorities for agriculture in the 21st century.

## Cascading crises

At present, the United States and the world are experiencing a set of cascading consequences of the COVID-19 pandemic in agriculture and the global food system. The stresses on agriculture, food supply chains, and our national and global food systems extend from abrupt and extreme interruptions in patterns of food consumption and transport to deflationary and inflationary trends, loss of numerous markets, and interruptions in labor.[31] The COVID-19 crisis has magnified the chronic stresses our nation's agricultural producers have experienced and has brought them to or beyond the breaking point.

The United States will emerge from the COVID-19 pandemic fundamentally changed. Massive stimulus packages will undoubtedly affect agriculture and rural communities in diverse ways. Already, disparities exist between farmers: between women and men, young and old, small and large operations, and across races.

While the COVID-19 crisis is unprecedented in the magnitude of its economic impact, rural America has already been swept by several other "epidemics": the opioid epidemic,[32] obesity and diabetes,[33] and spiking suicide rates among middle-aged to older white men whose livelihoods have fallen apart and who hold vast debt they cannot repay.[34] Persistent lack of access to healthcare puts rural women and Black Americans at higher risk for chronic disease and COVID-19.[35]

Fear among farmers about the long-term viability of their farming operations and their communities is rampant worldwide. This fear is particularly acute for women farmers, most particularly in low- and middle-income countries, who globally already face lower access to inputs, extension support, and land ownership than men.[36] These struggles are also felt acutely by farmers worldwide who identify as racial and ethnic minorities. In the United States, minority and women farmers have faced decades of active systemic discrimination with regard to eligibility and distribution of benefits from the US Department of Agriculture (USDA). To address a key issue for Black farmers, the 2018 Farm Bill included a provision that allowed access to government farm support programs in cases of intergenerational transfers of land without title, which had previously acted as a barrier to access, but the legacies of sustained discrimination persist.

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Globally, with the clear link between food insecurity and political turmoil, the effects of COVID-19 will extend far beyond food and public health systems, including direct implications for US national and global security. The toll in human lives, in financial losses, and on communities will be overwhelming—and farmers are on the front lines of this devastating impact.

## Climate change should be a high strategic priority for investment

A 2019 international report indicates with high scientific confidence that global food security is currently affected by climate change[37] and that these effects will intensify over time. The report projects that in 2050 there could be a 29 percent increases in cereal prices.[38] These estimates were made before the COVID-19 pandemic, which has already exacerbated global hunger and is likely to continue to do so. Climate change compounds the risks to food systems and can reverse socioeconomic development gains, especially within vulnerable social groups such as women and poor communities, pastoralists, people involved in vegetable or fruit production, or people located in tropical regions. Additionally, rising temperatures and $CO^2$ levels have been shown to affect not just the quantity of food grown but also the nutritional quality. The micronutrient content of key crops such as rice, wheat, sorghum, and maize are vulnerable to climate change.[39] These consequences on agriculture, nutrition, and on developing and rural economies create new and complex risks that are more severe, more frequent, more unpredictable, and more difficult to manage. As the world learned in 2008–10, climate change and high food prices can lead to social unrest and dramatic political upheaval. These challenges are not limited to smallholder farmers in other countries. US farmers are seeing the impact of climate issues on their incomes, land, crops, and families on a daily basis.[40]

### Extreme temperatures

Both the National Aeronautical and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) reported that 2019 was a record year for global warming. In aggregate, 2019 saw the second-warmest global surface temperatures ever recorded.[41] This past decade was the hottest ever recorded.[42] The last five years have been the hottest on record, and the 10 hottest individual years have all occurred since 2005.[43] In the past year, record-breaking heat waves, especially in the Southern Hemisphere, fueled horrific wildfires, with significant loss of livestock and wildlife as well as property and human lives.[44] Heat waves resulting from climate change are often most pronounced during the typical growing season, intensifying and extending periods of temperatures that exceed crop plant tolerances. Certain periods of plant growth are particularly vulnerable to high-temperature stress, notably pollination.

Pollen formation is sensitive to temperature in general and high night temperatures in particular.[45]

Plant survival and yields are being impacted by both increasing average night temperatures during the growing season and the number of nights per growing season that temperatures exceed specific thresholds. In the tropics, the rates of increase in night temperatures are climbing even more steeply than the overall average or daytime average temperatures, leading to concern about not just declining yields but total plant failure.[46] Farmers are then left without recourse for that growing season.[47]

Likewise, high temperatures stress livestock and human labor. In the United States heat waves are the deadliest type of weather event, consistently killing more people than storms.[48] Globally, a string of deadly heat waves struck in 2019, beginning with extreme heat episodes in Australia and the Middle East. By early May temperatures soared to a record 123.8°F (51°C) in northern India and Pakistan, and in June temperatures exceeded 113°F (45°C) in some parts of western Europe.[49] By the end of June the Indian heat wave, compounded by water shortages, became one of the most lethal and longest ever recorded.

## Wildfires

Within the last few years, wildfires driven by extreme heat and reduced rainfall as a result of climate change have caused catastrophic agricultural losses around the world. Lost vineyards in California and horrific losses of livestock in the 2020 fires in Australia have revealed the weaknesses in our response systems, as the very nature of wildfires have changed. Wildfires in 2019–2020 have also burned across Amazonia and Indonesia, likely due to agricultural clearing. Wildfires have similarly intensified in the Arctic, notably Siberia.[50] The amount of carbon and other harmful and toxic pollutants released in these fires is immense, with impacts across the globe on air quality, climate issues, and human respiratory health.

## Droughts and flooding

Droughts have shaped human civilizations for millennia, thought to underlie some of the dramatic falls of past empires throughout human history.[51] While droughts are inevitable, human actions before or during a drought can mitigate or exacerbate the damage that results. Efforts to ensure that soils have a high fraction of organic carbon and build favorable water retention properties along with investments in water harvesting and efficient irrigation practices can forestall damage to crops. Attention to the impact of civil engineering projects is also crucial. For example, a Turkish dam installed upriver from Syria exacerbated the effects of the drought that preceded the food shortages and civil uprisings in Egypt, Syria, Yemen, and elsewhere across North Africa, resulting in the "Arab Spring."[52]

Tragically, as this policy brief goes to press, Ethiopia is still experiencing shockwaves from two severe droughts in three years. Insufficient rainfall in 2017 led to severe water shortages, catastrophic livestock losses, and failed crops throughout the country. The drought in southern Ethiopia came as the country's north and central highland communities continued to recover from a severe drought in 2016 triggered by multiple consecutive seasons of below-average rainfall and the effects of the 2015–16 El Niño climatic event.[53] Delayed, weak rains in 2018–19 as well as the current desert locust infestation have prevented Ethiopia from fully recovering from years of drought. Rain variability, and therefore further droughts, will increase in coming years.[54] The complexity of these systems makes them difficult to predict because droughts in one region often have teleconnected impacts on other regions.[55]

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The past 10 years have also been the hottest on record for ocean temperatures, pushing large warm moist air masses into terrestrial weather systems. This causes more frequent and more extended droughts and floods.[56] In the United States and around the world, changing rain patterns have had a significant effect on agricultural production, civil infrastructure, and the well-being of agricultural producers and rural communities.[57] A recent paper suggests that the period 2000–18 was the second-worst multidecade drought in southwestern North America, and the effects are ongoing.[58] A new assessment of climate proxy data can now pinpoint substantial human-caused contributions to the severity of the current drought.[59]

In addition, storm systems tend to be larger, with protracted effects and shifts in the typical jet stream.[60] Major floods are striking closer together, as observed in Houston, Texas, and the recent devastating floods

in the Midwest. Houston was hit by the wettest storm ever to hit North America in 2017, Hurricane Harvey, which caused a 1,000-year flood, only to be followed in 2019 by Hurricane Imelda, causing a second 1,000-year flood.[61] Most Americans are unaware that the Great Mississippi Flood of 2019 was an interconnected catastrophe. A total of 400 counties in 11 states sought federal disaster funds as a result of flooding that affected an estimated 14 million Americans along the Arkansas, Mississippi, and Missouri rivers. These floods affected a system that drains more than 40 percent of the land in the contiguous United States, including most of America's richest agricultural lands.[62]

## The 2019 polar vortex

The 2019 floods in the United States were a secondary result of a major weather event, the polar vortex, that occurred in January 2019. The nature of this event and its implications for US agriculture highlight the importance of systems when considering policy interventions and research investments. While the problem started with a spell of cold weather, cold-hardy crops would not have mitigated the damage set in motion by the episode in January 2019. The episode of cold would also not have had the same impact if it had not followed an especially wet period. The period from May 2018 to May 2019 was the wettest 12-month period ever recorded by NOAA, including the wettest meteorological winter ever recorded.[63]

Flooding and further temperature swings in the spring, which continued into June 2019, delayed planting of corn and beans in some areas and prevented planting altogether in others. Across the Midwest, the area of unplanted acres in the spring of 2019 was 18 times greater than the previous year.[64]

## Pests and diseases

The rise in unpredictable weather patterns has been accompanied by a dramatic increase in the number and intensity of agricultural pests and disease outbreaks.[65] While efforts to address pest and disease outbreaks have always been a facet of agricultural research and innovation, global interconnectedness has increased the potential for outbreaks to have global consequences. In addition, climate change may cause familiar problems to surface in new ways. In 2019 alone the world saw a once-in-70-year locust invasion in East Africa, the Middle East, and South Asia *and* a devastating outbreak of African swine fever (ASF) shortly after an infestation of the fall armyworm spread throughout East and Southeast Asia.[66] The first plague, locusts, was a direct result of a changing climate—of the rapidly warming Indian Ocean bringing especially intense rains to East Africa.[67] The combination of heavy rains and warm temperatures was the perfect condition for an explosion of the locust population.[68]

Affected regions are now bracing for a second generation of the pests, up to 20 times worse than the first.[69] In one day, a single swarm can consume enough food to feed 2,500 people.[70] For nations already suffering from chronic food insecurity, the combination of locusts, national lockdowns due to COVID-19, and flooding (now affecting East Africa) may prove too much from which to recover. While the locusts may not spread to the United States, the disaster has the potential to exacerbate existing political tensions, sparking cycles of humanitarian crises and social and political unrest.

***The spread of a virus like African swine fever, diseases like wheat rust, or aggressive pests like locusts or the fall armyworm have, and could, cost national agricultural sectors billions in losses.***

ASF, on the other hand, could easily come to our shores with devastating results. The world lost an estimated quarter of the global pig herd in 2019 to the disease.[71] Already in June 2020, global hog fatalities due to ASF have reached the annual total from 2019.[72] This disease is complex, lethal, can survive in pork products, and has no known vaccine or cure. Should the virus come to the United States through illegal shipments of pork—such as the shipment intercepted at the Port of Newark in March 2019—stopping its spread may be extremely difficult.[73]

Experts are predicting that the number of pests and diseases such as these will only rise as the climate continues to change either as a direct result of shifted climatic conditions or more indirectly as the result of conflict that interfered with efforts to control the spread of the disease, as was the case with ASF.[74] Without concerted investment in prevention, mitigation, and solutions now, our farmers will be ill-equipped to battle these threats. The spread of a virus like ASF, diseases like wheat rust, or aggressive pests like locusts or the fall armyworm have, and could, cost national agricultural sectors billions in losses.[75]

Box 1

## Areas for further investment (with potential research questions)

### Emerging threats

How can we protect our food and agriculture systems from emerging threats that we can predict (such as African swine fever) and those we cannot foresee (such as COVID-19)?

### Biotechnology

How can various forms of biotechnology be used to feed a growing population sustainably? How can we better educate consumers to understand the science behind agricultural advances?

### Improving soil health

What data exist and how do we better capture information on a large scale on the health of our soils? How can carbon sequestration practices be scaled up so they are accessible to farmers?

### Drought- and flood-resistant crops

How can we build upon the current iteration of drought-resistant crops to become even more resilient while also being accessible to all farmers? How can we better model what crops will thrive in future uncertain conditions?

### The nexus with nutrition, health, and agriculture

How can we innovate to ensure proper nutrition for all with a growing population as the climate continues to change? How will a changing climate impact nutrient accessibility, availability, and health of the global population?

### Improving seasonal forecast mapping

How can we better predict weather to optimize production and make those data accessible to all, as extreme weather becomes increasingly common?

### Sustainable intensification

How can we intensify agricultural growth sustainably to meet the future demands of a growing population and a struggling planet?

### Animal, soil, and plant microbiomes

How might an increased understanding of microbiomes assist in meeting and overcoming challenges in agriculture?

### Transdisciplinary systems approaches

How can we better understand the interactions between agriculture and other sectors to holistically improve our food system?

### Cost/benefit analysis of climate adaptation for farmers

How should we continue to quantify and make accessible the full spectrum of benefits that accrue from farmers switching to climate resilient practices, such as prairie strips, cover crops, and low/no till practices? How can we quantify benefits to US farmers across the NOAA-recognized agricultural belts?[75] How can we use these understandings as a baseline when examining climate-resilient practices in low- and middle-income countries?

## The most vulnerable farmers

Smallholder farmers, disproportionately women and poor, are on the front lines of climate change issues around the world. Enabling smallholder farmers to respond more effectively to agricultural and other risks imposed by extreme weather will require the deployment of improved genetics and other technologies to produce food, improved agronomy and access to inputs including water, and enabling policies including safety nets. Faster replacement of climate-vulnerable crop varieties through engagement with local and regional seed companies will be essential to protect smallholder yields in Sub-Saharan Africa and Asia. Mechanisms to secure the survival and resilience of pastoralists and their livestock through droughts are also desperately needed. Securing the infrastructure required to get products to market is another urgent need.

In addition, a concerted effort must be made to ensure equal access to inputs, assets, and technical assistance for all smallholder farmers, especially those from historically marginalized groups. Globally, fewer than 15 percent of agricultural landholders are women. Land ownership often confers the right to manage and invest in land and affects access to credit. If women smallholders had the same access to land, inputs, and technical assistance as men, their yields are estimated to increase by 20 to 30 percent, with the potential to reduce the number of undernourished people in the world by 12 to 17 percent.[76]

Smallholder farmers across Sub-Saharan Africa and South Asia are already battling flooding, drought, and

locust swarms as well as the loss of market access due to national COVID-19 lockdowns. For farmers who lack the resources to plan more than one season ahead, climate disruptions in a post-COVID-19 world may prove too much from which to recover. Internal displacement and migration will put stress on national and international systems, increasing the potential for conflict and economic struggle. In conflict-stricken regions, loss of agricultural livelihoods may push male and female community members to join militant groups, further destabilizing regional economies.[77] Conflict and instability have ripple effects that can extend beyond borders and across oceans. As we are learning from recent disruptions to global supply chains, the fate of the most vulnerable farmers everywhere is intricately linked with US agricultural producers.

For farmers in these regions, climate change can be viewed as a major—if not *the* major—force for change in agriculture. It is imperative to innovate radically to increase adaptation to the changing climate. Sustainable intensification practices have the potential for relatively easy implementation with big impacts, but the future may lie in approaches to food generation that do not depend on soil. Access to knowledge, however, remains a problem in low-, middle-, *and* high-income countries due to steep learning curves. In addition, many techniques that enhance adaptation to today's climate have been pioneered by farmers, the majority of whom are women, not researchers. In the face of climate change it may be necessary to refocus user-driven, or applied, research more specifically on managing downside risk rather than focusing on yield potential as a proxy for system health and stability.

## How can public investment in agricultural research and development help solve these challenges?

In recent decades the United States has taken its agricultural ingenuity for granted. But this was not always so. US agriculture has been fueled since the late 19th century by publicly supported education and public support for scientific research aimed at improving every aspect of agricultural production, from goods, services, equipment, communication, statistics, and technology to the development of a vibrant agricultural and food economy.[78] Public support for agriculture was launched by President Lincoln as an essential strategy for building the economic, cultural, and intellectual capital necessary to recover from the Civil War and for ensuring the success of the American democratic experiment.

By the early 20th century, recognition that the strength of the US agricultural enterprise was a national strategic asset and essential for growth at home was baked into the US national identity. At the end of World War I, the United States found itself with grain surpluses that Herbert Hoover used to stave off widespread famine in Russia after the Bolshevik Revolution, a clear example of a response to a humanitarian imperative made possible by America's growing agricultural dominance.[79] Tragically, however, those surpluses, resulting in some cases from tearing up sod, caused the largest environmental catastrophe the United States has ever known. Those crop surpluses also led to chronically low farm prices in the 1920s, contributed to the Great Depression and the Dust Bowl, and set into motion the greatest internal migrations in US history, with rural Americans surging into northern cities and California.[80]

***Over the last 20 years, overall public funding of agricultural research and development at both state and federal institutions has declined in real terms.***

The first farm bill was passed at the height of the Great Depression in 1933 when the federal government stepped in to buy up American agricultural commodities at set prices that allowed farmers to stay on the land. The next 17 farm bills extended this handshake between the government, farmers, and poor Americans in need of food aid. However, this process has had its issues with unevenly distributing payouts across crops and to historically and presently marginalized farmers.[81] World War II stimulated an explosion of innovation focused on winning the war and ensuring the United States had the food needed to power to victory. America's agricultural abundance, stemming from a focused investment in agricultural research, was understood explicitly to be an enormous strategic asset. Innovations in chemistry, food processing and manufacturing, nutrition, crop protection, and uses of commodities were spurred by the needs of the warfighters.[82]

Over time, the primary focus of public funding for US agricultural research moved from widespread nutritional health and sufficiency for the largest number of

Americans to much narrower, commodity-by-commodity, state-by-state goals with complex and highly negotiated funding arrangements. The systems to distribute USDA funding are set according to formulas geared to state-level needs and priorities, including education, cooperative extension, and research, with each state's interests slightly different from the next. In all states support is coordinated in part through the state-supported land-grant universities. Over the last 20 years, overall public funding of agricultural research and development at both state and federal institutions has remained relatively flat, therefore declining in real terms.[83] Public funding provided through state support for agriculture rose until it peaked just after the time of the Great Recession and has been declining or flat since.[84]

Beginning in about 2000, private-sector funding in the United States for agricultural research began to skyrocket in some fields relative to public funding as a result of investments in genetic technologies and coordinated input packages such as chemicals, tailored seed, and "smart" implements.[85] By 2008 China surpassed total US public investment in agricultural research and development.[86] By 2015 six firms—"The Big Six," three of which were owned in Europe—dominated the world agricultural input and seed industry with a heavy influence in Congress on the research that should be prioritized.[87] In December 2015 an unprecedented number of consolidations within agribusiness began. While the mergers and acquisitions were scrutinized through existing mechanisms, concern remains about the extent to which reduced competition may lead to reduced investment in innovation and research. Furthermore, key private-sector companies essential to the US food system are now controlled by foreign interests.[88] Given that these companies collectively, along with the Chinese government, are now by far the largest investors in agricultural research globally, the potential impacts on US competitiveness, stability of US supply chains, and markets should be carefully evaluated.[89]

While the United States is still the most productive agricultural research system in the world, the future will likely look very different as private-sector funding is necessarily focused on shorter-term, less risky priorities that lead to proprietary innovations and advance a particular commercial interest. Public research, importantly, advances the interests of all stakeholders through its accessibility and can often be leveraged further by the private sector, multiplying original benefits through commercialization of technologies and products. Investing in public agricultural research also ensures that any innovations realized domestically can be applied globally through US agencies and programs.

## Who directs public agricultural research?

USDA, the federal department responsible for US agriculture and agricultural research, comprises 16 agencies, most of which are funded by mandatory titles in the US farm bill.[90] In the 2018 farm bill, which covers the five-year life of the bill from FY2019–23, the mandatory outlay for research is under 1 percent.[91] Agencies outside USDA that fund research related to agriculture, dietary health, and nutrition include the National Science Foundation (NSF), NASA Applied Sciences Program, the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), the National Institutes of Health (NIH), and the Departments of Energy and Interior, including the Bureau of Land Management and the US Geological Survey.

US government investments made to protect the domestic food system are generally administered by the Department of Homeland Security (DHS) and the Department of Defense (DOD). US government investment in international agricultural research typically involves the Department of State and the US Agency for International Development (USAID), which often work closely with USDA.

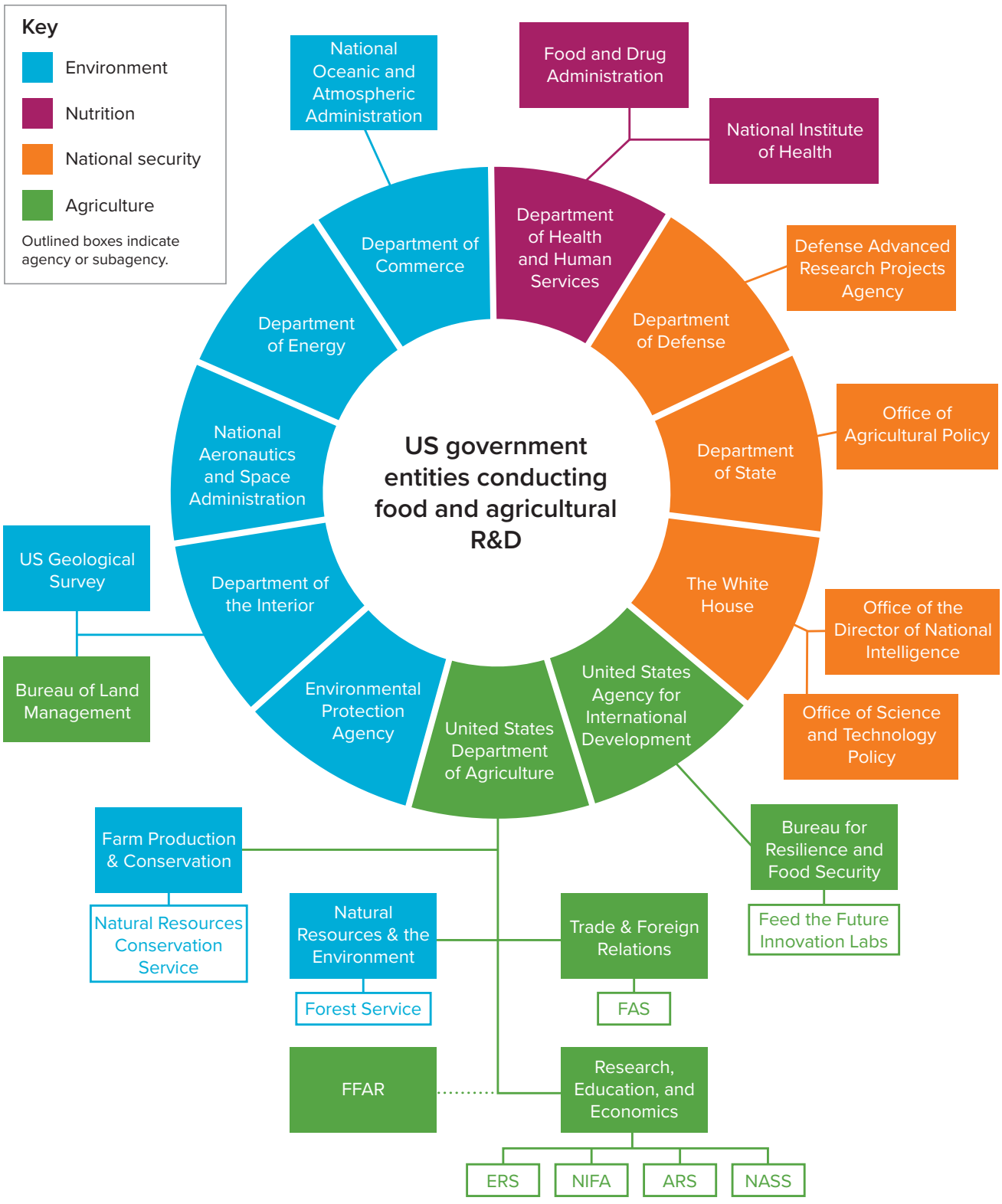
***In the 2018 farm bill, covering FY2019–23, the mandatory outlay for research is under 1 percent.***

### United States Department of Agriculture

The largest USDA agencies charged with conducting publicly funded agricultural research—with the exception of the US Forest Service (USFS)—fall into a mission area at USDA led by a deputy undersecretary for research, education, and economics (REE). The REE mission area includes four agencies that support public agricultural research and statistics: the National Institutes for Food and Agriculture (NIFA), the Agricultural Research Service (ARS), the Economic Research Service (ERS), and the National Agricultural Statistics Service. While these agencies intersect with the work of other agencies at

Figure 2

## US federal research and development




Source: CCGA

USDA, notably the USFS and the Natural Resource Conservation Service (NRCS), it was only in 2010 that they were instructed to exchange priorities and work together.[92] Other agencies at USDA that engage with research and research products include the Foreign Agricultural Service (FAS), the Food Safety and Inspection Service, the Agricultural Marketing Service, and the Agricultural Plant Health Inspection Service.

Overall, funding for agricultural research within USDA agencies has been declining in relative and real terms since approximately 2000. At one time, US public agricultural research was the largest research enterprise in the world. More recently, funding levels have fallen, in some instances precipitously. Notably, in 1980 US public investments in biomedical and agricultural research were comparable.[93] However, since the creation of NIH, which is funded at approximately US$40 billion annually, agricultural research represents only a fraction of a percent of overall spending.[94]

*At one time, US public agricultural research was the largest research enterprise in the world.*

This downward shift is a result of decreased levels of public spending and explosive growth in industry funding and government spending in other countries, notably China and India. In addition, USDA grants are still limited by statute to cover no more than 30 percent of a project's indirect costs such as salary, rent, and other routine costs of performing advanced research.[95] The standard negotiated indirect cost recovery rate between the US government and universities in other areas—such as NSF grants—is usually much higher, at or over 50 percent depending on negotiations between the grantor and grantee. This means that every time a university receives a USDA research grant capped at the 30 percent indirect cost recovery rate, the university must pay for expenses that under other grants would normally be covered. The history of formula funding and captive research funds, while providing steady, reliable funding to land-grant universities, has also resulted in universities performing agricultural scientific research at a loss compared to other types of research.

There have been some positive developments over the last decade, although with varying levels of funding and support. The 2008 farm bill created the office of the chief scientist to provide department-wide coordination and leadership on integrating science into USDA's operational missions. This continues to be an important, if under-recognized post, responsible for organizing and coordinating research and innovation across the department. The recent appointment of a USDA chief data officer as a result of a new requirement that all federal departments have such a position further opens up the opportunities for research to be done on USDA operational data.

In 2018 a new farm bill went into effect with some sweeping changes intended to boost the profile and impact of the USDA scientific enterprise. Research Title VII in the Agriculture Improvement Act (1) authorized the Agriculture Advanced Research and Development Authority (AGARDA), a new program focused on basic and long-term research; (2) increased the cap on indirect costs (overhead) for certain agricultural research grants to 30 percent, still significantly lower than other major research agencies allow; (3) mandated research on urban, indoor, and emerging forms of agricultural production; (4) authorized international capacity-building grants through partnerships with low- and middle-income countries; (5) provided some additional funding to minority-serving land-grant institutions; and (6) reauthorized the Foundation for Food and Agriculture.[96]

Further, the statute called for a plan for strategic germplasm and cultivar collection assessment and use. It also called for recommendations on public cultivar development, research gaps, and commercialization of federally developed cultivars for a diverse range of crops. The statute noted the need to make regionally adapted cultivars available to the public to improve farm productivity, crop marketability, and efficient nutrient use.

Additionally, prior to the 2018 farm bill USDA was required to demonstrate a domestic benefit to the research it conducted. The 2018 farm bill amended this requirement to allow for research with a global focus that may not have short-term, obvious gains for US farmers but will ultimately advance global food systems. Finally, the 2018 farm bill authorized two new initiatives: (1) the Next Generation Agricultural Technology Challenge, a competition to develop mobile technologies for beginning farmers and ranchers, and (2) competitive grants for the design of adaptive prototype systems for extension and education.

Although the 2018 farm bill introduced major changes, funding has not followed suit. AGARDA

remains unfunded. Nevertheless, recent developments indicate a renewed commitment to agriculture science innovation at USDA.

The USDA Agricultural Innovation Agenda (AIA) was released in February 2020. The AIA's first commitment is to develop a strategy to align public and private research efforts in the United States to achieve USDA's ambitious goal to increase agricultural production by 40 percent while cutting the environmental footprint of agriculture by half.[97] While this goal is lofty, it is unclear if such a narrow focus on increasing production of the same set of crops is the right path forward to address the true hunger and nutrition needs of the global population and ensure the future viability of farmers. Additionally, a narrow focus on emissions ignores other environmental and climate-related impacts from agriculture. The AIA highlights the importance of conservation and commits to investing in integrating technology to achieve the overall productivity and efficiency goals. Furthermore, the agenda includes improving USDA data collection to bring USDA into compliance with current Office of Management and Budget requirements and collecting data necessary to track progress on key aspects of agricultural performance. The AIA also draws heavily from the 2019 National Academies report *Science Breakthroughs to Advance Food and Agricultural Research*.[98]

***Although the 2018 farm bill introduced major changes, funding has not followed suit.***

## National Institute of Food and Agriculture

USDA's NIFA—along with ARS—remains at the heart of traditional public funding for agricultural research. NIFA was created in 2009 by the 2008 farm bill, the successor agency to USDA's main external granting agency awarding competitive scientific research grants in agriculture and food-related sciences.[99] Since its inception, NIFA has also served as the main convener across the US science enterprise on the topics of food systems, agriculture, and land-based strategies to adapt to and mitigate the impacts of climate change.

NIFA distributes many different funding streams, generally tightly prescribed by Congress, primarily through public state universities with agricultural colleges. It provides competitive research funding through the Agriculture and Food Research Initiative (AFRI) and manages the formula funding for state priorities.[100] NIFA also oversees grants from the Small Business Innovation Research (SBIR) program related to agriculture. The SBIR is a competitive funding opportunity for US-based small business to engage in federal research and development that also incentivizes small businesses with the potential of commercialization.[101] This initiative involves the private sector in the public US agricultural research and development agenda, stimulating new opportunities for innovation and commercialization.

In 2018 NIFA and ERS were reorganized and relocated to Kansas City, Missouri, resulting in temporary reductions in staff and output across all the agencies doing public research in agriculture, food, nutrition, conservation, and forestry. As a result of reorganization, relocation, and marked loss of long-term staff, particularly within NIFA, there is a major opportunity to build a new organization to address US agricultural research for the future. Despite the dramatic loss of long-term staff familiar with institutional practices and history, the present situation may represent a once-in-a-century opportunity to reorient, re-staff, and rebuild the flagship funding agency for research, education, outreach, and applications in agriculture and food systems.

As NIFA recovers, it remains in an excellent position to continue its historical role as the convener of other research sponsors across government, public/private partnerships, and industrial partners focused on the US agricultural enterprise. The National Academies of Science report as well as other parts of the US government, notably the DOD and the intelligence community, recognize the need for NIFA to invest in research on local, regional, national, and global food *systems*. Systems science has been pioneered in a number of other fields, from engineering, physics, and mathematics to planning and architecture to social sciences. However, it has not been the dominant paradigm for agricultural research, which is typically focused on maximizing local, short-term productivity at the expense of other considerations.

The importance of this transition from short-term, granular thinking about agriculture to a more holistic understanding of the role of innovation in driving US food systems to their desired states cannot be overstated.

## Agricultural Research Service

In contrast to NIFA, which funds externally, ARS is the US government's in-house agricultural research agency. ARS conducts a wide range of research activities managed in a highly decentralized system, with federal scientists and their staff often colocated with state land-grant universities. Funding for this agency has remained flat or declined in both real and relative terms. It now stands at approximately US$1.2 billion, a decline in real dollars of nearly 30 percent since 2000.[102] This budget covers work at more than 90 locations in the United States and at several overseas facilities. A number of global best-in-class laboratories operate within this system, including four leading institutes working on human nutrition; international biological control laboratories operated with USAID in partnership with their host countries (Argentina, Australia, China, and France); and two laboratories administered jointly with DHS, including the National Bio and Agro-Defense Facility, a new US$1.25 billion laboratory that will replace the Plum Island Animal Disease Center in 2022–23.[103]

*Funding for the Agricultural Research Service is now approximately US$1.2 billion, a decline in real dollars of nearly 30 percent since 2000.*

ARS operates a number of other stand-alone laboratories with specializations as diverse as American agriculture itself. ARS also collaborates with other agencies to advance a shared research agenda. Through a Participating Agency Service Agreement (PASA) with USAID, ARS uses scientific experts to engage with issues in low- and middle-income countries such as fall armyworm and desert locusts to benefit both US development assistance and US agricultural innovation.

Six years ago, ARS and US Forest Service teamed up with universities around the country to establish 10 regional hubs to study climate change and support local and regional efforts to adapt to its impacts.[104] With a budget of approximately US$10 million nationally, the roles of these hubs must necessarily be limited to catalytic convening and coordination across USDA, including with NRCS and other federal agencies with major relevant responsibilities such as the US Geological Survey and the Bureau of Land Management in the Department of the Interior, NOAA in Department of Commerce, and EPA. These hubs rely on interagency agreements and partnerships to gather data such as phenology and serve as regional resources for building resilience into local and regional agrifood systems. These hubs have international counterparts in Canada, Mexico, and Tanzania, among others, although USAID funding has not yet been leveraged to support these collaborative interactions.

## Economic Research Service

USDA's ERS is a federal statistical and research agency involved in a wide range of activities related to US agriculture and food systems. ERS tracks spending and evaluates the impact of agricultural research in the United States. ERS also works to prepare US agriculture for a changing climate through studies on the current and expected impacts of climate change. It looks at the impact on crop and livestock production, current and future agricultural markets and consumers, the cost of government agriculture and food systems policies and programs, US bioenergy and food production policies internationally, the potential and costs for US agriculture to adapt to changing climate and extreme weather, the potential to mitigate greenhouse gas emissions in agriculture, drought resilience, and risk management. Major recent works focus on both adaptation to climate change, measurements of greenhouse gas emissions from agriculture and the potential to reduce or sequester carbon in agriculture.

## The Foundation for Food and Agricultural Research

The 2014 and 2018 farm bills established and reinvested in a hybrid public-private foundation, the Foundation for Food and Agricultural Research (FFAR). The 2014 farm bill provided an initial US$200 million to invest in agricultural research with the requirement that these funds be matched with an equal or greater amount of nonfederal funds. The executive director was recruited from the NIH, and the board comprises the secretary and undersecretary of agriculture, along with the administrators of both NIFA and ARS. Six areas of focus have been established through consultations and partnerships that focus on soil health, sustainable water management, next generation crops, advanced animal systems, urban food systems, and the health-agriculture nexus. Several consortia are focused on topics such as stewardship of antimicrobial compounds, precision indoor plant production systems, and other topics where public and

private resources can be profitably merged. FFAR is a compelling example of how private-sector funding can be leveraged toward public-sector goals that benefit the food system over the long term.

For example, FFAR has initiated an Agriculture Climate Partnership with the US Farmers & Ranchers Alliance (USFRA) and the World Farmers' Organisation (WFO) that seeks to mobilize agriculture stakeholders to develop and implement climate-smart solutions for agriculture.[105] The partnership ultimately intends to spread the model globally and hopes to get the United States to reach net negative greenhouse gas emissions by 2030. FFAR and USFRA will match funds received for the partnership up to US$100 million and is already funding over US$50 million in climate-smart research.[106] As FFAR progresses, it also continues to partner with other US agencies, including USAID and NSF to amplify the US government's overall agricultural research agenda.

*FFAR is a compelling example of how private-sector funding can be leveraged toward public-sector goals that benefit the food system over the long term.*

## The Department of State and the United States Agency for International Development

USAID and the US Department of State (DOS) have supported global agricultural research and development since the 1960s, beginning with the African Graduate Fellowship Program (AFGRAD) and its successor, the Advanced Training for Leadership and Skills program (ATLAS). Together, these programs educated over 3,200 professionals at US universities, received nearly half a billion dollars in today's US dollars over 40 years, and provided mutually beneficial opportunities for US host universities and African development partners.[107] In concurrence with the AFGRAD program, USAID created the Collaborative Research Support Programs (CRSPs) in 1977, which ultimately became today's Feed the Future Innovation Labs.

At present, 20 Feed the Future Innovation Labs at 14 US universities serve as hubs for this investment to draw cutting-edge science and engineering and young talent to challenges in low- and middle-income countries. Some topics pursued by labs such as the Innovation Lab for Markets, Risk, and Resilience could also be useful for the United States. Feed the Future Innovation Labs generally collaborate with universities and research organizations located in priority countries, CGIAR centers, other US universities, and local nonprofits in focus regions to create sustainable solutions to agricultural development challenges. For example, CORAF, the West African association of national agricultural research systems, works with Feed the Future Innovation Labs and USDA to direct international research and development efforts to benefit local producers with emphasis on marginalized individuals, especially women, farm-based households, and communities. These collaborations often engage local youth and foster nascent markets that may become US trading partners. Additionally, developments from Feed the Future Innovation Labs can have immediate benefits for US producers—a new variety of black bean has already saved Michigan farmers millions.[108]

Feed the Future has made commendable efforts to integrate the concerns of women farmers into research and development. In collaboration with IFPRI and the Oxford Poverty and Human Development Initiative, USAID has developed a Women's Empowerment in Agriculture Index (WEAI) to measure women's empowerment and inclusion in agriculture. Feed the Future uses the WEAI to evaluate their programs, which helps ensure that benefits from Feed the Future extend to both men and women smallholder farmers.[109] These kinds of provisions are crucial to support all farmers around the world, reduce hunger, and improve nutrition.

Beyond Feed the Future, USAID has invested in research that could have large global implications. In 2017 a group of international development funding agencies, including USAID, launched the Crops to End Hunger initiative with the aim of modernizing public plant breeding in lower-income countries. As part of that effort, USAID partnered with ERS and IFPRI to model faster productivity growth for 20 food crops and the resulting changes in countrywide income and hunger levels. While it is understood that increases in agricultural production do not automatically lead to reduction in malnutrition or undernutrition, securing productive agricultural systems in the face of climate change can improve crop viability with the potential to increase global food security as long as market prices remain high enough to support livelihoods.

In addition to USAID, DOS engages in international food security through its Agricultural Policy office in the Bureau of Economic and Business Affairs and the Global Food Security office. DOS works with USAID, USDA, and implementing nongovernmental organizations to ensure

continued trade flows and access to food internationally. They are also a nexus for helping to disseminate new technologies and knowledge invented in the United States that could be beneficial to our allies abroad.

Overall, America's commitment to foreign agricultural aid is rooted in the dual benefits it creates for low- and middle-income countries and for Americans and the US economy. The investments improve quality of life, education, and health for recipients, especially the world's rural poor dependent on agriculture for their livelihoods, while creating new markets for US goods. Over the past 20 years, US agricultural exports have grown by 63 percent in real terms, with most growth in bulk commodities and high-value products in demand in low- and middle-income countries. It is estimated that in 2018 more than 1.2 million US jobs were supported by US agricultural exports.[110] Investment in international agricultural development carries additional benefits in technology spillover, bringing new goods into US markets, improved global public health and nutrition, improved global and national security, and reduced global poverty.

*Investments in foreign agricultural aid improve quality of life, education, and health for recipients while creating new markets for US goods.*

## Other US agencies that support agricultural research and development

In addition to the major US agencies funding agricultural research and development, several other agencies have specific programs that contribute to the whole-of-government research agenda for agriculture. For instance, NSF engages in environmental and sustainability engineering research, especially nanotechnology, that can benefit both domestic and global agricultural practices. NSF also participates with USDA and the Department of Energy (DOE) on plant biology and genome research through their National Plant Genome Initiative. In 2018 it released a five-year strategic plan with 22 other federal agencies to support research on the microbiome.[111] Although NSF-funded research is not constrained by short-term obligations, some NSF research culminates in innovative tools for agriculture such as self-calibrating, low-maintenance soil sensors that could benefit smallholder farmers worldwide.

Other agencies, including NASA, NIH, FDA, and even the Central Intelligence Agency (CIA) fund research on topics that often intersect and support agricultural research and development. These topics include climate, weather events, nutrition, food safety, pests and disease, and the nexus between global food security and US national security. Given the variety of agencies involved in these areas, investments in US public agricultural research and development should include all stakeholders approaching this research from various angles. The organizational chart in figure 2 examines the full range of actors involved.

## US investment in CGIAR

In addition to funding educational programs for international food security and agricultural development, the United States provides support to international research institutions. CGIAR, formerly known as the Consultative Group on International Agricultural Research, remains a network of research hubs and partnerships of immense potential for research innovation on local, regional, and global food security.[112] What began with the founding of the International Maize and Wheat Improvement Center (CIMMYT) in Mexico, the brainchild of H. A. Wallace, Franklin Delano Roosevelt's Secretary of Agriculture, to bring science-driven improvements to Latin American agriculture, has grown into a network of 15 international research and extension institutions located around the world. The US government as well as the Ford and Rockefeller foundations were pivotal in starting what is now a member-funded system supported by a combination of governments and foundations.[113] The United States, via USAID, has historically been the largest single contributor, providing over US$1 billion in support—23 percent of total funds received—since 2011.[114]

This investment in the CGIAR system has generated numerous mutually beneficial advances in agriculture. Research conducted throughout the CGIAR system has traditionally focused on increasing yields of key cereal crops such as wheat, rice, and maize. This launched the Green Revolution in low- and middle-income countries in the 1960s and 1970s. A range of additional crops, livestock, and aquaculture now also have dedicated centers. These advances also had profound benefits for the United States. An estimated 60 percent of the wheat area in the United States is currently planted with varieties that trace some ancestry to CGIAR breeding programs.[115]

As the world reaches the limits of production-driven advances in today's agricultural paradigms, CGIAR has

announced the ONE CGIAR initiative, primarily supported by USAID, the Bill and Melinda Gates Foundation, the World Bank, the UK Department for International Development (DFID), and the Netherlands. The initiative builds off CGIAR's multicenter, multipartner research programs with the goal of aligning institutional missions, unifying governance, and further integrating research on agricultural livelihoods in low- and middle-income countries and human well-being across centers.

CGIAR remains one of the greatest repositories of agricultural scientific knowledge and experience in the world and maintains invaluable genetic resources. CGIAR centers' long-standing and deep relationships with host countries and local and regional universities ensure localized understanding of the challenges facing farmers, their families, and their communities. With a historically proven record of sustained and important contributions, CGIAR has the potential to drive innovative, climate-smart solutions for agricultural producers in the United States and abroad. In 2019 alone more than 85,000 metric tons of CGIAR-derived, drought-tolerant maize seed was commercialized by small- and medium-enterprise seed companies in 13 countries across Sub-Saharan Africa, covering approximately 3.5 million hectares and benefiting over 60 million people.[116] This is only possible, however, with sustained US support.

## Conclusion

The last century of public investment in agricultural research has supported continuous agricultural advancement, driven groundbreaking innovations, and made huge strides toward a hunger-free world. However, the areas of investment that were critical to agricultural dominance 100 years ago will not provide another century of advances. In the face of climate challenges like droughts, temperature shifts, flooding, extreme weather, and new and expanding pests and diseases, we must forge a new path. The COVID-19 pandemic serves as a wake-up call for all Americans to understand that US food systems can fail and potentially fail big. Investing as we have for many years in maximizing short-term local yields, protecting major crops yields, and using resources efficiently has inadvertently driven massive consolidation in the private sector and therefore brittleness in the food system. As we are seeing now, this system can break down in times of stress, with potentially dramatic consequences for the everyday lives of consumers and farmers. The success of our most vulnerable populations—including smallholders and other historically and presently marginalized farmers—has a bearing on the future of global prosperity. To be considered sustainable, our food systems will need to supply sufficient nutritious food to all, on a consistent basis, while enriching natural resources and contributing to climate change solutions.

Publicly funded agricultural research and development has a singular and meaningful role to play in defining our future. A bold new research agenda is key to identifying vital areas of investment for the safety of the US food supply and for the betterment of agricultural producers worldwide. Public-sector investment has built the foundation for past progress, and that remains true as we look forward to meeting the demands of the next generation. Understanding how the current agricultural research system works—with its narrowed focus on specific crop advances and short-term, quantitative goals—is the first step toward recognizing what must change for American and international farmers to remain profitable and for global citizens to remain well nourished, food secure, and healthy. We need systemic change that cannot rely solely on USDA. An evolving understanding of the role and scope of global food systems has catalyzed new champions to step forward and ask for change. Coalescing around a whole-of-government approach that pools resources and draws strength from all corners of the US government is the only way that our farmers, ranchers, producers, and growers can maintain a bright future and continue innovating to confront global climate challenges.

*Coalescing around a whole-of-government approach that pools resources and draws strength from all corners of the US government is the only way that our farmers can maintain a bright future.*

The COVID-19 crisis has laid bare vulnerabilities in the US food supply, which has developed into a highly complex and, unfortunately, vulnerable system. Many experts predict that the dislocations in US food supply chains will permanently reshape the US food system. Consequently, now is the time to enact change. This moment presents a rare opportunity to reinvest in federal agricultural research and development to support a bold agenda for US agriculture that will transform a brittle system into a resilient one, while supporting thriving and healthy rural communities at home and abroad.

## US policy recommendations to improve stability, reliability, and resilience of the global food system by strengthening and reinvigorating agricultural research agencies

Overall US public funding for domestic and international agricultural research is at less than 1 percent.[117] Compared to our direct agricultural competitors like China and Brazil, this falls drastically short.[118] Agencies across the government, from USDA to DHS, need more resources to address the current threats and security challenges posed by climate change and pests. This would not even begin to address anticipated and emerging threats like natural resource scarcity and unpredictability or existential threats to the US food supply. History has taught us that where there are food shortages at any sustained level, there is unrest and political instability. Investment in agricultural research designed to ensure a steady, sufficient flow of foodstuffs to all people every day will be key to building a stable and resilient food supply for both US and international consumers.

### Overarching recommendations

#### Recommendation 1

Public agricultural research has been consistently underfunded for several decades to the detriment of US agricultural producers and consumers around the world. In order to assess how large the gap is, **Congress should request an assessment from the Government Accountability Office to determine the true whole-of-government spending on agricultural research and development across all US agencies**. This will ascertain how much the United States currently invests and how much more it needs to invest to address the known and unknown challenges of the future.

1a. In accordance with projected goals in USDA's Agriculture Innovation Agenda, USAID's Global Food Security Strategy, DOS' Global Water Strategy, and the US National Security Strategy, **Congress should properly fund USDA and others that focus on agricultural research, increasing total spending by at least 50 percent by 2050**. Specifically, Congress should fully fund authorized crucial research programs created in the 2018 farm bill such as AGARDA. Additional programs such as the Sustainable Agriculture Research and Education program (SARE) should include carve-outs that support research conducted at historically Black colleges and universities (HBCUs) and at the 1994 land-grant universities with the specific intent to support research and outreach that benefits minority communities.

1b. Where possible, **funding for research toward USDA's stated goals in the AIA should be matched by other agencies like NSF, DOE, and/or NASA to enhance collaboration across the government and increase the total funding to achieve longevity** of the initiative for the benefit of all Americans. This process could be modeled after the highly successful National Plant Genome Initiative, which ran for over 10 years and included joint funding from USDA, DOE, NIH, USAID, and NASA.

1c. In addition, **Congress should appropriate a special fund, assigned to the DOD's director of the Defense Advanced Research Projects Agency (DARPA), for a major agriculture technology innovation initiative to address potential strategic vulnerabilities in US and global food systems** to better advance the United States' foreign policy goals. Where possible, cofunding with NIFA or NASA should be considered to recruit a wide range of universities to engage in interagency initiatives.

#### Recommendation 2

The bipartisan America Grows Act of 2019 prioritizes funding for an expanded and sustained national investment in agriculture research. The bipartisan Climate Solutions Act was introduced in 2020 and provides technical assistance to reorient US agricultural producers to meet impending climate challenges while remaining profitable. **Congress should continue to lead legislatively and commit to a long-term authorization of climate-smart assistance through research and extension efforts to protect our food supply and support global food security goals.**

#### Recommendation 3

The Global Food Security Act will be up for reauthorization in 2023. **Congress should consider providing guidance on prioritization and increased investment in agricultural research related to climate challenges** that focus on youth and gender empowerment, global food security, and nutrition efforts.

### Recommendation 4

In coordination with the Office of Management and Budget, the National Security Council, **the Office of Science and Technology Policy, DHS, and USDA should conduct regular assessments on the state of the US food system**. These assessments should focus on identifying critical needs and/or weaknesses stemming from rising climate and logistical challenges and acute threats such as shocks, pests, or disruptions in the supply chain. The White House's Office of Science and Technology Policy should advise the president on potential threats and prioritize research funding to address these challenges.

### Recommendation 5

**The National Security Council, DHS, and the intelligence community should recognize in all policies and interagency initiatives and processes that US agricultural and forestry assets are strategic resources** essential for the economic and geopolitical goals of the United States and its allies.

### Recommendation 6

As Congress and the administration look toward revitalizing US public agricultural research and development, they must consider the critical role nutrition plays at the intersection of agriculture and climate change. **Public agriculture research must look at nutrition and diet as a critical component of agriculture and the US food system.** Research should consider investigating changing micronutrient content of crops and shifting food accessibility and supply of fruit and vegetables as well as livestock and animals.

## US Department of Agriculture

### Recommendation 1

As part of the USDA AIA, **the department should direct the Economic Research Service to assess the impacts of AIA goals on agricultural futures** to test whether the current areas of emphasis truly meet the needs of American consumers and support the stated sustainable development goals for the global food system. Congress should ensure that it exercises oversight to monitor and advise USDA as it implements stakeholder feedback for the AIA.

### Recommendation 2

**USDA should continue to commit to mandated standards for the archiving and curation of federally funded research data and mobilize its operational data for research**, funded by new initiatives for this purpose at NIFA, NSF, and DOD. The USDA chief data officer should be fully supported to ensure the integrity, availability of appropriate standards, stewardship, interoperability, curation, and full transparency of agricultural research and USDA operational data. If any public funding is involved in a study, resulting data should be made public according to current standards required by the granting agencies and curated long term.

**Congress should request a report from USDA that builds on the 2018 DHS study on cyber vulnerabilities in agriculture and examine the data being collected from smart devices on farm implements.** This study should provide guidelines for the protection of data obtained through the use of all publicly funded agriculture technology developed by the US government. In addition, these guidelines could be seen as best practices for agriculture technology developed globally in service of smallholder farmers.

### Recommendation 3

**USDA should ensure clear and regular communication with the Department of State's Agricultural Policy (AGP) office** regarding agricultural innovations that could benefit lower- and middle-income countries. Streamlined communication will ensure that AGP can focus on using these innovations to enable trade environments and build capacity in prioritized countries.

## National Institute of Food and Agriculture and Economic Research Service

### Recommendation 1

**Congress and the Agricultural Committees should grant USDA's NIFA and ERS direct hiring authority** to quickly staff up their offices after the location shift.

1a. In addition, **Congress should adjust NIFA's allowable overhead rate to match NSF**. This would better match industry standards for the cost of doing research and would allow all colleges and universities to compete for USDA research grants.

### Recommendation 2

As a part of NIFA's reorganization and revitalization in Kansas City, **increase funding for extension officers to better collect data on sustainability crops practices already implemented on farms across America**. Use of techniques like low till or no till and allowing fields to fall

fallow are already employed by many. However, data is scarce. In order to best assess climate research in the future, more data is needed on current practices.

2a. In addition to regular assessments by extension officers, the **National Agricultural Statistics Service (NASS) should include this information in their agricultural census taken every five years**. As with all census data, this information should be made publicly available and accessible.

### Recommendation 3

**Congress should mandate greater coordination between USDA and FFAR** by easing the barriers for funding to flow between USDA agencies (ARS, NIFA, ERS, and FAS) and FFAR. This will allow better coordination and collaboration with US agribusiness and could create more nimble responses to urgent issues.

### Recommendation 4

**The department should assign ERS and ARS Climate Hubs as keepers of compulsory "stress tests" to be applied to the US food system in studies conducted jointly by these agencies.** This would ensure agility and assessments of implemented policies to help maintain essential agricultural capacities in the short, medium, and long term. These comprehensive studies, similar to the Climate Assessment Reports, should be conducted on a regular basis—at least once every three years.

## The Foundation for Food and Agricultural Research

### Recommendation 1

FFAR is ideally positioned to work directly with commodity and trade associations due to its successful interface with the private sector. **FFAR should be directed to support commodity-focused science, engineering, economics research, and extension with matching funds required from commodity trade associations and stakeholder groups.** FFAR should conduct outreach to check-off organizations and other commodity groups to invite matching research funding that would allow these groups to leverage public funds to do vastly more cutting-edge, user-inspired research in agriculture and forestry.

### Recommendation 2

**Congress should increase funding to FFAR** to better leverage the vast investments in agricultural research and development made by agribusiness.

## USAID

### Recommendation 1

**Congress should fund and USAID should create an early pests and disease warning system that tracks the spread of the most devastating pests and diseases globally.** This could function alongside the incredibly successful and effective FEWSNET. USAID should create a set of indicators that would identify an imminent threat to the US food supply and be able to direct research funding toward mitigation and prevention.

### Recommendation 2

**Congress should mandate better coordination between USAID's Feed the Future Innovation Labs and ARS Climate Hubs.** Specifically, ARS Climate Hub directors and Feed the Future Innovation Labs directors should be required to meet and share research at least once a year. The NRCS and USFS offices with relevant activities should also be included.

### Recommendation 3

As part of the new nexus created at USAID to address emerging threats, **the agency should ensure whole-of-government coordination on research topics**.

## CGIAR

### Recommendation 1

**The United States should continue to fund the CGIAR system at current levels.** Congress should create a provision for this funding that requires a recurring evaluation every five years of the return on investment to US tax payers, including spillovers and add-on benefits from activities like impacts on global food insecurity.

### Recommendation 2

In support of the ONE CGIAR reorganization, **Congress should require a designated CGIAR week**, modelled after USAID's Feed the Future week. This week would allow CGIAR researchers to showcase their work for US audiences. There should be an emphasis on collaboration with US researchers, which will facilitate sharing of discoveries and innovation.

### Recommendation 3

**NIFA should create a category of competitive grants allocated for collaborative projects between CGIAR researchers and US universities.**

## About the author

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