BENEFITS OF INCREASED U.S. PUBLIC INVESTMENT IN AGRICULTURAL RESEARCH

About the Authors

The authors of this report are all part of the IHS Markit Agribusiness Consulting Group. The authors are entirely responsible for the content of this report but they would like to thank Tom P. Scott and others from IHS Markit, Dr. Stephanie Mercier and David Hong from the Farm Journal Foundation and Dr. John Newton from the American Farm Bureau Federation® for their insightful comments on earlier drafts of this report.

This report was commissioned by Farm Journal Foundation and the American Farm Bureau Federation®.

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FOREWORD

The success of U.S. agriculture is due in large part to strong public and private investment in food and agricultural research made throughout the 20th century. Because of this investment, the U.S. farmer is among the most efficient and productive in the world and the U.S. is the global leader in helping to meet the world's demand for food.

Although U.S. private agricultural research and development (R&D) funding appears to be increasing, U.S. public funding is stagnating. While private funding for agricultural research is beneficial, profit is the primary motive for that effort. Public agricultural research funding, on the other hand, focuses on the public interest and in that sense speaks most directly to the competitive position of the U.S. farmer.

In broad terms, without increased U.S. public sector investment in agricultural research funding into the next several decades, there are likely to be significant implications in key areas important to U.S. farmers and ranchers:

- Producers may not get as timely access to new technology needed to combat the emergence of crop and animal pests and diseases. They will also need more help addressing the adverse impacts of climate change such as the increased frequency of drought and heavy precipitation events. As a result, they will suffer from loss of productivity and face increased costs of production without increased investment in research.
- The ongoing COVID-19 global pandemic has exposed challenges and/or rigidities in the U.S. and global food systems, and more research is needed to identify and remedy the specific problems that have been uncovered.
- The U.S. agricultural sector risks falling behind other major agricultural countries such as China, India, and Brazil, who are investing more robustly in public sector agricultural research funding. Under such circumstances, the U.S. might begin to lose its competitive advantage.

This report focuses on some of the areas which additional public research funding will be needed to meet the future challenges including crop breeding; crop protection; global climate change; animal health; threat of foreign animal diseases; and pandemics. There are many other challenges that will also be a concern, but the purpose of this report is to highlight why public research is needed in those areas.

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SUMMARY

This paper examines the challenges facing production agriculture and the need to increase public spending on agricultural research. Public sector investments are needed:

- to complement private sector investment;
- in areas which the payoff from research investment is too uncertain or too far in the future to attract private investment;
- for research on minor crops that do not offer a large enough potential market to attract private investment and important areas of research for which no market exists;
- for potential partnerships with the private sector to harness specialized research capacity to address high-priority issues; and
- to help to meet broader social, environmental, health, and sustainability goals that benefit both society at large and farmers.

EXAMINING THE NEED FOR PUBLIC RESEARCH FUNDING IN SIX AREAS:

Increased productivity is needed to meet growing food demand. Expanding crop area is not the solution because the farm sector continues to lose land to a higher economic value land use. Crop breeding is needed to achieve higher production levels, but that takes increased research funding because it takes years to bring a new seed variety to the market. New seed varieties can be designed to respond to climate change, improve nutrition, and increase yields. The public and private sectors will need to work together to improve crop yields.

Improved crop protection against diseases and pests has been a major contributing factor to steady growth in agricultural productivity in the U.S. and globally since the development of fungicides and synthetic insecticides. But the battle against crop diseases and pests is continually evolving as diseases and pests develop resistance to established crop protection practices, and new diseases and pests emerge to pose new threats to crop production.

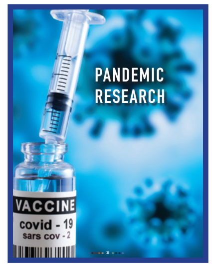
The public sector has long played an important role in crop protection, as it often funds most of the basic research that underlies new agricultural technology. With the commercial viability of new technology often uncertain, publicly funded research and development can be vital to initiating work that can be commercialized by the private sector and become available to producers.

Animal health is vital to the safety of the U.S. and world meat supply. The production of healthy livestock helps to ensure a safe food supply and keep consumer prices stable. With the projected increase in animal protein demand and per capita consumption over the next several decades, the production and productivity of animal agriculture becomes vital and this can only be achieved when the animals are healthy and disease resistant. Research is needed to meet the economic and human health risks associated with livestock.

Animal disease and foodborne illness threats emphasize the need for the U.S. and the world to be prepared for diseases that are rare, exist in other countries or have not yet been identified. Outbreaks of FMD, PEDv, and ASF have had significant impacts on livestock industries. The continuing threat of Foreign Animal Diseases (FADs) and their impact on U.S. food security and the economy emphasize the importance and need for public research funding in order to develop vaccines and treatments to improve public welfare.

Climate change presents challenges to agriculture at the global, regional and local level. Projected increases in temperatures, changes in precipitation patterns, changes in extreme weather events, and reductions in water availability will all likely result in reduced agricultural productivity. Public, and science-based research is vital to help farmers adapt to climate change.

The U.S. agriculture and food sectors in 2019 accounted for approximately 21.5 million full- and part-time jobs — 13% of total U.S. employment.



External shocks such as pandemics (COVID-19) create disruptions to agriculture production due to reduced availability of labor and other inputs, and reductions in output prices resulting from decreases in demand for commodities in certain market segments. From a private sector standpoint, researching pandemic issues that have very low probabilities of occurrence and/or have impacts or benefits that are outside a company's ability to capture return on their specific research investment are given low priority for funding. These issues are almost by definition best suited for being addressed by public sector research spending.

There are many other challenges that are also a concern, but the purpose of this report is to highlight why public research is needed in these six areas.

This paper concludes that over the next several decades, there will be an increasing need to improve yields and production efficiency to feed a growing global population without causing irreparable damage to the environment. Climate change, pandemics, animal diseases, and crop pests and crop diseases all pose potential threats to the global agricultural economy. The stagnation in U.S. public spending on agricultural R&D will have negative implications for agriculture. Public research is needed to serve the public interest and feed the world. Public research funding is vital to support and complement private investment and thus benefit farmers and the economy.

NEED FOR PUBLIC INVESTMENT IN AGRICULTURAL RESEARCH

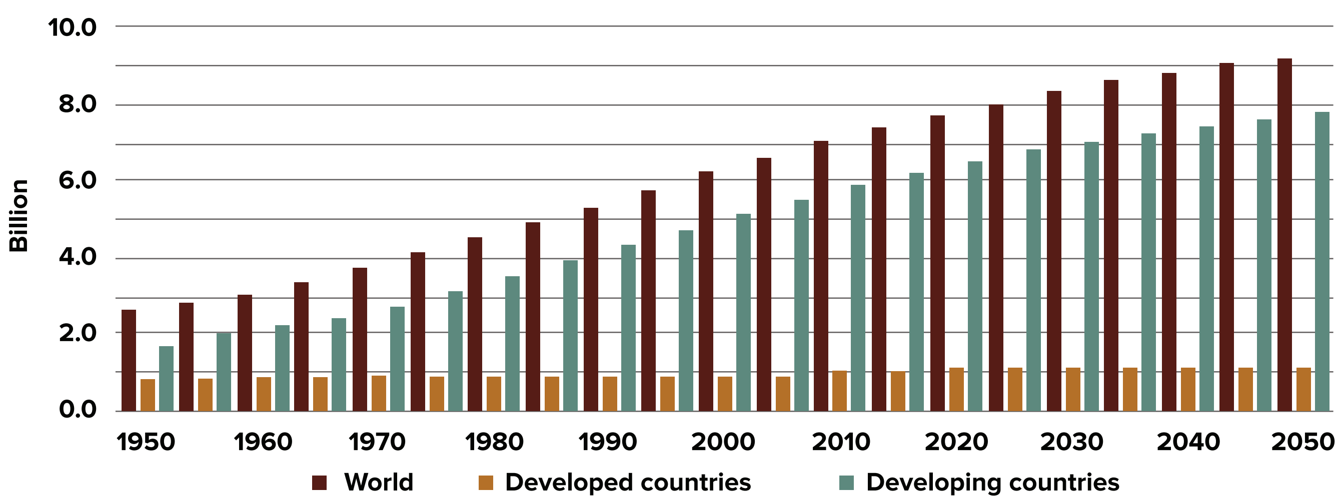
Public research is needed to feed a growing world population. The current global population is about 7.7 billion and is expected to reach nearly 10 billion by 2050. The consensus is that food production will have to increase between 60% to 70% from current levels to meet increased food demand in 2050. As incomes increase, consumers will seek to eat more resource-intensive, animal-based foods. More feed will also need to be produced for animals.[1]

Estimates of total factor productivity (TFP) support the argument that agriculture production is not growing fast enough to sustainably meet the growing global demand for food, feed, fiber, and bioenergy. TFP takes into account the contributions of all inputs, including capital, land, labor, and intermediate inputs such as agricultural chemicals and energy.[2] Globally, TFP is rising by an average annual rate of 1.63%, less than the estimated 1.73% needed to sustainably double agricultural output (2010-2050) through productivity growth. TFP growth is strongest in China and South Asia, but it is slower in the agricultural powerhouse regions of North America, Europe, and Latin America.[3]

Expanding agricultural land area is not a sufficient solution to meet growing food demand because of urbanization and limited new land area that can be brought into production. Climate change is also expected to be a threat to food security by reducing crop yields due to expected higher temperatures and more frequent extreme weather events. Climate change may also increase the prevalence of parasites and diseases that affect livestock and plant production. Greenhouse gas emissions also need to be reduced to mitigate climate change, and agriculture can play a proactive role in this effort.

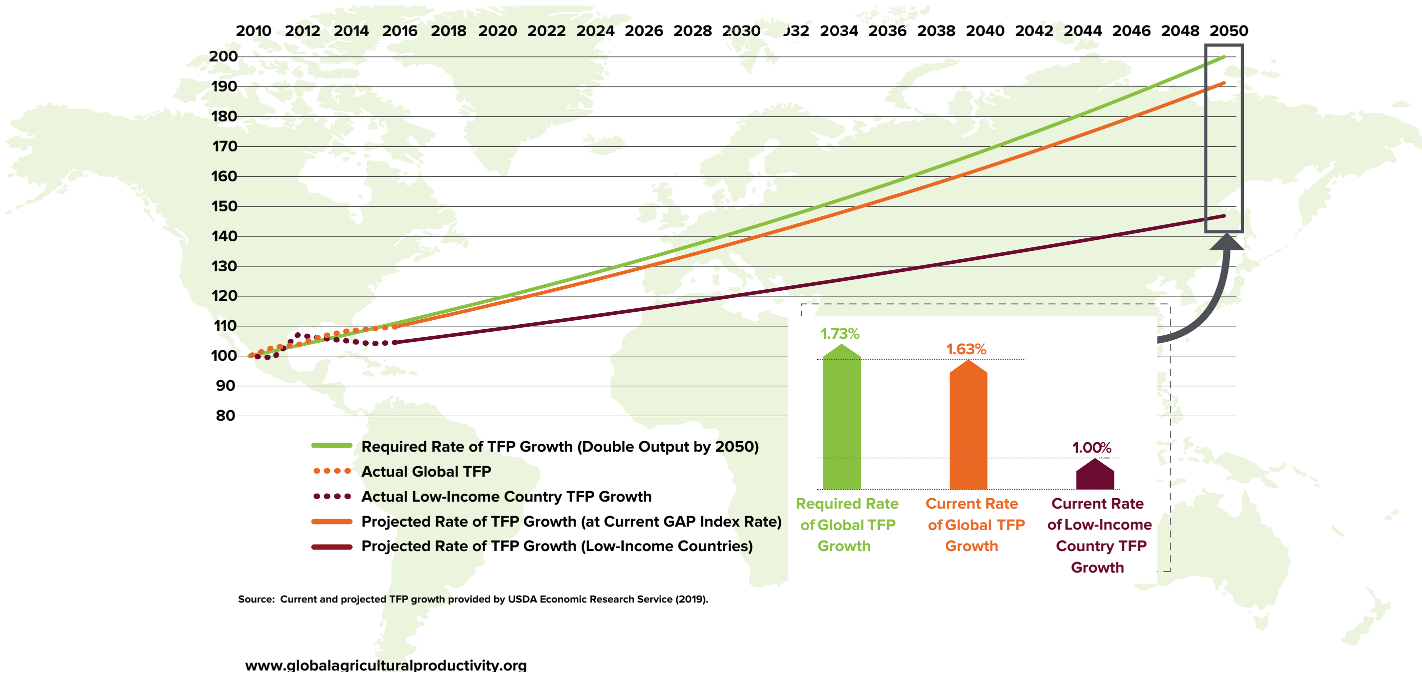
In order to meet the challenge of a growing global population, continual innovation in the agricultural sector is needed to improve efficiency by maximizing production. Innovations such as satellite and GPS technology, improved mechanical harvesting tools, gene-editing crops for improved yields, and reducing the spread of disease among crops and livestock have been vital to allowing agriculture to meet increased consumer demand. To continue to improve agricultural technology, investment in agricultural research and development requires robust amounts of both private and public resources.

Figure 1: Population growth 1950–2050



Source: Food and Agriculture Organization and World Bank.

Figure 2: Global TFP growth stagnant and low-income country TFP alarmingly low



Source: 2019 GAP Report, College of Agricultural Life Sciences, Virginia Tech

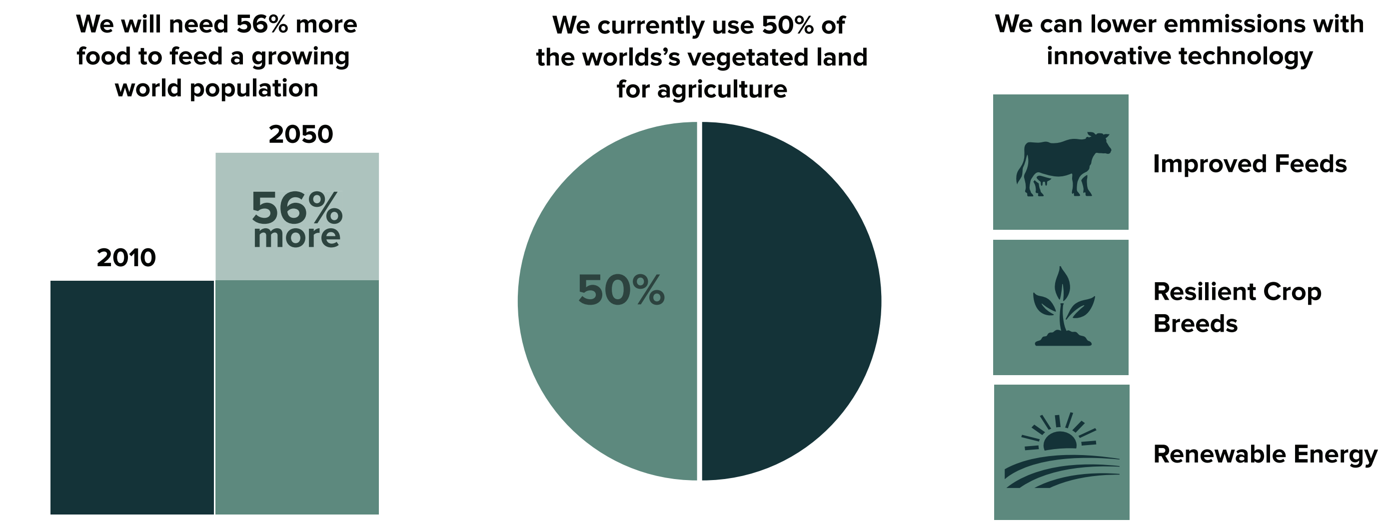
Over time, the success of U.S. agriculture has been due in large part to strong investment in food and agricultural research. Because of this investment, the U.S. farmer is among the most efficient and productive in the world and the U.S. is the global leader in helping to meet the world's demand for food. This investment also contributed to the U.S being the world's leader in agricultural product exports. The U.S. agriculture and food sectors in 2019 accounted for approximately 21.5 million full- and part- time jobs—13% of total U.S. employment.[4] With a 12.9% share, food ranked third behind housing (32.8%) and transportation (17%) in the average American household's 2019 expenditures.

Although funding for private agricultural research and development in the U.S. has been increasing rapidly, funding for public agricultural research and development has stagnated in recent decades. USDA agricultural agency budgets have been relatively flat at around $4.2 billion in 2020 compared with $4.1 billion in 2010.[5]

When private companies invest in agricultural research, they must be able to recoup the cost of their research and provide a return to their investors. They do this by turning the resulting technology into something that farmers will buy. It is necessary to protect the intellectual property that results from the research investment through patents or other forms of "not for reproduction and sale" agreements. The ability to protect intellectual property explains why historically the private sector led in research on agricultural mechanization, animal pharmaceuticals, crop protection chemicals, and hybrid seeds, for which non-purchasers can be excluded from benefitting from the innovation, but not in many other areas.

Intellectual property and the ability to profit from developments are necessary in order to ensure private companies can remain economically viable and fund further research. Thus, while intellectual property can reduce overall cohesion in research between companies, it is historically a key reason the private sector has led the way in

Figure 3: How do we feed 10 billion people, without using more land, while lowering emissions? Agricultural research will be key.



Source: Based on data from WRI

terms of innovation in various areas of agriculture. But private investment often tends to focus on a select few high-value opportunities in major crop and livestock categories, leaving other less attractive sectors and areas under-explored. Certain areas of agricultural development, such as environmental, animal health, specialty crops and food safety concerns require public funding because private companies have less incentive to pursue research in areas where society at large is the main beneficiary without providing high returns on investment. Public sector investments are also needed in areas where the payoffs from research investment are too uncertain or too far in the future. Partnerships between public and private investments can optimize agricultural research developments by capturing the advantages of each.

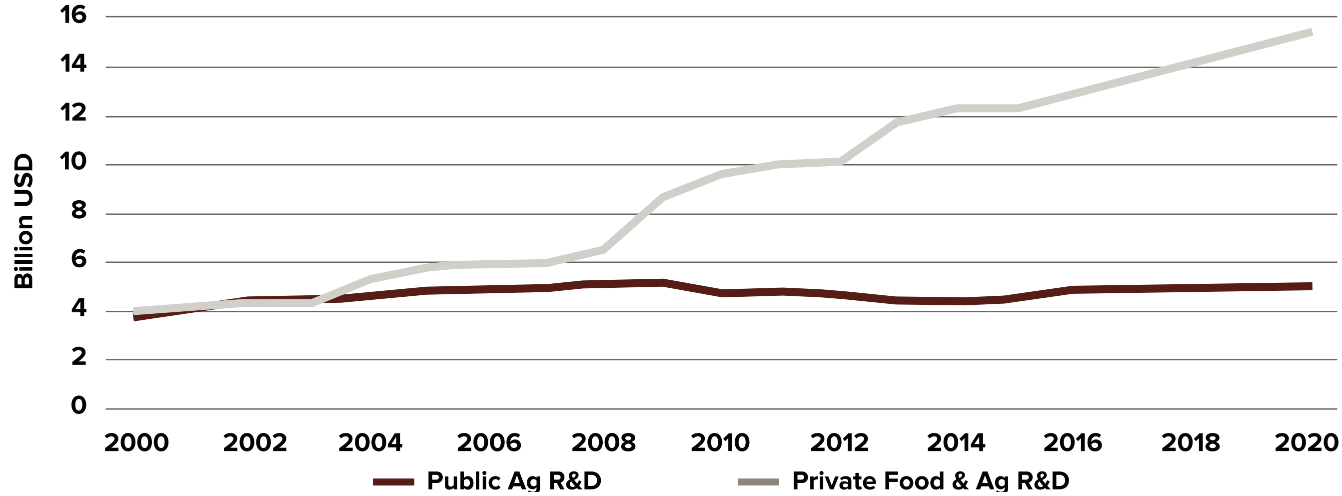
Producers need timely access to new technology to combat the emergence of crop and animal pests and diseases and to address the adverse impacts of climate. Without adequate public research funding, farmers will face loss of productivity and increased costs of production.

USDA agricultural research spending

Five USDA agencies are funded to conduct research and development: the Agricultural Research Service (ARS), the National Institute of Food and Agriculture (NIFA), the Forest Service, the Economic Research Service (ERS), and the National Agricultural Statistics Service (NASS). Research conducted, data collected or external research funded by these organizations provides crucial insight to farmers and the agricultural industry overall to meet challenges in crop and livestock production and to provide food to consumers.

ARS will receive $1.5 billion in funding for research and development in 2021. ARS is charged with extending the nation's scientific knowledge and solving agricultural problems through its four national program areas: nutrition, food safety and quality; animal production and protection; natural resources and sustainable agricultural systems; and crop production and protection. The budget included $280 million for developing and improving ways to reduce crop losses while protecting and ensuring a safe and affordable

Figure 4: U.S. public vs private agricultural research and development spending

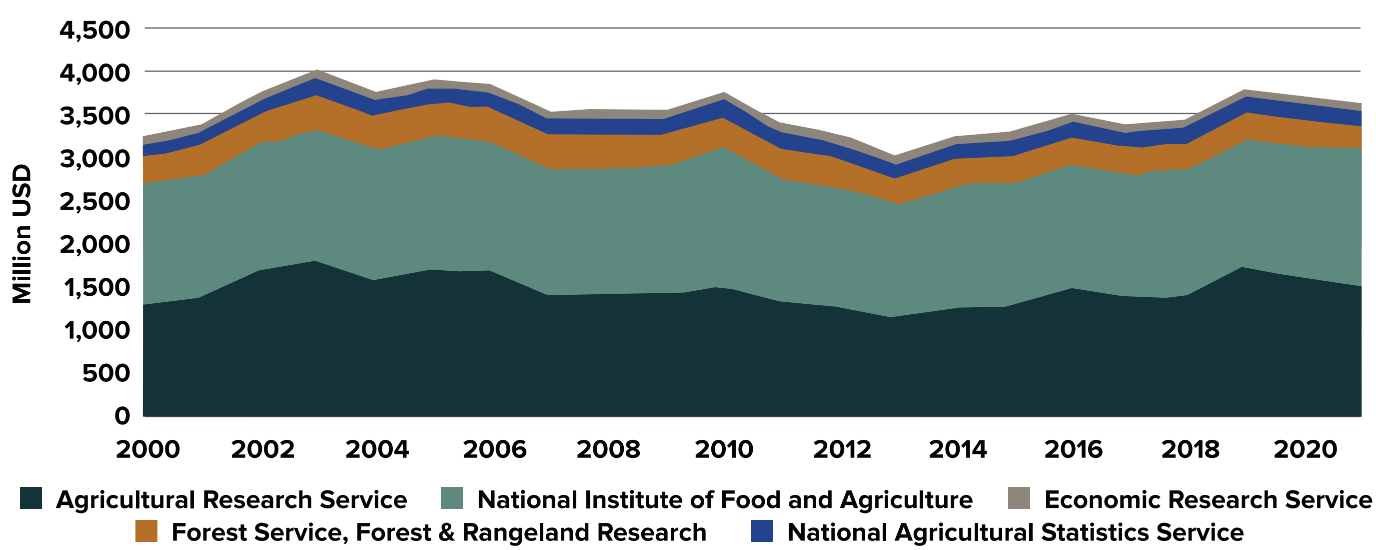


Note: Data is available through 2015, 2016-2020 numbers are IHS Market's based on spending brand
Source: IHS Markit, Economic Research Service

Figure 5: USDA research funding by agency, 2015-2021

USDA Agency (Budget in $ Million)	2015	2016	2017	2018	2019	2020	2021
Agricultural Research Service	1,285	1,468	1,351	1,397	1,718	1,607	1,527
Economic Research Services	93	92	92	90	89	85	85
National Institute of Food and Agriculture	1,414	1,436	1,450	1,463	1,500	1,527	1,570
AFRI	355	379	399	416	415	490	435
National Agricultural Statistics Service *amount is included in the NIFA totals*	188	182	182	199	178	180	184
Forest Service, Forest & Rangeland Research	323	315	307	309	306	305	249

Figure 6: USDA funding 2000 to 2021



Source: USDA, IHS Markit

food supply. The research program concentrates on effective production strategies that are environmentally sustainable, safe to consumers, and compatible with sustainable and profitable crop production systems. Research activities are directed at safeguarding and utilizing plant genetic resources that facilitate selection of varieties and/or germplasm with significantly improved traits.

NIFA will receive $1.6 billion in funding for 2021, of which about one-third will go to funding agricultural Extension activities. Using a peer-reviewed merit selection process, NIFA offers competitive grants for research in identified priority areas through the Agriculture and Food Research Initiative (AFRI). AFRI is funded at $435 million in FY2021.

NIFA also manages the federal funding provided to land grant university research efforts and Extension systems. This program, which generally requires matching state funds, is aimed at ensuring the capacity of these institutions to conduct the research and Extension activities that support U.S. agriculture.

Title VII of the 2018 Farm Bill included $780 million in mandatory funding over 5 years for the following programs:

- Scholarships for Students at 1890 Institutions – $40 million
- Specialty Crop Research Initiative – $800 million over 10 years
- Organic Research and Extension Initiative – $395 million over 10 years
- Urban, Indoor, and Other Emerging Agricultural Production, Education, and Extension Initiative – $10 million
- Foundation for Food and Agriculture Research – $185 million

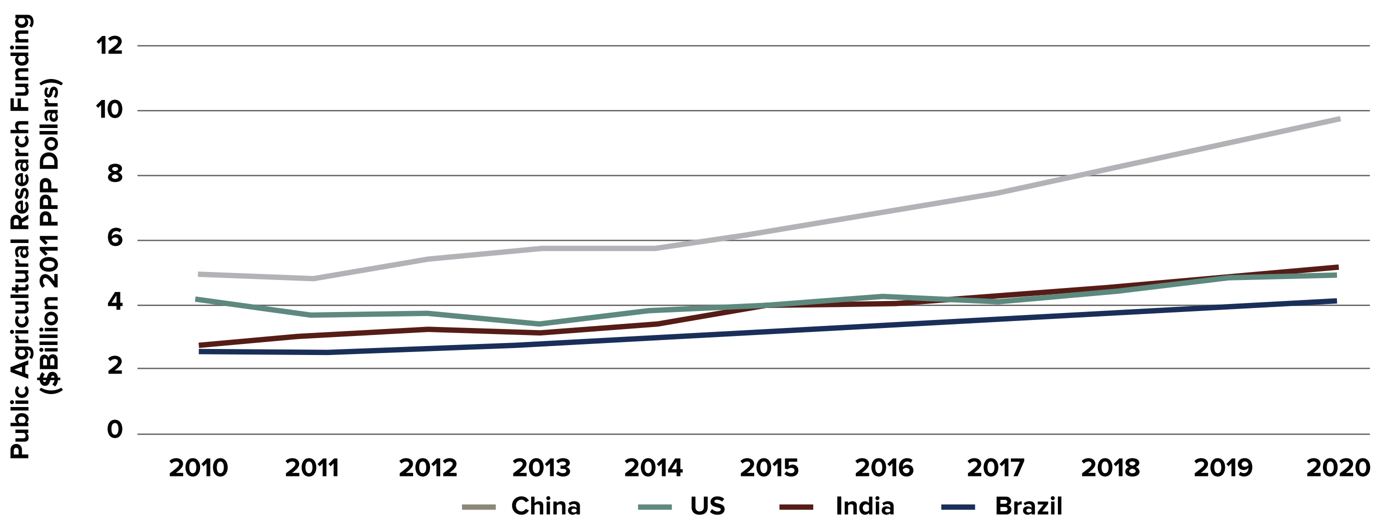
Other countries are investing more in public agricultural research

The U.S. could lose its competitive advantage in agricultural production and exports because of stagnant public research funding. Other countries are boosting their public investment in agriculture. China became the largest funder of public agricultural research and development globally in 2009, with funding increasing significantly since then, resulting in improved food security for its population of 1.4 billion.[6] India and Brazil have also recently increased their public agricultural research and development funding. India announced a 16-point action plan for farmers in early 2020, with the goal of doubling farmers income by 2022.[7] Brazil has benefitted from increased public agricultural research funding and became the world's largest producer of soybeans, surpassing the U.S., whereas ten years ago, the U.S. enjoyed a significant advantage in production (producing about 25% more soybeans than Brazil). Public agricultural research and development spending in Europe has stagnated, similar to U.S. public research funding. However, as part of the European Union Green Deal, there is a 10-billion EUR proposal for research and innovation into areas such as food, agriculture, fisheries and other related areas through the target year of 2030. Among the goals of the European Green Deal are to reduce the use of pesticides by 50%, reduce fertilizer use by 20%, reduce the sale of antimicrobials for farmed animals by 50%, and convert 25% of total farmland to organic farming.[8]

In terms of 2011 purchasing power parity (PPP) dollars, the growth rate of U.S. public spending on agricultural research and development lags behind China, India, and Brazil. PPP exchange rates provide a basis for comparison between currencies that compares the amount of currency required to purchase the same amounts of goods and services in the domestic market using U.S. dollars.[9]

Over the next several decades, there will be an increasing need to improve yields and production efficiency to feed a growing global population without causing irreparable damage to the environment. Climate change, pandemics, animal diseases, crop pests and crop diseases all pose a potential threat to the global agricultural economy. A proactive, prevention-oriented approach that complements the necessary reactive approach when a threat becomes prominent is optimal, so that the agricultural economy is at peak performance and all agricultural sectors and the public benefit.

Figure 7: Estimated public agricultural research and development funding



Source: IHS Markit, ASTI, Chai et al., Dehmer et al

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CROP BREEDING RESEARCH

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As indicated earlier, the world needs to increase food production to meet a growing world population. Crop breeding is one of the tools that can be used to improve yields. Increasing U.S. farmland area is not an option. Globally, the farm sector continues to lose land to non-agricultural uses, especially in the developed world. Based on data from USDA's Census of Agriculture, U.S. total farmland decreased by 38 million acres from 2002 to 2017. Competition from urban/suburban expansion and an aging farm population with a younger generation preferring to pursue careers off farm are the major reasons for the recent decline in farmland area.[10]

Conventional breeding, the selection of best-performing crops based on genetic traits, accounted for around half of historical U.S. crop yield gains over the last 20 years. Genetically modified organisms (GMOs) are those organisms whose genomes have been altered using genetic engineering technology. Transgenic organisms, a type of GMO, are created when a genome is altered by inserting the genetic material of a different species into it. Gene-editing, on the other hand, involves the alteration to the genome within the same species.

Although transgenic crops are the most adopted agriculture technology globally, with 191.7 million hectares of area covered under biotech crops in 2017, the technology has been criticized without compelling evidence by some consumers as not being safe. GMO technology has been thoroughly studied and regulated. New advances in molecular biology through gene-editing offer great promise for additional yield gains by making it cheaper and faster to map genetic codes of plants, test for desired DNA traits, purify crop strains, and turn certain genes on and off.

The potential benefits of gene-editing in crop agriculture can be broadly categorized as improved nutrition and greater productivity.

Furthermore, climate change and a decrease in arable land in developed countries are also creating the need for development of climate resilient, disease resistant, and high yielding crops.[11] The advantages of gene-edited crops are that they can be developed and commercialized at less cost and in less time than GMO crops.

In the past, individual transgenic traits in crops have cost private companies approximately $135 million to develop and took between 10-13 years to move from the lab to commercialization. In contrast, the cost of new trait development with gene editing is $10 million-13 million with a turnaround time of five years.[12]

Policymakers, producers, and consumers can help meet the challenge of improving yields with public investment in agricultural R&D such as in seed genetics, adopting science-based technologies and improving farm management practices, helping to refine measurement practices to support ecosystem services markets, improving transportation infrastructures, reducing food loss and waste, and making regional and global trade more efficient and cost-effective.

Trends in gene-editing investment

The agricultural gene-editing market is currently dominated by the North American region, mainly by the U.S. Owing to the large presence of agricultural gene-editing companies and a huge food processing sector, the U.S. serves as the largest market for agricultural gene-edited products. Supportive regulations for new plant

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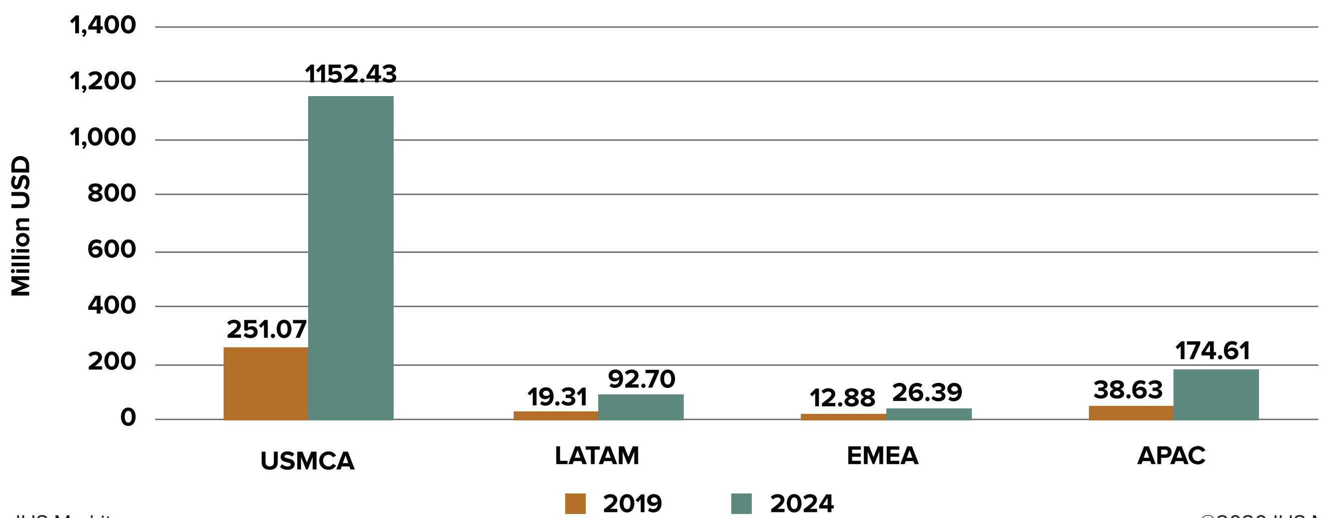
breeding/gene-editing techniques and public acceptance for agricultural biotechnology products are key factors in driving the market growth in the region.[13]

Although China's current investment is relatively small, food scientist Rodolphe Barrangou at North Carolina State University in Raleigh says the Chinese government signaled it would back modern genome editing of plants in a five-year plan issued in 2016, and many observers believe that the purchase of Syngenta by ChemChina in 2017 confirmed that intention.[14]

Most of the gene-edited crops are at a developmental stage and are not yet approved for market. The private sector is mainly focused on using gene-editing technologies to improve the largest, most profitable crops: maize, soybeans, canola, cotton, rice, and wheat.[15]

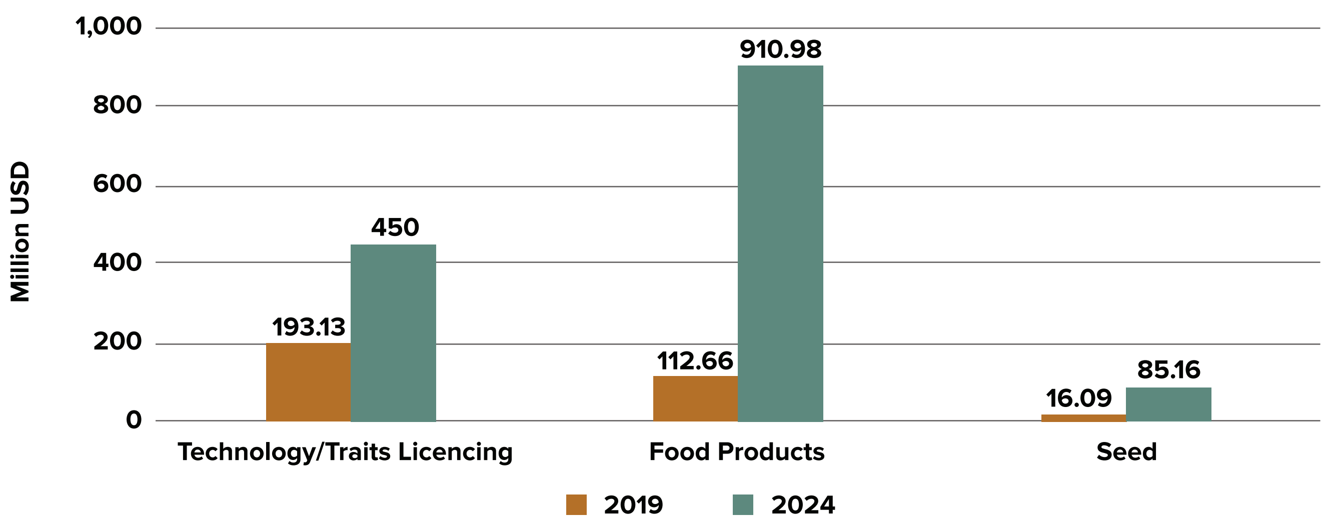
The ownership of intellectual property of gene-editing technologies is divided between the public and private sectors. Most of the companies using gene-editing technologies have licensed their technologies from the public sector.

Figure 8: Agricultural gene-editing technologies market value in $ million by region



Source: IHS Markit

Figure 9: Agricultural gene-editing technologies market value in $ million by product



Source: IHS Markit, 2019 GAP Report Global Agriculture

Challenges of gene-editing

In the agricultural sector there are bottlenecks associated with the technology itself for various crop species. Methods need to be developed and standardized for crop species of choice by industry, academia, or more importantly government entities. The major factors restraining the growth of the industry include non-acceptance of genetically modified crops by consumers and uneven government regulations relating to gene editing. U.S. authorities have supported gene-editing technology in agriculture by considering it as an extension of regular plant breeding techniques. However, in July 2018, the EU decided to regulate gene-edited crops under their existing GMO protocol as a result of a July 2018 ruling by the Court of Justice of the European Union (ECJ). In addition to domestic production, these regulations are also applicable to food imports. The difference in how gene-edited crops are regulated between the U.S. and Europe has the potential to disrupt the trade of crops and food produced through such techniques. This uncertainty and lack of a consistent regulatory framework between countries can impose a burden on trade and industry growth.

Consumer acceptance is one of the major limiting factors for products of gene-editing technology in crop agriculture. Demand for organic and non-transgenic crops is trending upward, and food companies all over the world are seeking to source non-transgenic ingredients. Globally, transgenic crops face a negative perception. Many food and beverage companies are disinclined to associate their name with gene-editing technology due to some consumer perception of gene-edited crops as no different than traditional transgenic crops.

CROP PROTECTION RESEARCH

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Crop protection is the practice of protecting crop yields against pests, diseases, and weeds that cause damage to plants. It can involve the use of chemical, biological, and physical tools, along with farmer production practices. Effective protection against crop diseases and pests has been a major contributing factor in the steady growth of agricultural productivity in the U.S. and globally since the development of fungicides and synthetic insecticides in the 1930s. Crop protection practices are thought to have halved the amount of potential crop production lost to weeds, pests, and diseases globally each year, and contribute to the conservation of natural resources by reducing the need for increasing amounts of land to meet the food needs of a growing global population.[16] But the battle against crop diseases and pests is continually evolving as diseases and pests develop resistance to established crop protection practices, and new diseases and pests emerge to pose new threats to crop production. In an environment of changing and new threats, maintaining crop productivity requires the development of new tools to meet these challenges.

Over the last century crop protection has heavily relied on the use of chemical pesticides to manage the threats to crop production, leading to the growth of a large and innovative crop protection industry that invests in the research and development of pesticide products. Mostly dominated by several large firms with global reach, this research and development has tended to focus on commercially profitable products that underpin modern crop production.

The public sector has also long played an important role in crop protection, as it often funds much of the basic research that underlies new agricultural technology. The public sector is also fundamental to the development and diffusion of new ideas and practices through the system of land-grant universities and Extension services that have fostered agricultural production in the U.S. for more than 150 years. Much of the knowledge to emerge from this system has the characteristics of a public good and does not lend itself to commercialization. Given this reality, without public sector support it is likely that some basic research important for crop protection would not be undertaken, which has important implications for the productivity of agriculture in the U.S. Research suggests that the growth in U.S. agricultural productivity since 1948 has largely been driven by total factor productivity (TFP),[17] as described earlier.

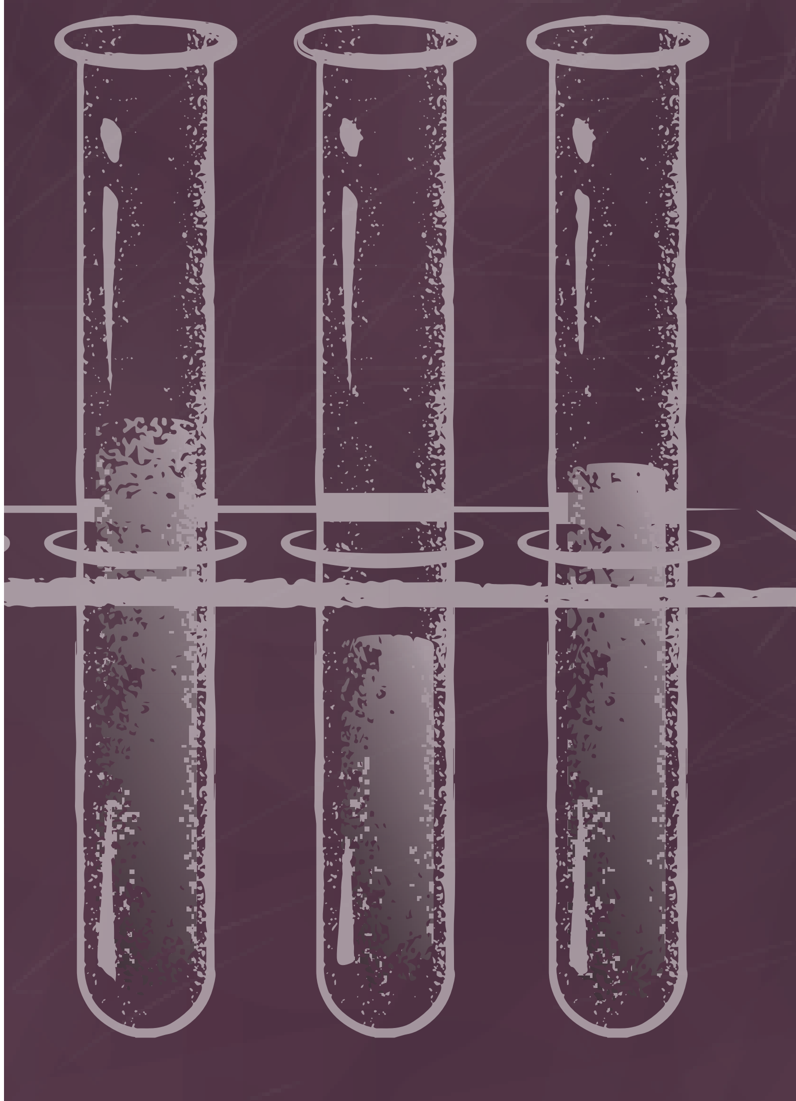
Despite the success of chemical crop protection products in reducing crop losses, there are a number of challenges facing the industry that will likely create an increased complementary role for the public sector in crop protection. Increased pest resistance to chemical formulations means new products and approaches are needed on a regular basis, while increased public concern over the environmental and human health implications of chemical pesticide use has resulted in reduced availability of existing products. In the U.S., six of the top 10 products in 1968 have been banned for use as of 2016, and more than 60 active ingredients are no longer available.[18] At the same time new product development has also slowed as the cost of developing and marketing new products, in part due to increased regulation stemming from environmental and health concerns, has increased. Since 1995 the discovery and development costs of a new crop protection product have increased from $152 million to $286 million between 2010-2014, with the average development time increasing from 8.3 to 11.3 years over the same period.[19] These costs have resulted in a marked slowdown in the commercial introduction of products with new active ingredients.

Given increased pest resistance to chemical products and concerns over the environmental and health impacts of chemical pesticides, one the most important strategies for agricultural pest management for producers is integrated pest management (IPM). IPM has a long history in agriculture but, in its modern form, evolved from university and Extension research conducted in the 1970s and 1980s[20] and involves using production techniques to exclude pests and create conditions that thwart their establishment and reduce their impact, while at the same time reducing chemical pesticide use. Leaning heavily on the wide sharing of acquired knowledge, public funding of research and development of new IPM practices will be vital to future agricultural productivity growth. This role for public support is recognized by NIFA in its Crop Protection and Pest Management (CPPM) program, which funds research into IPM approaches that strengthen agriculture at the state, regional, and national levels.

New technologies such as gene-editing, precision technology, and data science will also likely be important tools in managing existing and emerging crop pest and disease threats. ARS scientists conduct basic scientific research that underpins new innovations in crop protection. With the commercial viability of new technologies often uncertain, publicly funded research and development can be vital to initiating work on new technologies that eventually become available to producers and supporting the development of new industries. Funding for crop protection research at ARS is budgeted for $195 million in FY2021, down from $217 million in FY 2020.

Public research funding for crop protection – case examples

Public research and development funding in crop protection is already playing an important role in some of the most pressing current issues for agricultural producers.



Citrus greening disease

ARS is conducting research into disease detection, prevention, and mitigation of citrus greening disease, a bacterial pathogen that attacks citrus trees and has had a devasting effect on the Florida citrus industry since 1998. It is estimated that in Florida the industry lost $4.4 billion in cumulative output from 2012 to 2016, and acreage and yields have decreased by 26% and 42%, respectively since 2005.[21, 22] The disease has recently spread to other states including Arizona, California, Georgia, Louisiana, and Texas. Some of the activities devised to combat it include training dogs to detect outbreaks of the disease through their keen sense of smell much earlier and with a higher rate of accuracy than existing methods, the development of new citrus cultivars with greater tolerance to the disease, and the discovery of a set of molecules that can penetrate the biofilm protecting the bacterium and subsequently kill it. This treatment has been patented by ARS and may have applications for treatments for other fruit, nut, and vegetable crops facing similar disease outbreaks. Public funding of this research allows for an integrated approach using various techniques to find solutions for citrus producers.

Sugarcane aphid in sorghum

Sugarcane aphid is a new invasive pest in sorghum that has caused substantial crop production losses. The origin for the sorghum infestation is not fully established – either in Asia or Africa, with Asia the most likely source. The pest has been found in the U.S. in sugarcane since the 1970s as a minor pest, but this is a new strain that appeared in 2013. This pest is capable of causing substantial damage to crop production. To address the issue, ARS researchers have developed monitoring methods using remotely sensed imagery that can detect damage from aphid infestations and help to optimize the number of insecticide applications. Reductions in chemical pesticide use can help slow the development of resistance and lower the impact on environmental and human health. The research also led to the development of new grain sorghum breeding lines with genetic resistance to the aphid and other bugs and diseases.

Minor crop pest management program interregional research project #4 (IR4)

NIFA funds programs that assist with availability of effective crop protection products for minor/specialty crop producers. Given the often costly and lengthy development process for registering crop protection products, the smaller market size for minor and specialty crops means that the private sector typically cannot justify the expense of making these products available. The minor crop program works with federal agencies, land-grant universities and colleges, and the crop protection industry to meet the crop protection needs of these niche markets. The IR-4 program is coordinated at the regional level by four universities: Michigan State University, University of California, University of Florida, and University of Maryland. The goals of the program include the availability of reduced risk pest management products and research to identify more effective products for minor and specialty crop producers.

Crop protection and pest management program (CPPM)

The CPPM program provides funds to develop approaches for pest management using IPM across the nation. The program areas include applied research and development for new IPM practices and technologies, Extension services to encourage increased IPM implementation by farmers, and a program to enhance coordination and build stakeholder networks. The program represents a comprehensive approach to pest management that coordinates research and education efforts to improve pest management outcomes.

ANIMAL HEALTH RESEARCH

ANIMAL HEALTH RESEARCH

Monitoring animal health and preventing animal disease outbreaks is vital to the safety of the U.S. and world food supply. According to the UN's Food and Agriculture Organization (FAO), global livestock production contributes nearly 40% of the value of total agricultural output.[23] The production of animal goods, such as meat, dairy, wool, and leather, is a multi-billion-dollar-per-year industry and accounts for over half of the value of U.S. agricultural production.[24] FAO estimates that global meat production will increase from 318 million tons in 2016 to 455 million tons in 2050. In 2016, 36% of cereals produced globally were fed to animals, thus substantially more cereal production will be needed to feed livestock in 2050.[25]

In this environment it becomes necessary to have animal stock that is healthy, productive, and disease resistant. Investing in animal science research is the means to ensure a safe, high-quality, plentiful, and affordable food supply to meet future protein demand in the U.S. and the world.[26] Production of healthy livestock helps to ensure a safe food supply and keep consumer prices stable. Both public and private research is needed to meet the economic and human health risks associated with livestock diseases.

Vaccines are widely used to prevent infections in food animals. Vaccine use can lead to significant reductions in antibiotic consumption, making them promising alternatives to antibiotics. But, the research for development of veterinary vaccines requires considerable time and financial investments, which pharmaceutical companies could dedicate to other products that may be expected to generate a higher return on investment. Close collaboration between private industry, government, and academia is important to ensure that research efforts are complementary, and that each party's unique strengths will foster progress toward the common goal of developing vaccines effective in preventing disease while also reducing the need for antibiotics.[27]

Livestock genome editing is a way of making specific changes to the DNA of a cell or organism to make the animal, for example, more resistant to disease. Gene-editing is being used to alter the genes of livestock. For example, one application is focused on reducing the loss of livestock to disease by providing immunity to a virulent hemorrhagic virus that causes a deadly form of swine flu. Other potential benefits include improved lactation performance, meat production, and disease resistance, which cannot be easily achieved with conventional breeding procedures. Other livestock work includes research carried out by Recombinetics, a Minnesota company specializing in livestock genetic editing to produce hornless dairy cattle, more beefy and tender Brazilian cattle, and research on chickens that produce only female chicks for egg-laying, which will be carried out by researchers at the University of Georgia.

The Committee on Considerations for the Future of Animal Science Research, associated with the National Academies of Science, believes that animal agricultural research has borne the brunt of the decades of neglect in private funding as private R&D has focused mainly on related areas such as veterinary pharmaceuticals and feed manufacturing.

Current funding for animal health research

As can be seen in Figure 10, the allocation of funds for animal health through the Animal and Plant Health Inspection Service (APHIS) has been minimal.

Though the total annual allocation of funds to APHIS has seen an increase from $1,158 million in 2011 to $2,043 million budgeted for 2021, the funding for animal health research has been marginal and has barely increased over recent years (from $321 million in 2011 to $365 million budgeted in 2021). The percent allocation of APHIS funds to animal health has also gradually gone down. The majority of APHIS funds devoted to animal health have been allocated to the cattle sector.

The funding on animal agriculture research at ARS has also been stagnant over the years. The total outlay for ARS in 2020 was $1,631 million and the portion of funding for research on livestock production and protection was only $114 million, less than 7%. ARS' livestock production program is directed toward: (1) safeguarding and utilizing animal genetic resources, associated genetic and genomic databases, and bioinformatic tools; (2) developing a basic understanding of the physiology of livestock and poultry; and (3) developing information, tools, and technologies that can be used to improve animal production systems. The research is heavily focused on the development and application of genomics technologies to increase the efficiency and product quality of beef, dairy, swine, poultry, aquaculture, and sheep systems.

The funds allocated for animal health and disease research projects through NIFA have also been constant at about $4 million over recent years.

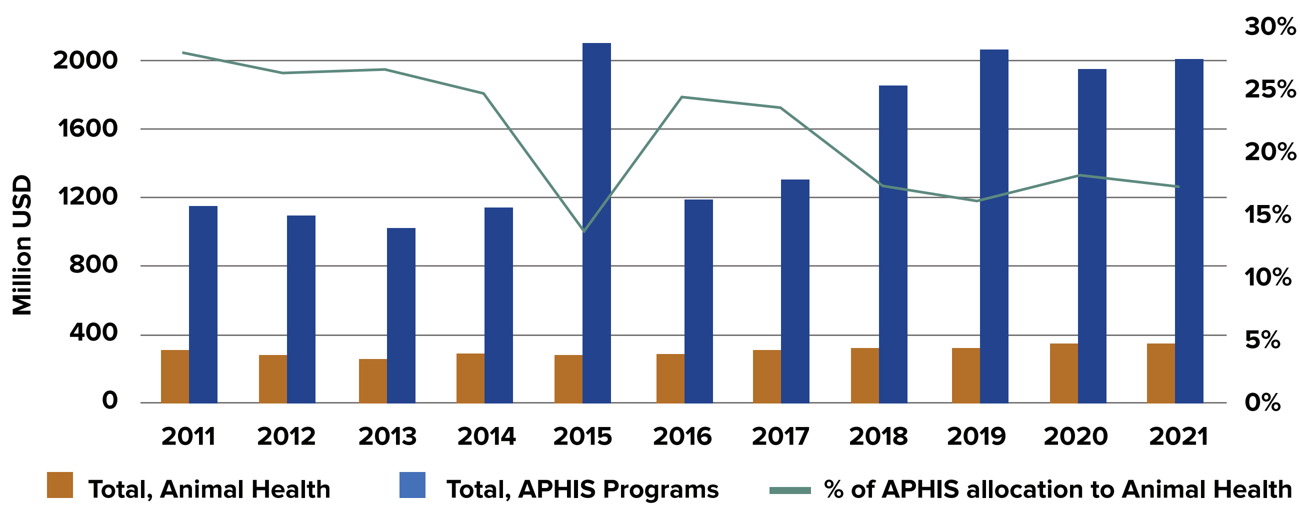
While public investment in animal health has been stagnant, in-house research programs at leading companies remain well-funded. As Fig. 13 shows, major industry participants are investing in the mid- to upper-single digits, in terms of percentage of annual sales, in their R&D programs.[28]

Future focus of research

Potential areas of research that will require additional public funding are increasing the focus on animal welfare, disease resistance and reducing the environmental impact of livestock production. The driver for this research, in part, is consumers. Private sector research is committed to enhancing sustainability and animal welfare to meet that demand. Applying the tools of molecular genetics to animal agriculture are likely to have considerable impact in the future. For example, DNA-based tests for genes or markers affecting traits that are difficult to measure currently, such as meat quality and disease resistance, will be particularly useful.[29]

Genetically modified (transgenic) livestock, stem cells, and other emerging biotechnologies (as

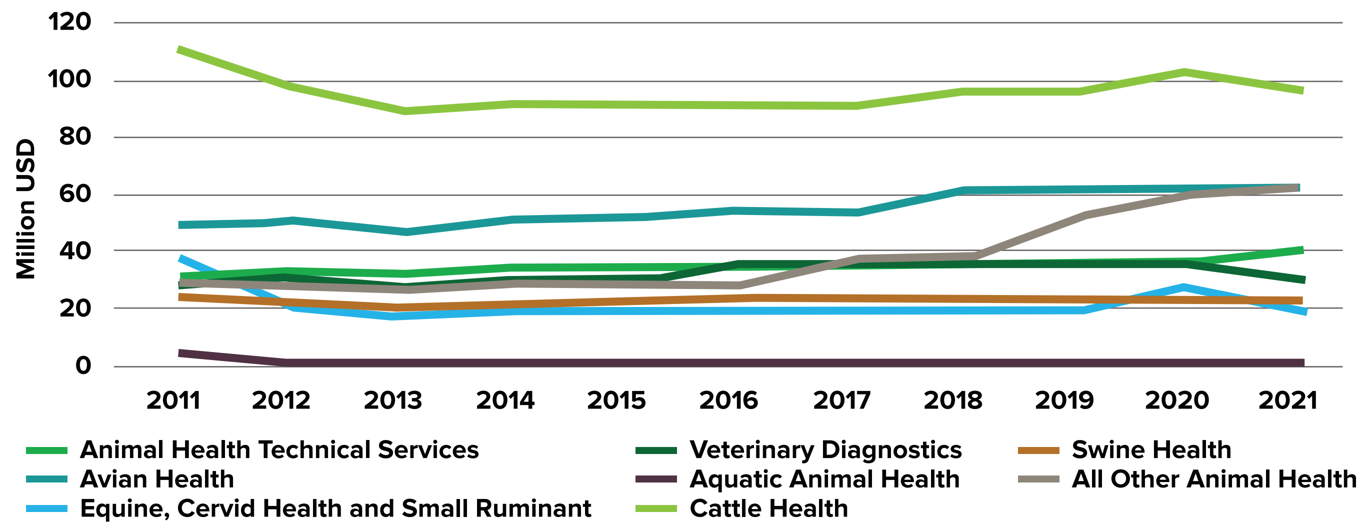
Figure 10: Allocation of APHIS funds



Source: USDA

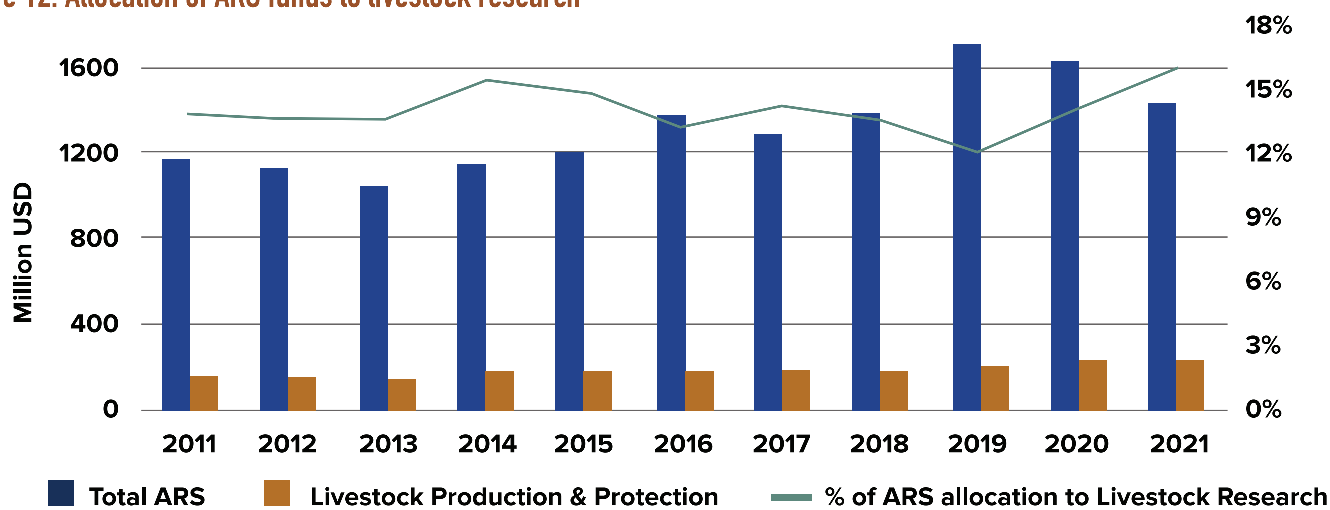
mentioned earlier) will have important roles in producing more and higher quality food derived from livestock. Practical applications of transgenics in livestock production include enhanced reproductive performance, increased feed utilization and growth rate, improved carcass composition, improved milk production and/or composition, modification of hair or fiber, increased disease resistance, and reduced environmental impacts.[30] Despite the technology being beneficial, U.S. researchers who work on genetically engineered livestock have long dealt with a dearth of research funding and an uncertain path to market.[31] There has also been very little support from the private sector in this area due to an expensive and unpredictable regulatory process.[32]

Figure 11: Allocation of APHIS funds to Animal Health



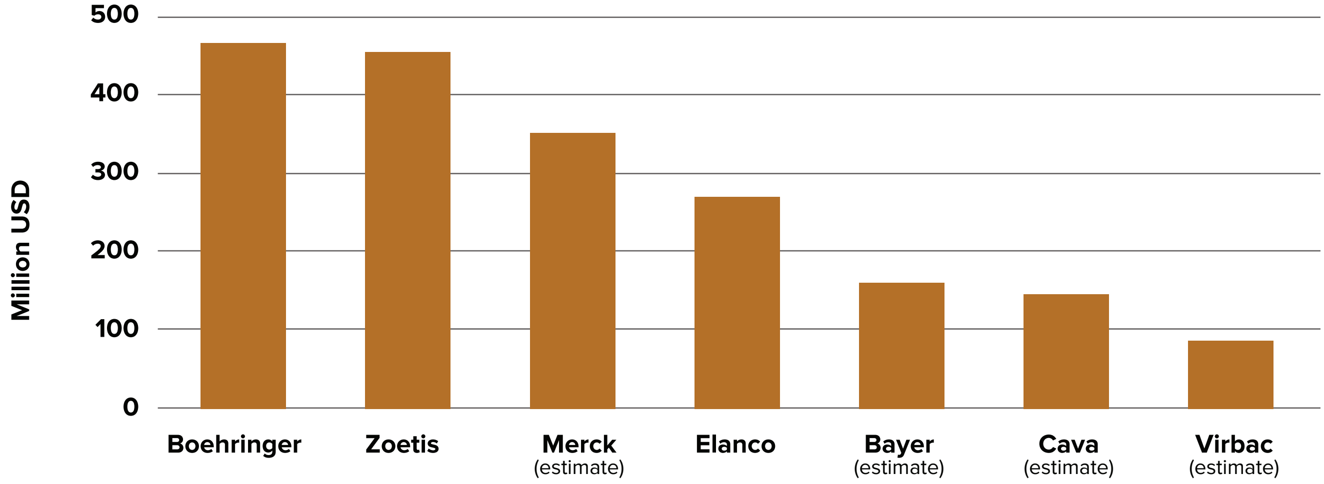
Source: USDA

Figure 12: Allocation of ARS funds to livestock research



Source: USDA

Figure 13: R&D spending among animal health leaders in fiscal 2019 ($m)



Source: IHS Markit

Public research funding for animal health – case examples

Examples of public R&D funding in animal health playing an important role in some of the most pressing current issues for agriculture producers are:

"Development of Gene-editing Technologies in Livestock to Address Agriculturally Relevant Problems." The project aims at systemically altering the DNA sequence predicted to cause beneficial changes in livestock production. The research will focus on cattle, pigs, and poultry, and the goal will be to develop livestock with improved traits of interest, without creating deleterious effects. The project aims to understand the relationship between genes and physiological functions in livestock, in order to make gene modifications that are likely to improve livestock production.

"Develop Alternatives to Antibiotics for Priority Diseases in Animal Agriculture" being carried out by ARS. This effort aims to discover and develop alternatives to antibiotics to prevent and/or treat infectious diseases, enhance gut health, feed efficiency, and production of livestock and poultry.

Apart from this research, APHIS supports the animal industry through various health programs such as the National Tuberculosis Eradication Program, the National Brucellosis Eradication Program, Bovine Spongiform Encephalopathy (BSE), Vector-Borne Diseases and other diseases in cattle such as FMD, Johne's disease, and many more.

The risk of an outbreak of a foreign animal disease (FAD) in the U.S. is a critical concern. The economic fallout for producers would be catastrophic. An FAD outbreak would likely result in immediate closure of international markets for U.S. product exports within days of any outbreak.

A highly pathogenic avian influenza outbreak between December 2014 and June 2015 in the U.S. Midwest resulted in the loss of 50 million birds and a $3.3 billion cost to the poultry industry. The U.S. government spent another $500 million in order to contain the disease and paid out $190 million to farmers to compensate for destroyed birds.

ANIMAL DISEASE & FOODBORNE ILLNESS RESEARCH

ANIMAL DISEASE AND FOODBORNE ILLNESS RESEARCH

The U.S. and the world have seen outbreaks of highly pathogenic avian influenza (HPAI), Porcine Epidemic Diarrhea virus (PEDv), Foot-and-mouth disease (FMD) and currently African swine fever (ASF) over the last decade. All have had significant animal health and economic impacts in affected countries while threatening the food supply. These and potential future outbreaks present a continuing threat and demonstrate the importance of public funding for research into these diseases and yet-to-be identified diseases. The creation of treatments and vaccines is of vital importance to protect human and animal health, farm income, and animal agriculture.

The risk of an outbreak of a foreign animal disease (FAD) in the U.S. is a critical concern. The economic fallout for producers would be catastrophic. An FAD outbreak would likely result in immediate closure of international markets for U.S. product exports within days of any outbreak. Reopening these markets would require international recognition that the disease has been eradicated, which can take months or more likely years.

Despite the development of new vaccines and the application of rigorous biosecurity measures, animal diseases pose a continuing threat to animal health, food safety, the economy, and the environment. Intense livestock production, increased international travel, and a changing climate have increased the risk of catastrophic animal losses due to infectious diseases.[33]

An HPAI outbreak between December 2014 and June 2015 in the U.S. Midwest resulted in the loss of 50 million birds and a $3.3 billion cost to the poultry industry.[34] The U.S. government spent another $500 million in order to contain the disease and paid out $190 million to farmers to compensate for destroyed birds.[35] The appearance of PEDv in Ohio in April 2013 spread to 30 states and led to the loss of 8 million hogs by August 2014.[36] The estimated economic impact was between $900 million and $1.8 billion.[37] FMD outbreaks in the U.K. (2001) and in South Korea and Japan (2010–2011) caused the loss of thousands of animals.

USDA has a number of programs that support research on animal diseases. For example, the USDA budget supports the continued establishment of the National Bio and Agro-Defense Facility (NBAF), which is scheduled to be fully operational in late 2022, and provided $79 million for operations and maintenance costs in 2020. NBAF and ARS will use the facility to study diseases that threaten the animal agricultural industry and public health while APHIS performs diagnostics related to FAD.

A three-part program to help APHIS support animal disease prevention and management was included in Section 12101 of the 2018 farm bill.[38] The farm bill created the National Animal Vaccine and Veterinary Countermeasures Bank (NAVVCB) and the National Animal Disease Preparedness and Response Program (NADPRP), while extending funding for the National Animal Health Laboratory Network (NAHLN). $150 million was allocated for these three programs. $20 million was included for the NADPRP over fiscal years 2019-2022. An additional $100 million for 2019-2022 was to be divided between the three programs. Permanent funding of $18 million a year for the NADPRP beginning in 2023 was included as well as an additional $12 million a year for the combined three programs.

A 2015 study initiated by Dustin Pendell while at Colorado State University on the hypothetical impact of an outbreak of FMD from the proposed NBAF in Kansas estimated median losses at $115 billion.[39] The authors of the study received financial support from the Department of Homeland Security and the School of Economic Sciences IMPACT Center.

The current spread of ASF across much of Asia and into Europe is one of the largest animal disease outbreaks in history, and it is likely to change producer behavior, impact global consumption patterns, and affect participants throughout the food production supply chain for at least the next several years. Thus far, the U.S. and Brazil have been vigilant and have been able to prevent the spread of ASF across their respective borders. USDA and U.S. Customs and Border Protection authorities at ports across the U.S. recognize the potential severity of the disease. For example, this tightened scrutiny led to the largest-ever seizure of agricultural goods in U.S. history in March 2019 as Customs and Border Protection officials seized 1 million pounds of contraband Chinese pork in Newark, New Jersey.[40]

We do not yet have an ASF vaccine, effective tests or methods to control transmissions. We are far from having the tools to effectively manage an outbreak without significant loss in domestic consumption. ASF research is currently a top priority. This was not the case in 2004 when funding for ASF research designed to find a vaccine was cut due to budget constraints. FMD was considered a more serious threat by USDA officials at the time and resources were allocated to its study instead. ASF was considered a distant threat at the time, unlike today. The move has delayed the development of a vaccine.[41] The Swine Health Information Center received a $1.7 million grant from the USDA in 2019 for research with the Canadian Food Inspection Agency, Iowa State University, National Pork Producers Council, University of Minnesota, USDA, and government officials, laboratories and producers in Vietnam.[42] Congress appropriated $9.6 million to ARS to study FAD and emerging diseases in 2019. The amount given to the study of ASF was not revealed.[43]

Foodborne illnesses

USDA's food safety mission is to ensure that the nation's supply of meat, poultry and egg products are safe and properly packaged. The Food Safety and Inspection Service (FSIS) performs this mission. The FSIS budget was $1.3 billion in 2020, up from $1.28 billion in 2019.

Foodborne illness is a significant public health problem in the U.S. About 48 million people get sick, 128,000 people are hospitalized, and 3,000 die each year from foodborne diseases, according to estimates from the Centers for Disease Control and Prevention (CDC).[44]

A May 2015 study by ERS states that of the 48 million people sickened from foodborne illness, only 20% (9.4 million) of the cases can be attributed to a specific pathogen.[45] Those 9.4 million cases impose over $15.5 billion in economic burden annually in terms of the cost of treating illness, lost productivity, pain and suffering involved with the illness, expenditures avoiding the illness and the pain and suffering it causes others.

A 2018 World Bank study found the impact of unsafe food costs to low- and middle-income economies to total $110 billion annually in lost productivity and medical expenses.[46]

Progress in controlling major foodborne pathogens in the U.S. has stalled and infections caused by five out of eight major pathogens rose significantly in 2019 compared to the last three years, according to new data from the CDC. A new report published May 1, 2020 in the CDC's *Morbidity and Mortality Weekly Report* found that infections caused by *Campylobacter, Cyclospora,* STEC, *Vibrio,* and *Yersinia* increased in 2019 compared to 2016-2018, while infections caused by *Listeria, Salmonella,* and *Shigella* remained level.[47] The new data indicates that the U.S. will fail to meet pathogen reduction targets set in 2010 for Healthy People 2020, the federal government's 10-year prevention agenda for building a healthier nation. It is a statement of national health objectives designed to identify the most significant preventable threats to health and to establish national goals to reduce these threats.

In March 2020, the Pew Charitable Trusts developed a detailed guide to encourage food companies to perform root cause analyses (RCA) after foodborne illness outbreaks. The guide was developed with input from federal agencies, food companies and trade groups, academia, and other stakeholders. Recognizing that RCAs of outbreaks may be staff- and time-intensive, the guide calls on food companies to not only to step up these investigations, but also to share their findings with the Food and Drug Administration (FDA) and other stakeholders – a move that Pew believes would help identify potential problems more quickly and ultimately prevent future outbreaks.

FDA's investigations of repeated outbreaks of *E.coli* in romaine lettuce, with one in 2017, two in 2018 and one in 2019, were part of the reason why Pew developed the new guide to illustrate how RCAs can help strengthen prevention even in cases when they don't pinpoint the precise origin of an outbreak. There have been cases where RCAs have been used successfully to help eliminate potential causes for outbreaks. For instance, produce growers in Delaware, Maryland, and Virginia applied RCA methods in response to a string of *Salmonella* outbreaks linked to tomatoes and cucumbers that occurred frequently in the early 2000s through 2014.

Public funding for FAD research – case studies

Public research funding for studying and preventing FAD outbreaks in the U.S. is critical. Some examples of current funding follow.

ASF virus survival and testing

In 2019, Kansas State University and Iowa State University were awarded $500,000 by the Foundation for Food and Agriculture Research (FFAR).[48] FFAR was created under the USDA by the Agricultural Act of 2014 to increase investment in research and development through public-private partnerships. Kansas State University is researching how ASF survives and continues to infect other animals in various environments. Iowa State University is researching the best means to identify FAD at low prevalence in large commercial pens. Understanding how the ASF virus survives and how to identify it quickly will better prepare the U.S. to respond to an outbreak if one occurs here.

Swine Health Information Center support

The mission of SHIC, headquartered in Ames, Iowa, is to protect and enhance the health of the U.S. swine herd through coordinated global disease monitoring, targeted research investments that minimize the impact of future disease threats, and analysis of swine health data.[49] A USDA Foreign Agriculture Service grant of $1.7 million was awarded to SHIC in 2019, with active support from NPPC. The work will include swine health field projects, including collection and analysis of disease samples, which will help inform North American pork producers about effective ASF preparedness and response. The ultimate goal of the research is to either prevent the emergence of ASF in the U.S. or minimize its impact it once it arrives.

Animal Health and Disease Research program

Section 1433 of the National Agricultural Research, Extension, and Teaching Policy Act of 1977, also known as the Animal Health and Disease Research (AHDR) program, provides the basis for federal funding for research activities into animal health and diseases at accredited state schools or colleges of veterinary medicine or agricultural experiment stations that conduct animal health and disease research.[50] The amount available for support of this program in FY2020 is about $3.7 million.

CLIMATE CHANGE RESEARCH

CLIMATE CHANGE RESEARCH

Climate change is expected to impact food security at the global, regional, and local levels. Climate change can disrupt food availability, reduce access to food, and affect food quality. For example, projected increases in temperatures, changes in precipitation patterns, changes in the frequency and severity of extreme weather events, and reductions in water availability may all result in reduced agricultural productivity.[51] Without action, some estimates suggest climate change impacts could push an additional 100 million people into poverty by 2030.[52] This means it is going to take adaptive research just to sustain current productivity in specific locations, and in some regions farmers will need to modify what they produce. Science-based research is needed to increase resilience of crops to extremes of temperature and precipitation. Public and private research will be vital to help farmers adapt production to climate change.

Since the initiation of international treaties to combat climate change such as the Kyoto Protocol[53] in 1997 and the Paris Agreement[54] in 2015, investments in research and development aiming to make industries more climate-resilient should become a top priority for many large economies, including India and China. Achieving climate-compatible growth will require governments to support low-emission investments and cost-effective climate policies. This should be implemented uniformly and should not place an undue burden on the U.S. economy.

In the U.S., federal funding for climate change research increased from $2.4 billion in 1993 to $11.6 billion in 2014, with an additional $26.1 billion for climate change programs and activities provided by the American Recovery and Reinvestment Act in 2009.[55] The funding focused on technology development to reduce carbon emissions, science to understand climate-related challenges and international assistance for developing countries.[56]

Climate-related challenges for agriculture

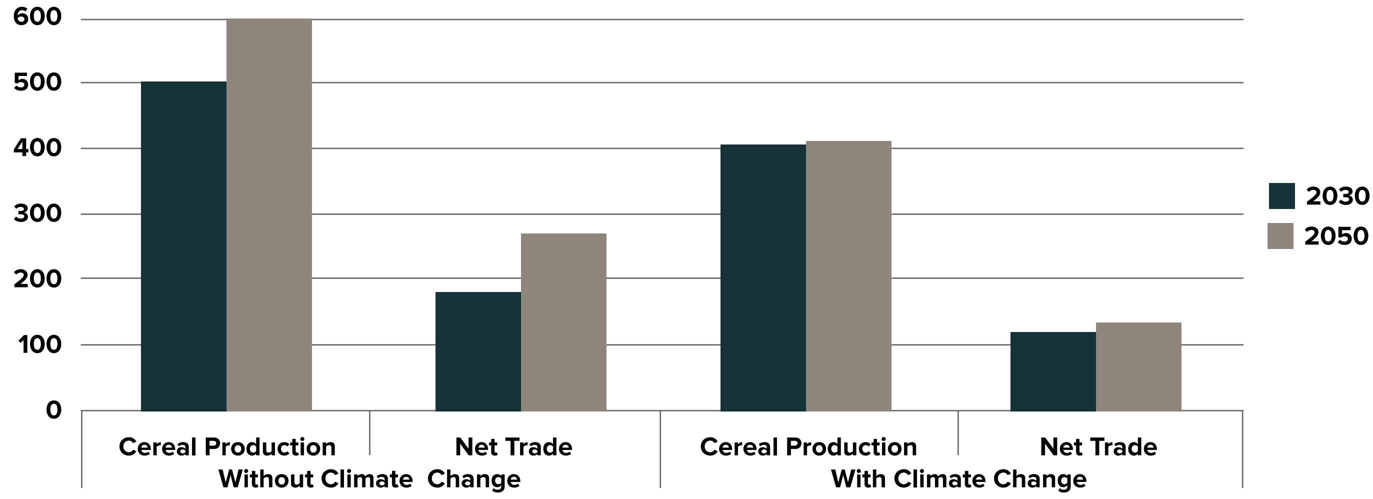
U.S. agriculture plays a crucial role in addressing global food security since over 20% of agricultural output is exported, making the U.S. one of the largest exporters of agricultural commodities in the world. To understand the extent of climate-related challenges for agriculture, one could look at cereals – one of the most produced and heavily traded commodities by the U.S. – as an example. Illustrated in the chart below, global impact studies estimate that without any adaptation effort, climate-related events have the potential to reduce cereal production in the U.S. in the coming decades. Should this occur, net agricultural trade has the potential to also decline substantially and potentially increasing food costs for people in developing countries.[58]

As a net exporter of staple crops, U.S. agriculture exports cereals to many developing and low-income countries such as Mexico and the Philippines that depend on a robust agricultural supply chain to avoid food insecurity. The impact of sustained annual weather disruptions on U.S. cereal production, as just one example, has the potential to impact global food insecurity. A reduction in cereal production will also impact livestock, as less animal feed is made available, directly affecting weight gain (i.e. livestock yield).[59]

Economic losses caused by soil erosion

Agriculture is obviously vulnerable to changing weather and thus more frequent floods, droughts, heat waves etc. can affect crop yields while reducing land productivity due to soil erosion and desertification.[60] Soil health is one of the most crucial factors in maintaining an agricultural value chain as soil quality, among other considerations (e.g. fertilizer use), determines the productivity of cropland. Soil erosion caused by water runoff or wind degrades the availability of nutrients needed

Figure 14: Impact of climate change on U.S. food production & trade, by 2030 and 2050 (million mt)



Source: IHS Markit, IFPRI

for a good yield. Currently, the average rate of soil erosion from agricultural fields around the world is more than 100 times higher than the soil formation rate. [61] As a result, global economic losses from soil erosion are estimated to have reached $400 billion per year.[62]

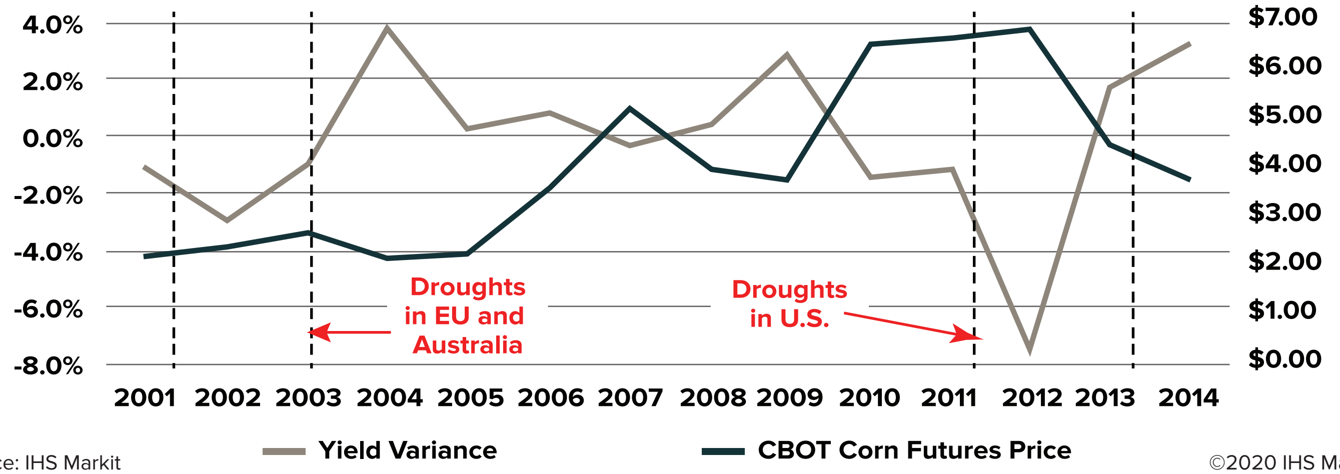
Price variation caused by adverse weather events

According to the fifth IPCC report and 2019 NASA report on global climate, climate risks from extreme and rare events such as heat waves, excessive precipitation, coastal flooding and limited water availability are already moderate and will likely be higher with 1.5 °C (2.7 °F) additional warming. This raises a growing concern as weather events caused by a changing climate have disrupted yields, crop prices, and global trade. For example, analysis illustrated in Figure 15 on corn production – an important global crop – shows that 56% of extreme weather impacts caused a variance of >10% decline in corn yield. Futures prices were impacted as a result of a decline in corn production and increasing demand for renewable fuels driving up prices. Due to finite acreage availability, and increasing Chinese demand for soy, similar relationships between yield, trade, and prices were seen for other crops such as wheat and soybeans. A decline in corn production can lead to significant price increases among its crop substitutes (e.g. wheat and sorghum). Price disruptions caused by more frequent and unpredictable weather events will likely lead to a long-term shift in affordability of staple crops with increased investment in agricultural research to build more resilient crop production systems.

Agricultural R&D as a climate solution

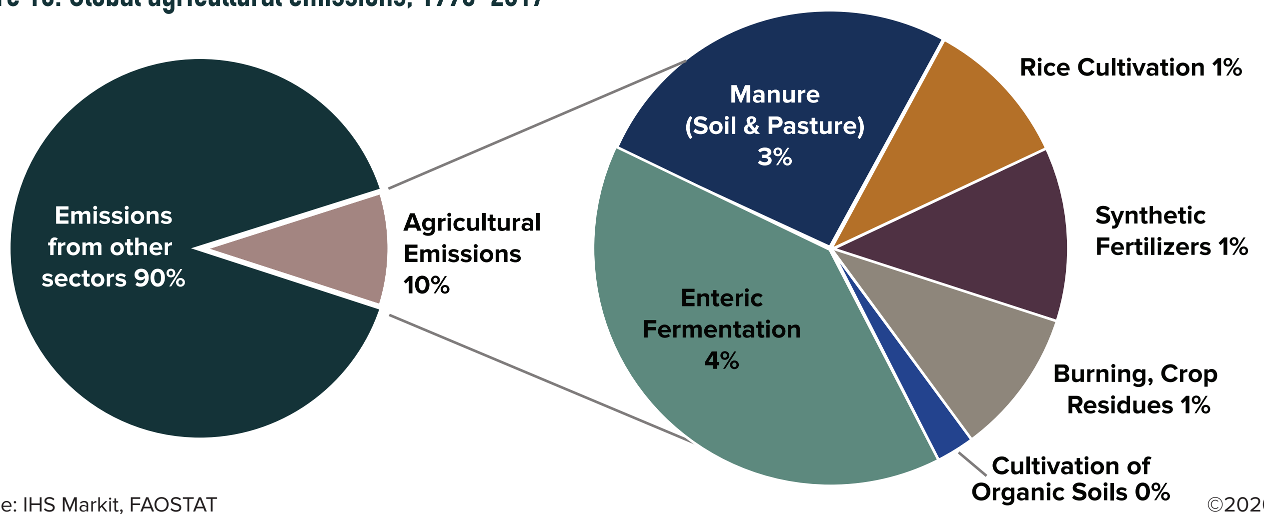
Agriculture is affected by climate change but can also become part of the solution through climate adaptation and mitigation technologies. Accelerated investments in climate-related R&D by the public sector and public-private partnerships are greatly needed. CO_2 emissions from global agricultural production currently account for 11% of direct global greenhouse gas emissions,[63] with 65% from the livestock sector and 35% from crop production, as shown in Figure 16. The agriculture sector has a major opportunity to offset and sequester carbon effectively through the adoption of more efficient technologies and farming practices developed through publicly funded research.

Figure 15: Impact on global corn production and prices due to yield variance caused by extreme weather events



Source: IHS Markit

Figure 16: Global agricultural emissions, 1990–2017

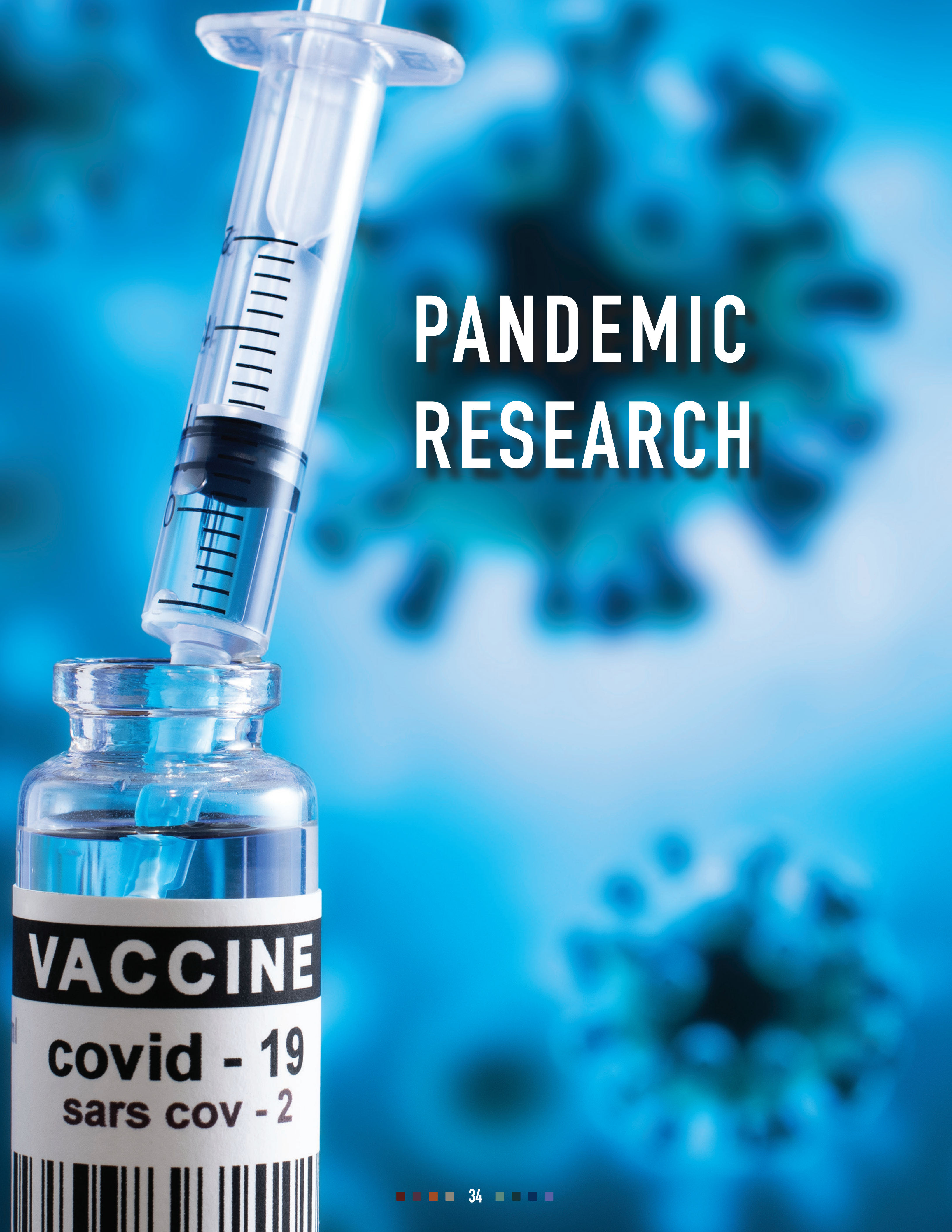


Source: IHS Markit, FAOSTAT

Public funding efforts made by NIFA for climate change-related research and development are playing a crucial role in finding adaptive and mitigating solutions to reduce emissions. Below are examples of NIFA funded program activities:

- Assessment of climate change impact on water and crop resources in the Black Belt Region of Alabama: Initiated in 2014, Tuskegee University proposes to predict climate change at the local level; quantify impacts of historical and future climate change on water quality and quantity and identify adaptation options to climate change for end users in Black Belt counties. Geospatial data will be assimilated into assessment tools to establish baseline conditions and forecast the impacts of climate change on water availability, quality and agricultural production at a county level.
- Assessment of benefits from conservation tillage during drought years in the Midwest Region: Initiated in 2014 by Indiana University, the project investigates the effect of tillage management on nutrient cycling, water budget, and crop productivity during drought years. Tillage management refers to preparation of soil to grow crops (e.g., digging, stirring and overturning). This will be done by collecting satellite images taken during the past 10-15 years to determine the distribution of tillage practices. Further analysis of the data will determine how tillage practices affect the response of crops to summer droughts of varying intensity. The results will inform farming practices that mitigate climate-related risks (i.e., droughts).

PANDEMIC RESEARCH



PANDEMIC RESEARCH

External shocks, such as COVID-19, have exposed the vulnerability of the global agricultural system. The COVID-19 pandemic has adversely impacted the U.S. economy, including the farm sector and farm households. The farm sector has experienced disruptions to production due to reduced availability of labor and other inputs, and reductions in output prices resulting from decreases in demand for commodities in certain market segments.

Prior to COVID-19, half of all food sales normally flowed through institutions like restaurants and dormitories, and half through grocery stores and supermarkets. When COVID-19 forced the sudden shutdown in March 2020, the supply chain was not prepared to suddenly redirect a significant fraction of what had been flowing through institutional outlets to grocery stores.

As a result, COVID-19 has impacted the whole U.S. agricultural supply chain. Reductions in farm labor and labor in processing plants have affected both crop and livestock production and processing capacity for crop and animal products (e.g., meat processing plants). Reduced processing capacity results in lower availability and higher prices to the consumer and reduced prices to farmers because of processing capacity constraints due to outbreaks of COVID-19 among meatpacking workers.

Meat industry workers across the world have been disproportionately impacted by COVID-19, with over 42,000 workers in the U.S. alone contracting the virus through September 2020.[64] Slaughterhouses and processing facilities have been forced to close or reduce capacity in "response to labor shortages and social distancing requirements".[65]

Although these downstream shocks originate outside of production agriculture, they manifest themselves in the prices that farmers receive for the products they produce and adversely impact farm income. Farm households have also been impacted through the loss of wages and benefits (such as health insurance) from off-farm labor that they use to fund farm production needs, household living expenses, investments, and payments on farm business debt.[66]

USDA and other agencies have established a number of programs to support farm income in the wake of the pandemic. Farm households can also have access to federal, state, and local programs to support traditional off-farm income streams disrupted by COVID-19. The Coronavirus Food Assistance Program 1 (CFAP 1) provided vital financial assistance to producers of agricultural commodities, giving them the ability to absorb sales losses and increased marketing costs associated with the pandemic. CFAP 1 was launched in May to provide $16 billion in direct payments to farmers. USDA is providing an additional $13.2 billion under CFAP 2 for agricultural producers who continue to face market disruptions and associated costs because of COVID-19.[67]

Research on responding to and handling of pandemics is very limited since they occur infrequently. Instead research has been focusing on farm animal health and productivity. In a report from USDA's National Agricultural Library spanning 2007-2012, all research reported under the category of Influenza Pandemic Preparedness dealt with animal production concerns rather than concerns with the supply chain. In a similar way, in a recent wave of pandemic research funding totaling $3.6 billion, only $10 million is specifically earmarked for research into worker safety.[68]

According to a group of experts from French animal health company Ceva Santé Animale, many governments have slashed funding to infectious disease and public health research, making it difficult for scientists to secure financial support to investigate zoonotic pathogens.

Ceva's global director of biology R&D, Dr. Zoltan Penzes, said although coronaviruses are not a new phenomenon, public awareness has been low and human coronaviruses have not been a priority. Despite early warnings about the COVID-19 pandemic, preparedness for infectious disease emergence has been inhibited by a serious funding deficiency.

Pandemic challenges

The impact of COVID-19 on people involved in the agricultural sector can be split into those involved in the harvest and processing of agriculture and food products (the supply chain), and consumers and the impact on purchase behavior, packaging needs, and distribution challenges. Indirect impacts of the pandemic have also been large. For example, lockdown mandates severely depressed gasoline demand, which in turn damaged ethanol demand. As almost 40% of the U.S. corn crop is used for ethanol production, the pandemic-related drop in gasoline consumption was a severe blow to demand for U.S. corn for much of the spring in 2020. At the highest level, research into resilience in the food supply in the context of the ongoing pandemic is an issue of national security and should rise to the highest level of importance.

While generally there has been a near-term flood of public and private research dollars going to coronavirus medical research, the true long-term commitment is less obvious. Recently, Jean-Pierre Bourguignon, the interim president of the European Research Council (ERC), stated that their budget was being threatened by a 10% cut from numbers agreed to in May 2020.[69] Some of the European cutback is associated with the economic realities of the pandemic and the loss of specific funds coming from the U.K. as it is no longer part of the E.U.

The SARS outbreak in 2002-2004 was estimated to have had a global impact of roughly $40 billion,[70] while COVID-19 has already cost the U.S. government several trillion dollars and will cost the global economy many multiples of that. A new estimate from two Harvard economists puts the cost at $16 trillion to the U.S. economy alone.[71] SARS has had some similarities to the current coronavirus but as we have learned it did not spread through airborne transmission in the way that COVID-19 does. As an example of how research is stimulated by an outbreak, over 4,000 publications resulted from the SARS outbreak, with the focus being research of the epidemiological, clinical, pathological, immunological, virological, and other basic scientific aspects of the virus and the disease. SARS infected 8,096 people in 29 countries and 774 died from the virus. The death ratio of 1 in 10 was dramatic, but the fact that only 8,096 people were infected worldwide means that SARS pales in comparison to COVID-19.[72, 73]

U.S. research into food supply chain resilience

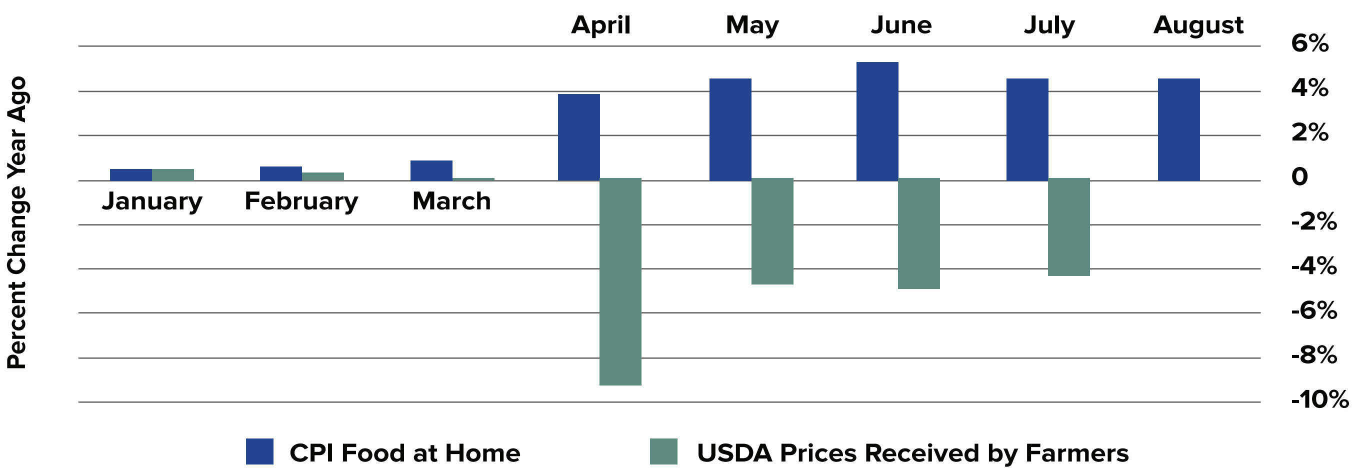
The ultimate impact and costs of COVID-19 will be measured in many ways, but as one indication of its impact on U.S. agriculture and the cost of food at home for the nation, Figure 17 shows U.S. food prices and prices received by farmers. The gap between them can be looked at as a measure of the disruption to the food supply chain.

A rough measure for food inflation for food consumed at home is that a 1% increase for one month costs U.S. consumers an additional $650 million and a 1% decline in the price received by farmers for one month costs U.S. farmers $304 million. Using these figures over the period April through July 2020, U.S. consumers spent an additional $9.7 billion in food and farmers lost $7 billion in revenue. This calculation is an oversimplification, but nonetheless demonstrates the significant cost of COVID-19 to agriculture and food supply chain disruptions and highlights the fact that more research is needed in this area.[74]

Recent medical and zoonotic research suggests that the animal channels can be the flash point[75] for pandemics such as COVID-19. While the current pandemic has been more disruptive than most anyone imagined, its magnitude is no protection against more serious events in the future. This fact alone supports the need for significant funding now and into the future.

Because pandemics cannot be readily predicted, as they could happen this year or 10 years into the future, the private sector's willingness to commit to sustained long-term research on pandemics is very limited. When you compound the way that many benefits from such research would be distributed, particularly aspects that deal with worker safety and the welfare of the general public, the private sector is highly unlikely to fund pandemic research at an adequate level. That is why public research will be vital to responding to pandemics.

Figure 17: U.S. price of food at home versus prices received by farmers



Note: January 2020 = 100

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CONCLUSION

Over the next several decades, there will be an increasing need to improve yields and production efficiency to feed a growing global population without causing irreparable damage to the environment. Climate change, pandemics, animal diseases, and crop pests and crop diseases all pose potential threats to the global agricultural economy. The stagnation in U.S. public spending on agricultural R&D will have negative implications for agriculture. While private funding for agricultural research is beneficial, public funding is needed to complement private sector investment; for potential partnerships with the private sector to harness specialized research capacity to address high-priority issues; to lead in areas where the payoff from research investment is too uncertain or too far in the future to attract private investment; for research on minor crops that do not offer a large enough potential market to attract private investment; and to help to meet broader social, environmental, health, and sustainability goals that benefit both society at large and farmers. The need to increase funding for public research is highlighted in this report as follows:

Crop-breeding research

The agriculture industry will need to increase productivity through crop breeding to satisfy growing demand for nutritious food, fiber, and animal feed in a highly variable climate, and mitigate the effects of agriculture on the environment. The public and private sectors will need to work together to improve crop yields. As indicated earlier, there are increasing investments in gene editing by the private sector. But, public expenditures on agricultural research and development in many high-income countries have stagnated and may be declining.[76] This is a clear case where additional publicly funded research is needed to support the public interest.

Crop protection research

U.S. public funding of agricultural research and development provides support for a wide range of technologies and approaches for crop protection that can be widely disseminated to agricultural producers across the nation. The funding and programs are often complementary to the commercial crop protection sector and can provide the basis for new commercial opportunities. With the challenges facing the commercial chemical crop protection industry, additional public support for agricultural research and development can help to ensure that agricultural producers have access to the latest knowledge and technology for crop protection. Public research funding can also help to meet broader social, environmental, health, and sustainability goals.

Animal health research

Private R&D efforts in animal health tend to focus on commercially useful applications[77] and target ventures likely to generate commercially viable, patentable products and technologies.[78] Publicly funded research forms the basic foundation for many of these applications. With the projected increase in animal protein demands and per capita consumption, the production and productivity of animal agriculture becomes vital and this can only be achieved when the animals are healthy and disease resistant. In the wake of new and emerging diseases that affect animal health, research areas to combat them becomes essential. Those research areas might be risk prone, take time to show results and are not likely to be profitable for private research to tackle, and thus more resources for publicly funded basic research is vitally needed.

Animal disease and foodborne illness research

The U.S. faces the challenge of needing to be prepared for diseases that are rare, exist in other countries or have not yet been identified. Outbreaks of FMD, PEDv, and ASF have all had significant impacts on livestock industries and in turn the economy. The continuing threat of FADs and their impact to U.S. food security and the economy emphasize the importance and need for public research funding in order to develop vaccines and treatments to improve public welfare.

Climate change research

Extreme climatic events, both temperature and rainfall, are becoming more frequent. This means it is going to take adaptive research just to sustain current productivity in specific locations, and in some regions farmers will need to modify what they produce. Accelerated investments in climate-related research by the public sector and public-private partnerships are greatly needed to help agriculture adapt to climate change.

Pandemic research

From a private sector standpoint, researching pandemic issues that have very low probabilities of occurrence and/or have impacts or benefits that are outside a company's ability to capture return on their specific research investment are given very low priority for funding. These issues are almost by definition best suited for public sector research spending. But at the same time public-private partnerships are needed to harness specialized private sector research capacity to address high-priority issues as they arise (along the lines of public support that has flowed to pharmaceutical companies to develop the COVID-19 vaccine).

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