



# The Challenge of Change

Harnessing University Discovery, Engagement, and Learning to Achieve Food and Nutrition Security



ASSOCIATION OF  
PUBLIC &  
LAND-GRANT  
UNIVERSITIES



## Association of Public and Land-grant Universities

APLU is a research, policy, and advocacy organization dedicated to strengthening and advancing the work of public universities in the United States, Canada, and Mexico. With a membership of 236 public research universities, land-grant institutions, state university systems, and affiliated organizations, APLU's agenda is built on the three pillars of increasing degree completion and academic success, advancing scientific research, and expanding engagement. Annually, member campuses enroll 4.9 million undergraduates and 1.3 million graduate students, award 1.2 million degrees, employ 1.2 million faculty and staff, and conduct \$43.8 billion in university-based research.

The Challenge of Change was supported by the W.K. Kellogg Foundation and APLU's Board on Agriculture Assembly.

### COVER PHOTOS

Bottom left: Uttam Kumar of CIMMYT testing the Field Book app at the USAID Kansas State University Feed the Future Innovation Lab for Applied Wheat Genomics trials, Borlaug Institute of South Asia, Ludhiana, India. Photo credit: Haley Ahlers, Kansas State University


Bottom middle: Stephanie Elwood, Extension Associate teaching the students at Bridge Academy how to grow a plant the correct way and how to eat healthy as part of the Growing Healthy Initiative. Photo credit: Southern A&M University

Bottom right: Professor Evan Fraser, Director of the Food Institute, meets with students in the Feeding 9 Billion program. Photo credit: University of Guelph

# Table of Contents

Executive Summary	1
Introduction	11
The 7 Challenges for Public Universities to Address to Help Achieve Global Food and Nutrition Security	25
Institutional Transformation for Public Research Universities to Meet the Challenges	95
Conclusions and Next Steps	119
Definitions	127
Commission, Working Groups, and Invited Expert Memberships	131
Notes	137



A young student with dark skin and hair is looking down at a large, green leafy vegetable, possibly bok choy, which they are holding. The student is wearing a grey polo shirt with a blue logo that says "BRIDGE ACADEMY" and a colorful beaded necklace. The background is a brick wall. A text box in the upper left corner contains the following text:

*A student learns about healthy eating and caring for plants through community engagement programs from Southern A&M University.*

PHOTO: SOUTHERN A&M UNIVERSITY

# Executive Summary

## The Challenge of Change: Harnessing University Discovery, Engagement, and Learning to Achieve Food and Nutrition Security

Achieving domestic and global food and nutrition security—when all individuals have reliable access to sufficient quantities of affordable, nutritious food to lead a healthy life—is truly a grand challenge and one of the most pressing issues of our time.

The world has a food and nutrition problem. The Food and Agriculture Organization (FAO) of the United Nations estimates 795 million people, 11 percent of the global population, were unable to meet their dietary energy requirements in 2014–16. Globally, about one in eight people do not have enough food for an active and healthy life. With an additional 2.6 billion expected to inhabit the world by 2050, FAO estimates there is a need to increase food production 60 percent to meet the challenge. The search for sustainable food and nutrition security solutions will grow even more complicated, particularly against the backdrop of limited access to clean water, finite land for agriculture production, climate change, and evolving diets that demand more high-value food products.

Food insecurity varies in its nature and severity, but it is not confined to low-income nations. For example, the U.S. Department of Agriculture (USDA), reports 12.7 percent of U.S. households were food insecure in 2015, representing 42.2 million people. Food insecurity exists in every county in the United States, ranging from a low of 4 percent in Loudoun County, Virginia to a high of 38 percent in Jefferson County, Mississippi.

Food insecurity includes the double burden of both under- and over-nutrition, both of which can result in insufficient consumption of nutrients for a healthy lifestyle. In North America, obesity as a result of over-nutrition is reaching epidemic proportions, with the United States, Mexico, and Canada experiencing some of the highest obesity rates in adults and children in the world. The Milken Institute estimates the annual cost of obesity to the U.S. economy is \$1.4 trillion in health costs and lost productivity.

The challenge is multidimensional, multinational, and meeting it requires accelerated and coordinated contributions from multiple areas of expertise in both the public and private sectors.

Public research universities have decades of experience, broad-ranging subject matter expertise in hundreds of countries, and are uniquely equipped to tackle food, nutrition, agriculture, and environmental issues. They have been powerful problem solvers and are recognized for outstanding accomplishments in global food and nutrition security. If we are to solve this grand challenge, public research universities must play a unique role in addressing and solving the complex issues at hand.

But public research universities alone will not solve the global food and nutrition security crisis. It will be important to partner with public and private entities in agriculture, public health, nutrition, health care, and beyond.

Government resources will also be critical to solving the challenge of ensuring food and nutrition security for all. This report does not attempt to quantify the amount of government resources required—it is clear budgets are tight. But over time, substantial government resources and increased collaboration across agencies and disciplines will be required. These resources should come from coordinated efforts by multiple agencies through a “whole-of-government approach,” as well as through collaboration by governments across borders, because the challenges to be addressed (i.e., production, food safety, nutrition, health, and others) are of concern to multiple agencies and cross borders.

## What if we do not act? The World in 2050

In 2017, leaders were aware of the projections of food and nutrition insecurity, population growth, and impacts of climate change, but they did little. Public research university budgets related to food and nutrition security (state, national, and global) were flat-funded or reduced, recommended public policy change stimulated little action, and only a few U.S. foundations or private sector companies showed interest in this issue.

Food loss and waste remain high. Crop, livestock, and fisheries yields have not increased fast enough to meet growing demands. As a result, more lands and oceans have been brought into production. Tropical rainforests have been converted to soybean and corn production, the Serengeti is lost to wheat, and regional conflicts over water have accelerated. The tight relationship between food supply and demand, coupled with extreme weather events, creates persistent instability of global food markets, resulting in food shortages worldwide. This spiral of events has caused unrest and increased migration from rural to urban areas and low- to high-income countries, placing increasing pressures on global political and social stability.

In North America, food insecurity continued to affect child development and the annual health related costs of obesity have become greater than the interest on the national debt. The costs of global humanitarian and other interventions now consume an increasing portion of high-income countries national budgets, including that of the United States. Low-cost solutions to solving the challenges are gone.

This is not a far-fetched scenario—action is needed now to ensure we can sustainably and nutritiously feed the world of 2050.



Food is central to human existence. Robust food systems enable productive and vibrant societies. Productive and sustainable agriculture systems lift people out of poverty and into food security while poorly functioning food systems create food insecurity that can ignite social and political instability.

Finding solutions to achieve the grand challenge of sustainably feeding an expanding population and improve prospects for food and nutrition security for all is pivotal for human existence. Better health and longer lives, economic growth and opportunity, improved environmental sustainability, and of course, stronger security and greater stability—all are among the benefits of access to and utilization of affordable and nutritious food.

## The Purpose of the Commission

The Association for Public and Land-grant universities (APLU), is an association of more than 230 public research universities and systems in the United States, Canada, and Mexico and is dedicated to strengthening and advancing the work of public universities.

APLU established the Challenge of Change Commission with funding from the W.K. Kellogg Foundation. The 34 Commission members included university leaders, subject matter experts, and current and former private and public sector officials from the United States, Canada, and Mexico. In addition to the Commission members, more than 100 individuals from universities, the public and private sector, and non-governmental organizations were engaged in the project as members of interdisciplinary working groups or expert advisors. Similarly, more than 75 organizations were invited to provide comment and feedback throughout the process.

The objectives of the Commission were to:

- Identify the key challenges that public research universities, working with their partners, can successfully address to advance food and nutrition security in North America and the world.
- Recommend how universities can best organize themselves and mobilize their resources to more effectively address the challenges; and
- Identify next steps to further explore how to enhance and align private and public sector resources, including substantial government resources, to foster innovative solutions to the identified challenges.



*Promoting the Family Nutrition Program, which was setup at the Ag and Gardening Day at the University of Florida Stadium.*

PHOTO: UF/IFAS COMMUNICATIONS

# The Challenges of Achieving Food and Nutrition Security

Traditionally, the effort to achieve food security has been largely focused on the need to increase yields in order to produce more food. There is now broad recognition that production alone will not solve the grand challenge. All aspects of our food systems must be considered: nutrition, food safety, food loss, economic costs, individual behaviors, incentive structures, and societal factors affect not only production, but also access and utilization. There is also now an understanding that production increases must be achieved in the context of water availability, energy limitations, and environmental impact.

## THE GRAND CHALLENGE

**Sustainably feed an expanding population and improve prospects for food and nutrition security for all**

### The 7 Challenges for Public Universities to Address to Help Achieve Global Food and Nutrition Security

#### Availability



##### Challenge 1

Increase yields, profitability, and environmental sustainability simultaneously



##### Challenge 2

Develop the varieties and breeds needed for sustainable food systems



##### Challenge 3

Decrease food loss and waste through more efficient distribution systems

#### Access



##### Challenge 4

Create and share resources that serve all populations



##### Challenge 5

Ensure inclusive and equitable food systems

#### Utilization



##### Challenge 6

Address the dual burdens of undernutrition and obesity to ensure full human potential



##### Challenge 7

Ensure a safe and secure food supply that protects and improves public health



The availability, access, and utilization of food and fiber must be achieved with greater efficiencies and less impact on the environment. It must also be achieved with methods that support long-term productive capacity in a supportive policy environment. In short, there must be an integration of disciplinary strengths to unravel the complexity of interactions in the food system. This transdisciplinary approach to problem solving requires the involvement of a range of expertise including the biophysical, medical, information technology, social sciences, and engineering. This approach underpins the recommendations of this report and is critical to solving the challenges identified.

The Challenge of Change Commission identified seven challenges where universities and their partners are particularly suited to make critical contributions to solutions. The Commission calls on public research universities to draw on their core and interrelated functions of discovery, engagement, and learning to address these challenges.

All challenges are categorized within the organizational scheme of availability, access, and utilization, with the fourth component, stability, woven throughout.

## **The Key Roles of Public Research Universities and the Challenge of Change**

North American public research universities are uniquely positioned, in collaboration with public and private partners, to make critical contributions toward sustainably feeding an expanding population and to improve prospects for food and nutrition security for all. They can do so through research and technological innovation; engagement with local communities and outside partners; and training students to be the next generation of problem solvers. All relevant disciplines are present at public research universities and, with adequate resources and funding, universities are able and willing to undertake this important work.

## **The Challenge Approach is Working**

Many public research universities are currently strategizing and reorganizing, using challenge-based approaches to address critical societal issues. The challenge approach encourages coordination of disciplinary strengths and achieves commitment at a higher level to solving the most complex and pressing problems of a changing world. These universities have moved from discipline-focused research to transdisciplinary research—research conducted by investigators from different disciplines, working jointly to create new conceptual, theoretical,

methodological, and translational innovations that integrate and move beyond discipline-specific approaches to address the higher level challenges of our time.

These universities have captured both internal and external funds for key issues and created centers and other institutional structures to pursue knowledge creation, dissemination, and innovation. Collaboration includes not only partnerships within, but among universities. Strategies include creating exciting curricula and training the next generation of professionals to solve complex societal problems that relate to more than one discipline. The resulting innovations emanating from public research universities have been recognized by external sources as exceeding those of the most outstanding private universities.

## Conclusions of Report

Public research universities are uniquely positioned to respond to the challenge of meeting global food and nutrition needs by 2050. Solutions to the problems of global food insecurity are attainable by employing university discovery, engagement, and learning strategies in the seven challenges identified by the Challenge of Change Commission. However, universities will also need to change in the following ways:

- Elevate Food and Nutrition Security to a Top Priority
- Align University Resources and Structures for Transdisciplinary Approaches
- Enhance and Build University-Community Partnerships
- Educate a New Generation of Students to be Transdisciplinary Problem Solvers

The challenges of achieving food and nutrition security will need to be addressed in the context of interrelated issues and requires contributions from experts across disciplines. This transdisciplinary approach, while not traditional, is critical to addressing the complex problems. Specific attention will need to be paid to:

- Broaden the Focus Beyond Yields
- Change the Food System's Incentive Structure
- Develop the Capacity of Universities in Low-Income Countries
- Leverage Technology, Big Data, and Information Science Information

Government leadership will be required for a national vision that gives top priority to the challenge of food and nutrition security, but specific solutions will come from partnerships across sectors. Universities must work with and have the support of key partners to undertake this work.



PHOTO: UNIVERSITY OF MINNESOTA

*University of Minnesota Extension SNAP-Ed and 281 partners, like Echo Food Shelf, helped nearly 40,000 people make healthy food choices.*

# Next Steps for Implementation

The challenges of food and nutrition security are embedded in complex systems and solutions require a transdisciplinary approach.

On that basis, this report recommends the following next steps:

## 1. APLU ACTION

The Commission recommends APLU plays an important role in fostering discovery, engagement, and learning activities among public research universities, which should include individual institutions, groups of universities, and their partners in order to achieve domestic and global food and nutrition security. This will require a major, sustained effort by APLU.

The Commission recommends APLU and its members further develop recommendations for reducing institutional barriers to transdisciplinary research.

The Commission recommends APLU, in close coordination with its members, develop and undertake advocacy efforts in support of this report, including making funding recommendations, as appropriate.

## 2. U.S. “WHOLE-OF-GOVERNMENT” ACTION

With enactment of the Global Food Security Act (GFSA) in July of 2016, Congress required the administration to develop a “whole of government approach” to combat global food insecurity and authorized appropriations for such programs for fiscal years 2017 and 2018. The pending reauthorization of the legislation provides an opportunity to build on the progress already made as a result of GFSA and act on the recommendations of the Commission. Similarly, with the Farm Bill due for reauthorization, Congress will have the opportunity to expand the U.S. Department of Agriculture’s commitments to global food security and expand the Department’s partnership with U.S. universities.

APLU and its member universities will advocate to policymakers for a “whole-of-government” approach within the federal government. A whole-of-government effort would encourage multiple federal departments and public agencies to work across their portfolios to achieve a significant goal. Such an approach would help to focus existing resources and should allocate new resources, given the critical importance of domestic and global food security.

An explicit goal of the whole-of-government approach—in collaboration with the university community and stakeholders, including the private sector—must be to mobilize private sector and foundation resources to address the challenges. Given the current federal budget constraints, it is important to make the case for resources to tackle these consequential issues.

### **3. MEXICAN, CANADIAN, AND U.S. GOVERNMENT JOINT ACTION**

The Commission also recommends the governments of the United States, Mexico, and Canada together sponsor collaborative research partnerships with universities and their partners to advance the recommendations of this report.

The Commission recommends the Canadian and Mexican governments work, as appropriate, with their universities and research entities to advance the recommendations of this report in their respective countries.

### **4. PUBLIC RESEARCH UNIVERSITY ACTION**

In connection with current processes being undertaken on public research university campuses, the Commission encourages public research universities and their partners to individually and as consortiums of universities, to identify challenges and related activities in this report that they might undertake. As noted above, APLU has an important role in fostering this work.

The Commission also recognizes that public research universities alone will not solve the global food and nutrition security crisis. As universities work on the challenges, it will be important to partner with public and private entities in agriculture, public health, nutrition, health care, and beyond.

## **The Time for Innovation and Investment is Now**

Global investments in food and nutrition security have languished for decades and the world food crisis in 2007–2008 is a harbinger of what the future may hold if this grand challenge is not resolved. Investments are still inadequate in light of future projections.

Developing new approaches to sustainably feeding an expanding population and improving prospects for food and nutrition security is an urgent necessity, not an option. If nothing changes, national security will be at risk, and future costs of military and other interventions to address global volatility will skyrocket beyond the capacity of national budgets. Failing to make forward-looking investments now and to bring more partners to the table to work on these issues will mean lower-cost research and development-based options will disappear and be replaced by high-cost crisis intervention, instability, food insecurity, and social unrest.

Attending to the grand challenge of food and nutrition security is pivotal. It must be a top priority of policy makers, governments, and the private sector because it is closely linked to other social issues and goals. National security and stability, health and human capital, the safeguarding and enhancement of environmental resources, the alleviation of poverty, economic growth and opportunity, the survival of children, gender equity, and fostering democratization—all are made possible by availability of, access to, and utilization of, an affordable food supply, or foiled by its absence.





*The Cornell Alliance for Science conducts public outreach to ensure that small-holder farmers like Mike Kamiya, a third-generation farmer in Hawaii, have the right to grow crops that can help them survive, such as papaya genetically engineered to resist the deadly ringspot virus.*





*Scientists at the Borlaug Institute for South Asia (BISA) in Jabalpur, India using the Field Book app to record data in a wheat breeding trial.*

PHOTO: JESSE POLAND

# Introduction

## The Grand Challenge of Global Food and Nutrition Security

One of the greatest challenges facing humanity today is how to sustainably feed an expanding population while improving food and nutrition security for all. The Food and Agriculture Organization of the United Nations (FAO) estimates 795 million people, 11 percent of the global population, were unable to meet their dietary energy requirements between 2014 and 2016. Globally, about one in eight people do not have enough food for an active and healthy life. The vast majority of hungry people, 780 million, live in developing regions, where the prevalence of chronic undernourishment is estimated at 13 percent.<sup>1</sup> While global leaders and international development bodies have made progress to reduce chronic and transitory food insecurity, malnutrition, and hunger, more must be done. A lack of reliable access to sufficient quantities of affordable, nutritious food exacts a toll on individuals, families, and societies and constrains economic, social, and political development, and global peace prospects.

A report by the Food and Agriculture Organization of the United Nations (FAO), the World Food Programme (WFP), and the European Union reports 40 million people are acutely food insecure across seven countries in Africa and the Middle East due to conflict.<sup>2</sup> Acute food insecurity can spark political instability, forming a dangerous combination of forces that often indicate national and global inequality. These global events can lead to threats to U.S. national security strategy by disrupting global trade, inspiring insurgencies or civil wars, displacing individuals, or creating ungoverned spaces.<sup>3</sup>

While the statistics on food insecurity worldwide are stunning, it is important to note that food insecurity is not only an issue in low-income countries or areas of conflict. Using a household survey index of food insecurity (a different methodology than that of FAO), the United States Department of Agriculture (USDA), reports that 12.7 percent of U.S. households were food insecure in 2015—a total of 42.2 million people.<sup>4</sup> Food insecurity exists in every county in the United States, ranging from four percent in Loudoun County, VA to 38 percent in Jefferson County, MS.<sup>5</sup>

By 2050, the world's population is projected to increase from 7.3 to 9.7 billion people.<sup>6</sup> This growth will have an enormous impact on the availability of, access to, and utilization of food. An expanding global middle class eating more high-value food products will further strain the global food system. At the same time, both low- and high-income countries have felt significant impacts from overnutrition. Estimates predict that by 2020, chronic diseases associated with



diet will account for two-thirds of the global burden of disease and become the principle causes of morbidity and mortality.<sup>7</sup>

The 17 goals of the 2030 Agenda for Sustainable Development, adopted by governments, businesses, and civil society together with the United Nations, includes Goal 2: “*End hunger, achieve food security and improved nutrition and promote sustainable agriculture.*” The UN document notes that a “*profound change of the global food and agriculture system is needed if we are to nourish today’s 795 million hungry and the additional 2 billion people expected by 2050.*”<sup>8</sup> Experts estimate food and nutrition demands due to the two billion people that will be added to the world population by 2050 will require at least a 60 percent increase in global food and fiber production.<sup>9</sup>

Beyond food production increases, the grand challenge calls for achieving greater efficiencies across the entire food system: reducing food loss and waste; making dietary changes; improving nutritional knowledge and communication strategies; and increasing underserved populations’ access to a nutritious diet. Compounding this challenge, scientific models project climate change and other environmental pressures will further constrain domestic and global food and nutrition security. Clearly more, not less, attention will need to be paid to this complex set of issues if humanity is to flourish, not falter, in the next decades.

Global food and nutrition security affects billions of people across the globe. It has an impact on, and is impacted by other issues including, but not limited to:

- **ENVIRONMENT** - Production systems place stress on water quality and quantity, energy resources, and land and ocean use. Both plant and animal production systems

## ENVIRONMENT



Soil is being lost  
at a rate of

**10-40 times**

faster than the  
rate of formation.

## HEALTH AND HUMAN CAPITAL



The cost of malnutrition in terms  
of lost productivity and health care is

**\$3.5 trillion** or  
**11 percent**

of the global gross domestic product.

Sources: Pimental, D. & Burgess, M. (2013). Soil erosion threatens food production. *Agriculture*, 3, 443–463;  
International Food Policy Research Institute. (2016). *Global nutrition report 2016: From promise to impact: ending*



contribute to greenhouse gases and are implicated in climate change, and conversely, climate change and severe weather events affect production systems and ultimately, food and nutrition security.

- **HEALTH AND HUMAN CAPITAL** - Mental and physical health is compromised by lack of access to proper nutrition, especially during the one-thousand-day window between a woman's pregnancy and her child's second birthday, limiting productivity, output, and earning potential. Malnutrition is a key factor in nearly half of all deaths among children under five. An estimated 2.6 million children every year die because they or their mothers did not get the right nutrition.<sup>10</sup> According to the Milken Institute, although no global estimates of the economic costs of overweight and obesity exist, the cumulative cost of all non-communicable diseases, for which overweight and obesity are leading risk factors, were estimated to be about \$1.4 trillion USD in 2010.
- **POVERTY** - The first of the U.N. Sustainable Development Goals is to eradicate poverty. Poverty's manifestations include hunger and malnutrition, limited access to education and basic services, social discrimination, and exclusion. In a vicious cycle, hungry and malnourished people find it difficult to seek education and work to lift themselves and their households from poverty.
- **STABILITY AND SECURITY** - The absence of reliable access to sufficient quantities of affordable, nutritious food is one of the most immediate threats to national security. As seen in several countries during the global food price crisis in 2008, high food prices and lack of access to food can contribute to political instability and spark new civil conflicts. It is difficult to achieve food security in unstable, conflict-ridden areas.

## POVERTY



**43.1 million**

people in the U.S. (13.5 percent)  
lived at or below the poverty line  
in 2015.

**14.5 million**

of these people are children  
under the age of 18.

## STABILITY AND SECURITY



**21 percent** or  
**172 million**

people are undernourished  
as an effect of conflict.

malnutrition by 2030. Washington, DC: Feeding America. (2016). *Hunger and poverty facts and statistics*; FAO (2013). *The state of food and agriculture*.

## Gardens over Gangs

### *Reducing Violence and Gang Involvement through Hydroponic Urban Gardening*

Texas A&M University is working to generate a culture of peace in violent neighborhoods. The university's Center on Conflict and Development (ConDev) leads research and development initiatives to address the drivers of conflict around the world, including food insecurity and youth unemployment.

In El Salvador, the Center engages youth in urban gardening to prevent them from being recruited by gangs and other criminal organizations. Already, 60 young people who were previously active gang members have moved away from crime and are developing teamwork, social, and agricultural skills. These marketable skills will prepare them to enter legitimate employment rather than turning (or returning) to a life of crime.

The project employs a holistic, science-based approach to youth development. Project activities including interactive workshops, theater performances, and psychological therapy to help

strengthen values related to violence prevention, and seeks to address drivers of violent behavior such as social exclusion and family dysfunction.

These program components are coupled with research and agricultural activities to identify the roots of youth violence. The research component of this project, however, is what sets it apart. Besides being situated at a Tier 1 research institution—Texas A&M University—ConDev is also part of the USAID's Higher Education Solutions Network (HESN). As a member of HESN, ConDev focuses on researching, testing, and accelerating solutions in partnership with local organizations and communities. For this particular project, ConDev has teamed up with the Conflict and Development Foundation, the Food for the Poor, and the New Horizons for the Poor Foundation.

The evaluation component seeks to collect data on the inter-relationship between youth malnutrition, school desertion, and gang recruitment in the target communities; identify the main types of violence affecting youth in the target communities; and determine if participation in the semi-urban hydroponic gardening project and complementary social and cultural inclusion activities reduces youth violence activities and gang involvement.

On its current trajectory, the project could effectively take youth who would have otherwise been a source of violence in their communities, and transform them into productive, valued members of society, serving as a model for urban neighborhoods everywhere.

**Learn more: [condev.org/gardens-over-gangs/](http://condev.org/gardens-over-gangs/)**

PHOTO: CONDEV AT TEXAS A&M UNIVERSITY



*Texas A&M's ConDev Center is reducing violence and gang involvement in El Salvador through urban gardening.*

# The Role of Public Research Universities

Accelerating the potential of the world's greatest scientific and educational resource for food and nutrition security—North American public research universities—is critical to answering the grand challenge of achieving global food and nutrition security. Due to their broad-ranging subject matter expertise, recognized experts, and domestic and global experience, universities are uniquely equipped to respond to the multidimensional obstacles impeding progress toward food and nutrition security globally. Public research universities foster a wide range of disciplines relevant to this complex challenge, and given supportive public policy, adequate funding and incentives, and strategic partnerships with public and private sectors, these institutions can and will more fully engage at home and abroad.

The problems at hand are not simple, nor are they one-dimensional. Solutions will require both disciplinary strength in the biophysical sciences, social sciences, medical sciences, engineering, and others, coupled with the capacity to integrate efforts across disciplines and funding sources. Moreover, with a global food supply, issues related to food and nutrition security cannot be approached solely from a domestic perspective. Consider that the United States exported \$133 billion and imported \$113.5 billion in food commodities in 2015.<sup>11</sup> Public research universities have the qualifications and capacity to simultaneously focus on addressing food insecurity in the United States, Canada, Mexico, *and* beyond. Frequently, food security and hunger alleviation programs have addressed either domestic or international concerns, not both, largely because of competitive funding allocations. A combined approach—long overdue—will strengthen university programs in the United States, North America, and around the world. The future requires leveraging both domestic investments and global partnerships to increase overall food and nutrition security.

## What is Food and Nutrition Security?

Food and nutrition security is when all individuals have reliable access to sufficient quantities of affordable, nutritious food to lead a healthy life.<sup>12</sup> Food and nutrition security has four dimensions that encompass both chronic and transitory (acute) situations:

- **AVAILABILITY:** ensuring sufficient quantities of food are available on a consistent basis from either domestic production or importation
- **ACCESS:** having sufficient resources and access to obtain appropriate foods for a nutritious and culturally appropriate diet

FOOD SECURITY INDICATORS	DIMENSION	
Average dietary energy supply adequacy Average value of food production Share of dietary energy supply derived from cereals, roots and tubers Average protein supply Average supply of protein of animal origin	AVAILABILITY	STATIC and DYNAMIC DETERMINANTS
Percentage of paved roads over total roads Road density Rail lines density	PHYSICAL ACCESS	
Domestic food price index	ECONOMIC ACCESS	
Access to improved water sources Access to improved sanitation facilities	UTILIZATION	
Cereal import dependency ratio Percentage of arable land equipped for irrigation Value of food imports over total merchandise exports	VULNERABILITY	
Political stability and absence of violence/terrorism Domestic food price volatility Per capita food production variability Per capita food supply variability	SHOCKS	OUTCOMES
Prevalence of undernourishment Share of food expenditure of the poor Depth of the food deficit Prevalence of food inadequacy	ACCESS	
Percentage of children under 5 years of age affected by wasting Percentage of children under 5 years of age who are stunted Percentage of children under 5 years of age who are underweight Percentage of adults who are underweight Prevalence of anaemia among pregnant women Prevalence of anaemia among children under 5 years of age Prevalence of vitamin A deficiency (forthcoming) Prevalence of iodine deficiency (forthcoming)	UTILIZATION	

Recreated with permission FAO, State of Food Insecurity in the World, 2013.  
 Original image can be found <http://www.fao.org/docrep/018/i3458e/i3458e.pdf>



- **UTILIZATION:** the appropriate use of food based on knowledge of basic nutrition and care, as well as adequate water and sanitation to prevent foodborne disease
- **STABILITY:** availability, access, and utilization of food

The prevalence of undernutrition as a standalone indicator cannot capture the multidimensionality of food and nutrition security. FAO's report *"The State of Food Insecurity in the World"* presents a suite of indicators describing the four dimensions of food security: availability, access (economic and physical), utilization, and stability (vulnerability and shocks) over time and shows the issue's complexity.

One of the key challenges of discussing food insecurity is the physical and temporal shortage of comparable data at a national level, further compounded by the difficulty of discussing unique contexts of food systems at the national and global levels. The *Integrated Food Security Phase Classification* (IPC) standardizes the severity and magnitude of food insecurity for both chronic and acute manifestations. This approach uses a national consensus-building process to consolidate field evidence, analyze data, and recommend approaches for communication and response. This framework can be an effective means of high-level comparison and decision-making, but its usefulness is limited without broader engagement from stakeholder, government, NGO, and other inter-governmental bodies, along with integration into university and training programs' curricula.<sup>13</sup> While the commission recognizes the distinct drivers that create acute and chronic food insecurity, in this report we will not distinguish between these scenarios except to emphasize that the intensity of shocks and resource access and availability will likely increase without a revolutionary approach to food system management.

Universities can lead the conversation and contribute wide-ranging expertise on the multiple dimensions of availability, access, utilization, and stability, while actively promoting equity and inclusion in discovery, engagement, and learning efforts. Indeed, finding ways for institutions to remove the constraints of global food systems and university operations will help pave the way to successfully feeding the world.

## Challenge of Change Commission Charge and Objectives

The Association of Public Land-grant Universities (APLU), an organization of more than 230 public research universities in North America, established the Challenge of Change Commission, with funding from the W.K. Kellogg Foundation. The Challenge of Change Commission was charged with examining contemporary threats to food and nutrition security and recommending the necessary actions universities should take to accelerate their discovery, learning, and engagement to meet the challenges facing a food and nutrition insecure world.

## Local Institutions, Local and Global Impacts

Three pillars drive the missions of public universities: discovery, engagement, and learning. Those missions often have a focus not only on their local communities, but also in creating education, research, and outreach that reaches beyond borders to provide resources to create a better world.

Many public universities include both the local and global aspects in their mission, vision, or strategic plan, stressing the importance of creating education and research opportunities that lead to positive impacts within their local communities and beyond. The following list includes just a few examples of such language, which reflect those adopted by the majority of North American universities:

- The Ohio State University is dedicated to “creating and discovering knowledge to improve

the well-being of our state, regional, national, and global communities.”

- The University of Washington “provides the context and support for students to reflect on their growth and challenges, and to explore who they are, who they will become, and how they will contribute to communities in Washington State and around the world.”
- UCLA’s “primary purpose as a public research university is the creation, dissemination, preservation, and application of knowledge for the betterment of our global society.”
- The University of Florida is a comprehensive learning institution built on a land-grant foundation. UF is a diverse community dedicated to excellence in education and research and shaping a better future for Florida, the nation, and the world.

A premier example of this commitment to local and global impacts is “The Wisconsin Idea.” The Wisconsin Idea signifies a general principle: that education should influence people’s lives beyond the boundaries of the classroom. Synonymous with Wisconsin for more than a century, this Idea has become the guiding philosophy of university outreach efforts in Wisconsin and throughout the world. You’ll see how the Wisconsin Idea influences the work of the Food Research Institute to better the lives of the citizens of Wisconsin, the United States and the world on page 89.



PHOTO: UNIVERSITY OF WISCONSIN

*Kathy Glass, associate director of FRI, worked with animal sciences professor Jeff Sindelar to ensure the safety of organic meats by developing antimicrobials from fruits and vegetables.*

The 34 Commission members included university leaders, subject matter experts, and current and former private and public sector officials from the United States, Canada, and Mexico. In addition to the Commission members, more than 100 individuals from universities, the public and private sectors, and non-governmental organizations were engaged in the project as members of interdisciplinary working groups or expert advisors. In addition, more than 75 organizations were invited to provide comment and feedback throughout the process.

Research institutes and scientific associations have done much work to study the challenges that must be addressed to create a food secure world by 2050. Building on this work, along with that of previous APLU reports, including the work of the Kellogg Commission on the *Future of State and Land-grant Universities*<sup>14</sup> and the more recent, *Healthy Food Systems, Healthy People*<sup>15</sup> and *Addressing Antibiotic Resistance in Production Agriculture*,<sup>16</sup> this Commission sought to:

- Identify the key challenges that public research universities, working with their partners, can successfully address to advance food and nutrition security in North America and the world;
- Recommend how universities can best organize themselves and mobilize their resources to more effectively address the challenges;
- Identify next steps to further explore how to enhance and align private and public sector resources, including substantial government investment, to foster innovative solutions to the identified challenges.

Historically, public and land-grant universities have been instrumental in solving food and agricultural challenges both at home and abroad. But today's food and nutrition security issues have grown in complexity—they are multidimensional, interdisciplinary, and multinational. They occur in conflict zones around the globe, in areas severely impacted by weather-related shocks, and even on our own campuses.

Universities can respond to the issues affecting global food and nutrition security through the pillars of discovery, engagement, and learning (also commonly referred to as research, service, and teaching). The original Kellogg Commission, in the report, *Renewing the Covenant: Learning, Discovery, and Engagement in a New Age and Different World*, redefined the three pillars to emphasize the interactive nature of the process between the university, its faculty, its staff, its students, and broader society.<sup>17</sup> For these Challenge of Change efforts, we return to the definitions of the Kellogg Commission. The work of this Commission generally, and this report more specifically, represent a strong commitment to university engagement with external stakeholders as a primary vehicle through which universities can realize impact in food and nutrition security. It will be through engagement with and in our communities, business and industry, government, and non-profit organizations that we will be able realize the kinds of goals and intended impacts described in this report.

For the purposes of this report, the terms of discovery, engagement, and learning are defined in the following way:

- **DISCOVERY:** Universities will conduct transdisciplinary research and promote understanding of complex realities and ethics of food and nutrition security to enable evidence-informed, ethics-based decision-making.
- **ENGAGEMENT:** Universities will work with communities as equal partners, defined by mutual respect for two-way transfer of knowledge and expertise. Universities will partner with industry,

governments, organizations, and networks of geographic and interest-based actors to engage in understanding the problems of and solutions for domestic and global food and nutrition security from multiple viewpoints.

- **LEARNING:** Universities will promote the use of knowledge generation, knowledge synthesis, communications, engagement, and implementation in establishing effective pathways to food and nutrition security in both domestic and global contexts.

Existing partnerships between universities and the public and private sectors are in place and can be leveraged to complement public investment. However, universities must better align their resources and structures, incorporate the rapidly expanding array of new technologies, and engage community input to solve these complex problems. The role of government is also central to supporting the public university resource through public investment.

Universities are not without structural challenges that can impede problem solving. A pertinent statement was made at the initial Commission meeting, a variation on one from the third report of the Kellogg Commission,<sup>18</sup> with respect to how universities need to change to address these complex issues: *“The world has problems and universities have departments.”* While systemic change, new funding patterns, innovations in public policy and governance, and unprecedented global partnerships are needed, universities need to change as well. Universities must commit to more community engagement domestically and globally, to break down barriers to transdisciplinary science and innovation, to become more effective problem solvers, and to align their resources and incentive structures to support transdisciplinary efforts.<sup>19</sup>

## Report Organization

In the coming pages, this report presents the findings from members of the Commission and its working groups—more than 100 people total, representing more than 40 universities and members from the public and private sectors—all done in consultation with more than 50 invited experts and 75 organizations representing the international development community, the private sector, scientific associations, commodity organizations, and the university community. In all, over 200 people were engaged in the creation of this report. These outcomes are presented in *Part I: The 7 Challenges for Public Universities to Address to Help Achieve Global Food and Nutrition Security*.

The Commission has also identified institutional transformation that is needed at public research universities in order to tackle these challenges, presented in *Part II: Institutional Transformation for Public Research Universities to Meet the Challenges*.

In *Part III: Conclusions and Next Steps*, the commission presents a path forward.



Throughout the report, you'll find examples from public research universities who are working toward domestic and global food and nutrition security in their discovery, engagement, and learning efforts. Definitions for many of the terms used in the report are included on page 127.

## Who Is the Audience for this Report?

The audience for this report includes:

- University leaders, professionals, and students engaged in innovative discovery, engagement, and learning on university campuses;
- Public policymakers who authorize and appropriate funds for supportive programs;
- Key university partners (e.g., private sector companies, non-government organizations, foundations); and
- Individuals among the general public who care deeply about their fellow humans having adequate and reliable access to sufficient quantities of affordable, nutritious food to lead a healthy life.

All must be aware of the complexity of the issues, the need to collaborate more efficiently, the need to advocate, and the potential for consequences of inaction. Long-term commitment to food and nutrition security and public policies, programs, advocacy, and improvements in funding will be key to sustainable improvements in food and nutrition security.



## Hunger on Campuses

A report about the role of universities in resolving global food insecurity would not be complete without addressing the growing evidence of hunger and food insecurity on many university campuses.

Four campus-based organizations—the College and University Food Bank Alliance (CUFBA), the National Student Campaign Against Hunger and Homelessness, the Student Government Resource Center, and the Student Public Interest Research Groups—conducted a survey of college students on food insecurity between March and May 2016. The study included 3,765 students in 12 states attending 8 community colleges and 26 four-year colleges and universities.

Findings include:

- Consistent with prior studies, 48 percent of respondents reported food insecurity in the previous 30 days, including 22 percent with very low levels of food security that qualify them as hungry.
- Food insecurity occurs at both two-year and four-year institutions: 25 percent of community college students qualified as having very low food security, compared to 20 percent at four-year schools.
- Food insecurity was more prevalent among students of color. In particular, 57 percent of black or African-American students reported food insecurity, compared to 40 percent of non-Hispanic white students.
- More than half of all first-generation students (56 percent) were food insecure, compared to 45 percent of students who had at least one parent who attended college.

Similar research across the 10 campuses of the University of California system found more than 40 percent of students responding indicated a low or very low level of food security.

The data suggest hunger may be more common among college students than in the national population. Hunger affects student performance in school, including reducing the ability to focus in class.

It can force a choice between buying food or books and can result in lower grades or suspended studies.

### *What Are the Drivers of Hunger on Campus?*

Food insecurity among university students is likely not a new phenomenon, but students obligated to full-time work, returning students, financially independent students, and single parents are becoming more common. Indeed, according to CUFBA, 73 percent of students fit the criteria for non-traditional students, and fewer than one in five have parents who cannot pay for all of their college expenses. There are a number of shifts in the university climate leading to greater need. These include rising tuition costs, limited financial assistance availability, and stagnant wages around campuses. Other environmental factors may further contribute: limited food storage space and cooking facilities, limited access hours for the cafeterias that conflict with work schedules, and time constraints for shopping or cooking may lead to coping behaviors such as eating out at fast food restaurants, seeking out free food from events, and an over-reliance on high-calorie, low-nutrient foods. These, coupled with medical insurance unaffordability, may lead to poor long-term health.

### *Three Examples of Fighting Food Insecurity and Hunger on Campus*

#### **THE COLLEGE AND UNIVERSITY FOOD BANK ALLIANCE (CUFBA)**

CUFBA, co-founded by the Michigan State Student Food Bank and the Oregon State University Human Resource Center, is a professional organization consisting of campus-based programs focused on alleviating food insecurity, hunger, and poverty among college and university students in the United States.

CUFBA provides resources to schools and non-profit organizations interested in assisting students. They provide tools and guidance for starting up a pantry, and they connect schools to one another for support and learning.

One tool CUFBA offers is the Campus Food Pantry Toolkit, a guide written for students. It outlines how to assemble leaders across various segments of

campus that represent different perspectives and areas of expertise, how to demonstrate need through surveying and public discussions, how to partner with regional food bank and find a financial sponsor. They further guide students through the process of governance and administrative changes and then model various ways to set up and run the pantry.

Learn more: <http://www.cufba.org/>

### UNIVERSITY OF CALIFORNIA FOOD SECURITY ACTION PLAN

The University of California System funded the UC Nutrition Policy Institute to monitor food security among its students. An immediate grant to each campus of \$75,000 was allocated to enhance access and promote projects for preventative measures. Further, funding has been provided to focus across five areas: on-campus student services and programming, off-campus partnerships and engagement, campus coordination, system-wide coordination, and research and data collections.

UC's plan includes:

- Opening food pantries
- Integrating food preparation and storage into housing design and construction
- Collaborating with state and county registry services for food assistance programs
- Launching campaigns for students on support services and food access awareness
- Providing mobile kitchen services
- Enhancing financial aid communications about housing and food costs
- Mobilizing crisis response teams
- Promoting student- to-student donations to reduce hunger on campus
- Highlighting voucher and financial aid guidelines for on-campus resource access

Learn more: <http://www.ucop.edu/global-food-initiative/best-practices/food-access-security/>

### KENTUCKY HUNGER DIALOGUES “FROM OUTRAGE TO ACTION”

In November 2016, over 120 individuals representing 8 colleges and universities, 15 organizations, and community members from across Kentucky gathered to discuss ways to end hunger and malnutrition on college campuses and in communities. It began with a vision from University of Kentucky faculty, staff, and students who learned about dialogues hosted in other states at the Universities Fighting World Hunger Summit in February 2016.

The university Department of Dietetics and Human Nutrition in the College of Agriculture, Food and Environment and the Kentucky Campus Compact, hosted the event during which participants discussed efforts to fight food insecurity across campuses. With 17 percent of the state population experiencing food insecurity, this was not new concern for many university students. One existing effort is the Hunger Task Force, which brings together farmers, businesses, charitable organizations, faith groups, community leaders, government entities, and other Kentuckians to search for ways to combat hunger.

Learn more: <http://www.kyhungerdialogue.com/>



PHOTO: CLEMSON UNIVERSITY

*Clemson Paw Pantry Student volunteers stock shelves with supplies that are available to any student in need.*





Women gather for a gender and nutrition in extension training workshop in Bangladesh through the University of Illinois's AgReach program in March 2016.

PHOTO: ANDIEA BOHN



## PART I

# The 7 Challenges for Public Universities to Address to Help Achieve Global Food and Nutrition Security

## Why Define Challenges?

Defining a challenge allows stakeholders to focus on finding solutions to problems. A problem-solving approach organizes the discovery, engagement, and learning needed to tackle complex and urgent challenges. Many past efforts to fight food insecurity have been successful but narrow in scope; these include eradicating a crop disease or addressing a food safety issue. The major challenges facing society today, however, cut across disciplines, nations, and socioeconomic sectors. Solutions rest at the intersection of science, policy, and human behavior.<sup>20</sup>

A challenge-based approach also allows students and researchers to address important global issues through a solution-driven, interdisciplinary perspective to learning and discovery. Challenge-based courses can be taught by interdisciplinary instructors who bring their distinct perspectives to exploring problem-based challenges to bring together disciplines.

A transdisciplinary approach is a way to bring multiple stakeholders and areas of expertise together to address global research challenges in areas such as food systems, health care, energy, and the environment. For example, the Transdisciplinary Research on Energetics and Cancer Initiative, funded by the National Cancer Institute, which includes research centers at the University of California, San Diego; University of Minnesota; and University of Southern California, studies the complex relationship between obesity, energy balance, nutrition, physical activity, and cancer risk.

# The Challenges Universities Are Best Poised to Address

Many of the challenges identified in this report are well known. Several groups, within both the public and private sectors, have undertaken major efforts to lift significant barriers to domestic and global food and nutrition security. The Challenge of Change effort is unique because it identifies the specific challenges universities and their partners are particularly suited to take on in order to contribute significant solutions. Many of the challenges identified in this report are similar across low-, medium-, and

## THE GRAND CHALLENGE

**Sustainably feed an expanding population and improve prospects for food and nutrition security for all**

**The 7 Challenges for Public Universities to Address to Help Achieve Global Food and Nutrition Security**

### Availability



#### Challenge 1

Increase yields, profitability, and environmental sustainability simultaneously



#### Challenge 2

Develop the varieties and breeds needed for sustainable food systems



#### Challenge 3

Decrease food loss and waste through more efficient distribution systems

### Access



#### Challenge 4

Create and share resources that serve all populations



#### Challenge 5

Ensure inclusive and equitable food systems

### Utilization



#### Challenge 6

Address the dual burdens of undernutrition and obesity to ensure full human potential



#### Challenge 7

Ensure a safe and secure food supply that protects and improves public health

high-income countries. For example, both international and national communities must increase crop yield while protecting natural resources and intervene with existing food systems to ensure equitable availability of nutritious foods for all. At the same time, it would be misguided of stakeholders to fail to recognize that low-and high-income countries face different challenges as well.

This diverse group of stakeholders engaged in the Commission process dubbed this massive but urgent undertaking the “Grand Challenge.”

Digging deeper, the Commission and its stakeholders identified seven challenges public research universities are best poised to address, within the grand challenge. These seven challenges are categorized within the organizational scheme of the dimensions of food and nutrition security: availability, access, and utilization, with the fourth component, stability, woven throughout each section. It should be noted that an additional challenge area, Knowledge and Education, was ultimately woven into the pathways and activities across all seven challenges.

## Availability

The first dimension of food and nutrition security, Availability, requires sufficient quantities of food to be accessible on a consistent basis from either domestic production or importation. Many factors can affect availability, including agricultural productivity, soil fertility, population flows, harvesting time, distribution systems, storage, and food wastage. While numerous factors dictate availability, the Commission identified three areas as critical for public universities and their partners to address: Sustainable Production Systems; Plant and Animal Performance; and Distribution, Loss, and Waste in Food Systems. Working groups focused on these areas developed three challenges to be addressed under the availability component:



### Challenge 1

Increase yields, profitability, and environmental sustainability simultaneously



### Challenge 2

Develop the varieties and breeds needed for sustainable food systems



### Challenge 3

Decrease food loss and waste through more efficient distribution systems



## CHALLENGE 1 OVERVIEW

### **Increase yields, profitability, and environmental sustainability simultaneously**

Simulation models predict that by 2050, the world will need to produce at least 60 percent more food to adequately feed the population. FAO officials offered a more complete view of the challenge when they stated, “...we need to improve people’s access to food in their communities, increase production by 60 per cent by 2050, drastically reduce huge losses and waste of food and manage our natural resources sustainably, so that [the earth] flourishes for future generations.”<sup>21</sup> The challenge is to increase production without sacrificing natural ecosystems and resources that support food production, and while providing appropriate nutrition, employment, and economic growth. All this must be done while creating production systems and equipping producers (which will refer to farmers, ranchers, and fishers throughout this report) that are resilient in the face of climate change, increasing weather-related shocks, global trade policies, and water and energy constraints.

To engage in this challenge, public research universities must account for animal health and welfare, as well as the social, cultural, and ethical considerations of applying genetic tools to improve production and resilience of crops and animals. Methods of production, harvesting, and distribution must become more efficient while minimizing environmental impacts. In the long term, the total costs of production (e.g., water, land, labor, fertilizer, machinery, and livestock) and their impacts, especially on the loss of ecosystem elements (e.g., healthy soils, clean water, increased biodiversity, and sequestered carbon) integrate with food and production systems. With some minor exceptions, most agricultural sectors (including aquaculture and fisheries), the total global factor productivity growth has not kept pace to meet projected demands, particularly in low-income countries. Focusing on local production would create opportunities for engaging untapped resources, human and physical, in both urban and rural communities.<sup>22</sup> In other words, sustainable agriculture is key.

Sustainable agriculture is defined as “practices that meet current and future societal needs for food and fiber, for ecosystem services, and for healthy lives, and that do so by maximizing the net benefit to society when all costs and benefits of the practices are considered.”<sup>23</sup> The focus on sustainable production systems builds on the idea that producers are already invested in the long-term health and stability of their livelihoods, but should be fiscally rewarded for sustainable practices. Producers cannot risk, for instance, converting rainforests of the world into farmland or overharvesting the oceans, and they must also be wary of increasing levels of nitrogen and phosphorus flows into the Mississippi Delta and other such watersheds. Indeed, the increase in production must come from existing land in use, combined with more sustainable use of coastal waters and ocean resources, otherwise the natural ecosystem and other resources will be sacrificed. Today’s domestic and global production systems need to respond to these challenges and do so within environmental, social, and economic constraints.



The development and implementation of sustainable production systems falls well within the core mandate of public research, and especially U.S. land-grant, sea-grant, and urban-universities. Discovery, engagement, and learning will all play key roles in this challenge. It is a transformative challenge because, while a great deal of progress has been made in the field of sustainable agriculture, much of the ongoing research, curricula, and extension efforts remain devoted to the support of high input, production agriculture. North American universities, however, are poised to tread new paths to address the broader challenges of the entire food system.



## The Pathway to Meeting the Challenge

Develop local, regional, and global models that integrate land, water, and ocean use; trade policy; and ecosystem services to thoroughly evaluate the costs of production and harvesting, including environmental impacts, that allow producers, policymakers, and the public to understand the inherent tradeoffs in production systems and to form the basis for generating and evaluating options and provides alternatives.

Define measurable standards for sustainable production that are site-specific to provide producers with realistic goals for their management practices and that are scale independent so that they apply across the spectrum of agricultural enterprises.

Provide a strong, integrated focus on soil, water, and oceans health, considering impacts on the environment and management of how human activities leading to pollution, environmental degradation, and climate change affect the ability to sustainably produce food.

Engage scientific resources to increase the efficiency of water use, with specific emphasis on irrigation and recirculation technologies that are effective, environmentally responsible, and applicable at a range of spatial scales.

Develop and engage new technologies to generate innovations that provide precise spatial and temporal information and use big data to improve production system efficiencies and meet environmental standards.

**Develop local, regional, and global models that integrate land, water, and ocean use; trade policy; and ecosystem services to thoroughly evaluate the costs of production and harvesting, including environmental impacts, that allow producers, policymakers, and the public to understand the inherent tradeoffs in production systems and to form the basis for generating and evaluating options and alternatives.**

With the recent expansion of capabilities to monitor ecosystems, as well as economic and social systems, modeling has become the primary way to address choices for both policymaking and operational design of food and fiber production systems.<sup>24</sup> Critical to model development is capturing the environmental and social impacts of production alternatives, as well as the benefits that healthy ecosystems provide (ecosystem services include clean air and water, fertile soil, pollination, flood control).<sup>25</sup> Given the advances in information technology, geographic information systems, and field measurements, there are new possibilities to analyze food and fiber production systems and alternative management options.<sup>26</sup> The opportunity also

exists to scaling these techniques and technology for use at the small-holder producer level in low-income countries.

There is a need for greater effort to coordinate at regional scales to integrate local land use patterns and capture their regional and external impacts. Not only are these systems complex, but the interactions are nonlinear, making their outcomes more difficult to assess without strong modeling analysis.<sup>27</sup> Regional efforts such as the Spatially Referenced Regressions on Watershed attributes (SPARROW), a modeling tool for the regional interpretation of water-quality monitoring data used by the U.S. Geological Survey (USGS) and similar efforts within the U.S. Department of Agriculture (USDA) involving public research universities, have made progress in developing statewide nutrient management plans.<sup>28</sup> To be most effective in engaging farming, ranching, and fishing communities, models need greater precision in the field and the ability to aggregate field level production practices into regional impacts. This would allow many production options to be assessed at the regional level.

Furthermore, trade policy can have major impacts on food availability and access, agricultural productivity, and environmental impacts. Economic and trade integration can provide significant food and nutrition security benefits such as increased long-term productivity in the context of severe weather events.<sup>29</sup> The impact of market segmentation (restricted trade) and market integration (global open commodity markets), coupled with globalization that allows freer flow of information and technology, are major forces shaping our food systems locally, regionally, nationally, and globally. Global economic models of agriculture, food, and environment show the strong impact that trade policy has, not only on food security and environmental impact at different spatial scales, but those impacts on food security and levels of undernutrition are often counterintuitive.<sup>30</sup>

For this pathway, public research universities are best poised to undertake the following activities:

- Define and set a research agenda, with community participation, that leads to a clear understanding of the biophysical, social, and economic factors that drive sustainable production systems.
- Identify and research ecosystem services and their economic attributes for agricultural and fisheries management practices. This includes non-market valuation and estimation of externalities in areas such as environment, health, community and civic engagement, and alternative economies.
- Use global and regional agricultural and commodity models to provide recommendations for developing trade policies to best support smallholder viability, national agricultural growth, and food and nutrition security in the face of the climate change and to effectively target development efforts in local and national food systems.
- Develop both institutional and human capacity to conduct trade analysis that allows evidence-based decisions for policymaking to ensure food and nutrition security.

- Engage with local communities to more fully understand their assets, priorities, and constraints as part of the model development and research agenda setting process. Analyze new sources of information aggregated from the producers' fields to landscape scales, to improve the function and efficiency of production and harvesting and their impacts on the environment and societies. Remarkable technologies (see challenge on technologies below) are being developed that provide precise monitoring and application of inputs and have potential for improving system performance and increasing ecosystems services. Such approaches are only one of the many new monitoring systems that create "big data" for open source use in the analysis of all aspects of production systems.

## Food From Thought

*"It is not just how much food we produce but also the way we produce it that will be key in the next century."*

—MALCOLM CAMPBELL, PH.D., vice-president research, University of Guelph

The question of how to sustainably produce food to meet the needs of the growing population is driving a new wave of research at the University of Guelph in Canada. The Food From Thought research program, associated with the Food Institute of the University of Guelph, is funded by a \$76.6 million investment from the Canada First Research Excellence Fund. The founding premise of Food From Thought is the concern that while we work to produce enough food for a growing human population, we must also sustain the earth's ecosystems.



PHOTO: UNIVERSITY OF GUELPH

*Professor Evan Fraser, Director of the Food Institute, meets with students in the Feeding 9 Billion program.*

Food From Thought intends to advance research by emphasizing the use of high-tech and big data information systems for the benefit of food and agriculture. With a team of 10 scientific leaders from different fields, Food From Thought is also backed by dozens of other participating scientists and includes a large range of industry and governmental partners.

At the core of Food from Thought is the Barcode of Life Database. The database, headquartered at the University of Guelph, is a global project involving thousands of researchers working together to build a comprehensive DNA barcode library for all life. Researchers use Barcode of Life technology to identify where there is risk to the security of the food supply chain. Researchers also use Barcode of Life to address food-borne ailments and invasive pests, improve environmental impact assessments, and foster a more sustainable and secure food system.

Food From Thought's emphasis on high-tech information systems will also require researching the social and legal impacts of big data collection and use.

Devising ways to sustainably feed the world's growing population represents one of the 21st century's greatest Grand Challenges. Through Food From Thought, the University of Guelph is committing itself to work with a range of partners towards this goal.

Learn more: <http://foodinstitute.ca/>

- Develop a strong curriculum in food and production systems (including fisheries) that places emphasis on the role of ecosystem services in food and production systems for undergraduate majors and graduate education.
- Develop novel methods and assess options that adequately address the impact of bycatch discards (unwanted fish and other species caught while commercial fishing) in fisheries.
- Work with the public and policymakers to shape research and share results of the analysis of food and fiber production systems to assist policy development.

**Define measurable standards for sustainable production that are site-specific to provide producers with realistic goals for their management practices and that are scale independent so that they apply across the spectrum of agricultural enterprises.**

University research will need to use both known and new technologies and practices to equip producers with a toolbox of standards and resources that increase production, profits, and ecosystem services. The challenge here is to produce standards integrating all aspects of production (yield, profit, quality) with internal and external measures of ecosystem services. Standards for output from the system need to take into consideration both direct and indirect costs and benefits. The indirect costs represent the greatest challenge to estimate and will require increased transdisciplinary research and the use of participatory research methodologies. The approach will need to start with easily measurable standards—just as there are for nitrogen runoff and water quality—relevant to the target ecosystem (land, coast, and ocean) This will allow practitioners to develop a framework for more complex analysis that incorporates a wider range of direct and indirect costs and benefits.

For this pathway, public research universities are best poised to undertake the following activities:

- Design and implement, through engagement with local producers, extension agents, and policy working groups, an ecosystem services implementation system.
- Establish goals for nitrogen and water, using existing knowledge where possible, that are measurable. The standards should be based on best estimates of the impact of different sources, levels, and methods of application on cost and benefit.
- Develop measurement techniques for producers in low-income countries to capture progress towards sustainability and economic success.
- Research how and if producers will use technology. Human science research, included within technology development efforts, will powerfully enable the success of technological advances as used by both male and female producers, processors, marketers, and consumers.
- Design a model integrating the components of the production system that affect the measured standards.



## Between Earth and Sky

### *Climate Change on the Last Frontier*

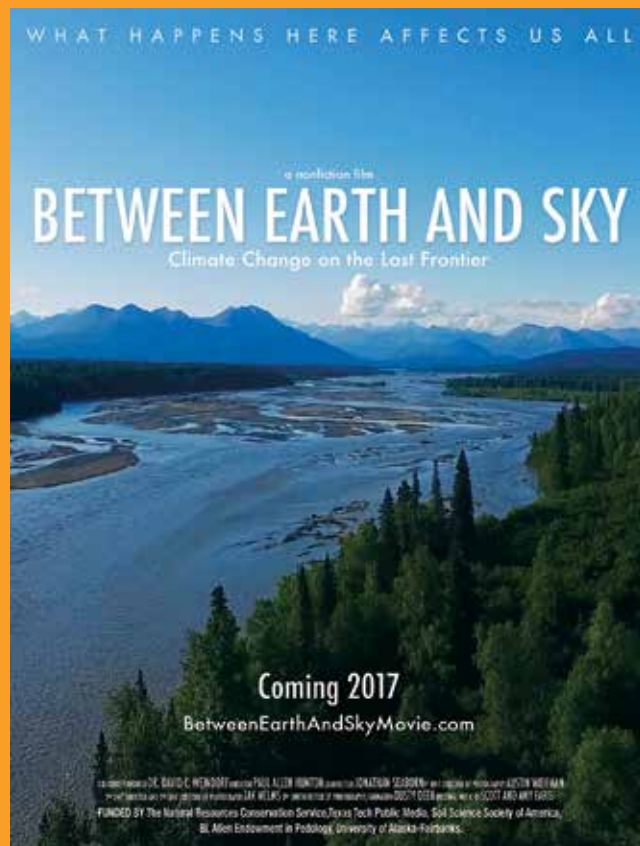
Grand challenges require a grand vision and an understanding of complex issues. Universities can lead the way, simplifying issues so that they are more easily understood. For example, one of the most important problems of our time concern global climate change and its impacts on our environment. Texas Tech University led an effort to develop a

feature-length, science-based documentary film chronicling the impact of global climate change on arctic soils and ecosystems of Alaska. In partnership with the University of Alaska Fairbanks, the USDA Natural Resources Conservation Service, and the Soil Science Society of America, the film “Between Earth and Sky – Climate Change on the Last Frontier” presents the science of climate and soil dynamics in concert with stories of Alaska natives and others who are living through these changes.

Comprising roughly 20 percent of the U.S. land surface, the soils of Alaska are unique in that they hold a tremendous amount of soil carbon within them. While frozen, those soils effectively lock that carbon out of the atmosphere and store it within the soil. However, as temperatures warm, permafrost melts and carbon is released back to the atmosphere as both carbon dioxide and methane. Coastal erosion and sea-level rise are ancillary, related issues stemming from a changing climate that are dramatically affecting more than 25 native coastal villages across Alaska.

While presenting many of the challenges posed by climate and ecosystem change, the film also demonstrates how the aggregated efforts of millions of everyday citizens can have a lasting, meaningful impact in curbing the changes underway. A complementary film, which is more technical in nature, “Between Earth and Sky – An Arctic Soils Perspective,” was simultaneously produced for the training of future arctic soil scientists.

Learn more: [www.betweenearthandskymovie.com](http://www.betweenearthandskymovie.com)



- Determine the comprehensive economic value of ecosystem services. This includes non-market valuation and estimation of externalities in areas as environment, health, community and civic engagement, and alternative economies such as economy of scope in addition to economies of scale.
- Evaluate trade-offs between food production, ecosystem services, and biodiversity using multiple valuation methods.

**Provide strong, integrated focus on soil, water, and oceans health, considering impacts on the environment and management of how human activities leading to pollution, environmental degradation, and climate change affect the ability to sustainably produce food.**

Soil and water resources provide environmental services that create greater food and energy security, water quality, and adaptation to and mitigation of climate change.<sup>31</sup> New research must address processes that affect soil, water, and ocean health, particularly in high input production systems in the face of extreme weather events that have major impacts on the ecosystem, particularly soil loss. What happens in the soil is legacy of a production system. Soil loss and degradation, as well as declines in ocean health, are critical issues that limit current and future food production in North America and around the world.

For this pathway, public research universities are best poised to undertake the following activities:

- Research the remarkable diversity and function of soil microbes to increase nutrient cycling, decrease food contamination to reduce health risks, and improve soil health.
- Consider the impacts of different production practices on watersheds, estuaries, and marine ecosystems.
- Create systems where soil can naturally act to remove waste produced by industry, agriculture, and rural/urban environments to minimize environmental impacts, maximize water quality, and reduce dependence on below ground water resources.
- Develop manure management practices that increase carbon sequestration and optimize crop yields and soil tilth.
- Develop carbon sequestration systems that store carbon in the soil and other components of the carbon cycle and which create policy and/or market options that reward producers for efforts to decrease greenhouse gas emissions.
- Develop regenerating agriculture and aquaculture systems that recycle waste products produced by runoff to improve water quality and sediment microbial communities.

**Engage scientific resources to increase the efficiency of water use, with specific emphasis on irrigation and recirculation technologies that are effective, environmentally responsible, and applicable at a range of spatial scales.**

Water is a critical component of food production and human existence. Irrigated agriculture produces 40 percent of the world's food on 20 percent of global farmed land and will be a critical component of achieving a 60 percent increase in global yields. It is estimated that agriculture accounts for 80 percent of ground and surface water usage in the United States alone; worldwide, 70 percent of water drawn from rivers, lakes, and aquifers is for agricultural use.<sup>32</sup> It is estimated that agricultural water demands could rise as high as 89 percent of all water usage by 2050.<sup>33</sup> Systems-level modeling of watershed and ground water is essential for crafting responsible policy that provides

the greatest opportunity to sustainably meet future food demands. Governance is also critical for aquaculture and fisheries, which heavily rely on the use of shared resources.

Universities possess unique expertise in agriculture, environment, economics, and modeling to address domestic and global

## Nebraska's Natural Resources Districts and Groundwater Governance

### *A Unique Example of Stakeholders Successfully Managing a Shared Resource*

Groundwater is a shared resource, and many aquifers face problems with governance and challenges to sustainability including over pumping, transboundary, endangered species, surface water-groundwater interaction, and water quality and quantity impacts on drinking water supplies.

Water is vital to Nebraska's economy; the state has more irrigated land than any other state in the United States. To support the extensive high-productivity agriculture in Nebraska, almost 100,000 irrigation wells are in use. This possibly represents the largest private investment in irrigation infrastructure in the world, and is supported by several of the largest irrigation companies, equipment dealers, well drillers, irrigation advisors, and other consultants. In parallel, Nebraska has strong regulatory and technical capacity at state and local levels.

Most of Nebraska's water comes from the High Plains Aquifer, one of the largest groundwater systems in the world. To meet groundwater management challenges, the state of Nebraska has developed a unique governance system with its Natural Resources Districts (NRDs). Although other states have components of collective groundwater management systems, no similar system currently exists. The University of Nebraska has played an important role in providing the data and training to support this unique system that governs a critical shared resource.

The NRDs, founded in 1972, integrate several key features. They are governed through locally elected boards with the support of technical staff, many trained by the University of Nebraska system and assisted by university-sourced analysis and data. NRDs have the legal authority and willingness to set and enforce rules, including large fines for severe cases of noncompliance. They are provided appropriate funding for their mandate (approximately \$250 million a year across 23 NRDs) and are accountable at the state level.

The public university system provides support for both public and private water management needs in the state. The Conservation and Survey Division of UNL collects and maintains key hydrologic and geologic data, hundreds of university researchers as well as the Nebraska Water Center and Daugherty Water for Food Global Institute provide technical and analytical expertise for the State and for other water stakeholders, and the UNL Extension system provides education and outreach programming statewide that support sustainable water use. Collectively, this complex ecosystem serves to help to maintain food and water security in Nebraska.

Learn more: <http://waterforfood.nebraska.edu/>



*Daugherty Water for Food Global Institute Faculty Fellow and University of Nebraska-Lincoln irrigation engineer Derek Heeren leads a center pivot lab with UNESCO-IHE students at UNL's Agricultural Research and Development Center near Mead, Nebraska.*

water issues. Combining science and systems that engage users (producers) and other stakeholders to buy into a management and governance scheme for a shared community resource such as ground, coastal, or ocean water will be difficult. A promising example of a system with this integration is the coordination by the Nebraska Association of Resources Districts (NARD) of Nebraska's 23 Natural Resources Districts organized by stakeholders, including producers and the state public university system (see sidebar). This coordinated effort accomplishes collectively what may not be accomplished individually—to conserve, sustain, and improve natural resources and the environment.<sup>34</sup> Universities could also study water and carbon credit markets in California to understand policy that allows market forces to support sustainable resource use.<sup>35</sup> Another example is the Integrated Coastal Zone Management concept, in which aquaculture production and fisheries harvesting systems are part of integrated governance systems across multiple sectors within a given region or ecosystem, as opposed to conventional management that focuses on single target species and maximizing economic output. Integrated governance of ecosystems takes into account all potential uses of shared resources (mining, energy, recreation, food production) with the goal of maximizing collective benefits while minimizing ecosystem and environmental impacts.

For this pathway, public research universities are best poised to undertake the following activities:

- Engage research, extension, and communities of users to extend models like that developed in Nebraska for water to a wider range of ecosystem services.
- Determine the organizational, social, and economic constraints to the establishment of such local governance systems.
- Develop solutions for maximum efficiency of water and natural resources in sustainable production systems.
- Develop a set of best practices to guide the establishment of policy and organizations that manage common resources for long-term sustained use.
- Engage public and private stakeholders to help establish codes of conduct for the sustainable management of shared resources and ecosystems in both urban and rural areas.

**Develop and engage new technologies to generate innovations that provide precise spatial and temporal information and use big data to improve production system efficiencies and meet environmental standards.**

One of the key challenges to sustainable use of inputs such as fertilizer and pesticides is the spatial variability and inherent heterogeneity of the landscape. Many universities and their partners have developed remarkable technologies that provide precise monitoring and application of inputs which have potential for improving system performance and increasing ecosystems services. Such approaches are only one of



the many new monitoring systems creating big data for open-source use in analyzing production systems. Transforming these data to useable information for producers is critical to developing an array of tools that can be applied to farm, ranch, and fishery operations to meet sustainability standards and economic realities. This is fertile ground for university-private sector collaboration and partnership.

## Yield Forecast Center Provides Producers with Real-time, Reliable Yield Data

In recent years, producers in the Corn Belt have experienced extremes in weather and crop yields. Following the devastating 2012 drought, corn yields were the worst in 30 years. Two years later, yields reached all-time record highs in Nebraska. Facing such variability, corn producers and agribusiness have looked to the Yield Forecast Center developed at the University of Nebraska–Lincoln for accurate corn yield predictions to help guide in-season decision-making.

The biweekly model forecasts yield for 41 sites in 10 states across the Corn Belt, including Illinois, Indiana, Iowa, Kansas, Michigan, Missouri, Minnesota, Nebraska, North Dakota, and Ohio. For each site the forecast considers over 20 years of historical data on yield, soil property, water regime and crop maturity as well as current data on solar radiation, minimum and maximum air temperatures, rainfall, and plant evapotranspiration.

Patricio Grassini, assistant professor in the Department of Agronomy and Horticulture, started releasing corn yield forecasts in 2011. He initially focused on four sites in Nebraska before taking his model to sites in Iowa and Illinois. As the in-season forecasts proved accurate when compared to end-of-season actual harvest yields and as demand for the forecasts grew, Grassini formalized the Yield Forecast Center and built a team of faculty and extension educators from across 10 universities. The approach to forecasting corn yield relies on robust simulations that capture the influence of weather, soil, and management on crop growth and yield, together with a spatial framework to upscale results from location to state and region.

Beyond yield, UNL's model predicts real-time crop stage and forecasts the date of maturity. This information helps producers, grain elevators, trucking companies, and others to know when the crop will mature so they can prepare for harvest.

"Free, open-access information is in high demand, and we believe that the Yield Forecast Center helps level the playing field for everybody who trades grain in the open market," said Grassini. "Farmers, crop consultants and others in the industry are using our model to inform management, logistical and marketing decisions."

A significant amount of data is collected to develop the yield forecasts. For each forecast, faculty and extension educators from all partner universities provide input on their crop stage.

Learn more: <http://cropwatch.unl.edu/tags/corn-yield-forecasts>



PHOTO: CRAIG CHANDLER - UNIVERSITY COMMUNICATION, UNIVERSITY OF NEBRASKA

*Scott Spohn, with Spohn Farms, pauses after offloading corn and watches as his father continues harvesting in October 2015.*

For this pathway, public research universities are best poised to undertake the following activities:

- Create new technologies to better measure field processes that allow producers to capture the spatial and biophysical heterogeneity to increase both profit and environmental services.
- Provide advanced techniques to analyze these new sources of information from the farmer's field, rancher's range, or the fisher's harvest area to aggregate information at landscape scales for the public good, to improve the function and efficiency of production/harvesting, and to measure the impact of that production/harvesting on the environment and societies.
- Capture and use the expanding data available from new monitoring capacities to create models and projections for policymakers and producers (see above path on regional models).



## CHALLENGE 2 OVERVIEW

### Develop the varieties and breeds needed for sustainable food systems

A rapidly growing human population, along with climate change and weather variability, continue to pose challenges to agricultural production. They also put pressure on land, water, and ocean resources.<sup>36</sup> Public research universities have long provided leadership in the development and application of technologies for breeding crops and animals that adapt to biological and physical stresses. Increasing growth in agricultural productivity requires substantial investments in innovation, adoption and use, and better identification of the most appropriate technologies and practices for improved plant and animal performance. Development of new breeds should also consider the potential impacts of the introduction of these breeds on ecosystem health, focusing on preserving biodiversity, minimizing the introduction of invasive species, and restoring habitats degraded by human use.

# 50%

estimate of the gain in U.S. farm productivity since 1949 is a result of the public and land-grant university system

Based on the analysis in Alston, J.M., Andersen, M.A., James, J.S., & Pardey, P.G. (2010). *Persistence pays: U.S. agricultural productivity growth and the benefits from public R&D spending*. New York: Springer.

Plant and animal adaptation is a key factor that will determine how severely climate change will affect food production. Climate change poses a serious threat to species and agro-ecosystems essential to food and fiber production.<sup>37</sup> Breeding plant and animal species that are adapted to these environments and environmental stresses, as well as pest and disease pressures, requires the need to assemble and screen germplasm strategically and discover new sources of variation that enable the development of new cultivars and breeds.<sup>38</sup> Genetic biodiversity is considered as a source of continuing advances in yield, disease, and pest resistance, as well as improvements such as nutrient quality.<sup>39</sup> This enables agricultural systems to maintain productivity over a wide range of conditions, scales, and production styles. The impact of breeding on agricultural production is dependent upon complex relationships involving producers, the cultivars and breeds available to them, and the developers of these cultivars and breeds.



## The Pathway to Meeting the Challenge

Identify and use genetic material to improve the performance of plants and animals. This includes using local biodiversity to produce varieties that meet the needs of sustainable production systems with attention to the impacts of climate, unpredictable weather events, and disease on the rights and needs of local communities.

Use new genetic technologies to tap into global genetic diversity in animals to produce breeds that are profitable, productive, sustainable, and appropriate for evolving production systems.

Access, contribute, and assemble relevant data and information involving crop and animal germplasm, agroecosystem expertise, climate, and biotic and abiotic stress to develop and assess the site-specific suitability for producers, as well as evaluate long-term health and environment risks related to genetic modification.

Build on new advances in photosynthesis efficiency to increase crop productivity and create more efficient renewable energy sources.

**Identify and use genetic material to improve the performance of plants and animals. This includes using local biodiversity to produce varieties that meet the needs of sustainable production systems with attention to the impacts of climate, unpredictable weather events, and disease on the rights and needs of local communities.**

Because yield and quality dictate the economic value of crops and animals, the most important criteria for the acceptance of new cultivars and breeds are their adaptation, suitability, resilience, and greater yield stability within local environments and conditions.<sup>40</sup> Taking a holistic approach to assessing the suitability of newly developed breeds in an area of critical importance. This must involve interdisciplinary genetic improvement strategies that account for ecological, socioeconomic, and public

stakeholder considerations to help identify traits leading to suitable cultivars and breeds requiring less input, energy, and land.<sup>41</sup> A holistic strategy, which integrates genetic and natural resource management in combination with improved sustainable agricultural production practices and suitable breeds, will ensure adaptability and suitability. These goals and the challenges are applicable in both low- and high-income countries.

Researchers can achieve genetic improvements through selection either with empirical breeding or analytical/physiological breeding.<sup>42</sup> Empirical

## Grafting Plants and Partnerships

Thanks to North Carolina State University, several U.S. growers have been able to use grafted tomato plants to return land plagued by bacterial wilt to production. And a new project promises to give growers even more choices.

Grafting takes the rootstock of one plant and combines it with the stem of another plant. The result is a new plant with the best qualities of both plants. Because it uses two plants and requires more labor than traditional plant breeding, it is often more expensive. Yet, it is much faster.

The first project helped grafted-plant suppliers, such as Ontario Plant Propagators, connect to growers who needed disease-resistant varieties and

sought better quality fruit. The disease resistance of grafted plants created high demand among small- to mid-scale growers. In addition, a trio of Israeli, Italian, and American companies set up Tri-Hishtil, a plant-grafting company that planted roots in North Carolina two years ago.

As demand for grafted plants increased, suppliers also noted an increase in the expectations of what grafting can provide, leading to a second project.

With a \$3.2 million specialty crops research initiative grant from the U.S. Department of Agriculture's National Institute for Food and Agriculture, the new project continues to pursue fruit traits that consumer's desire, paired with disease-resistant rootstocks, adding even more rootstock traits to the mix.

The research team ultimately hope the project continues to modernize the technique of grafting and further integrates grafting technologies into major industries such as seed, robotics, and nursery/propagation companies. They also want to optimize return on investment for growers trying to expand production while dealing with a variety of environmental challenges.

Learn more: <https://ipmsouth.com/2016/11/02/national-specialty-crop-project-explores-new-possibilities-for-grafted-tomato-and-cucurbit-plants/>



PHOTO: DAVID SUCHOFF, NC STATE

*Non-grafted plant killed by a soilborne bacterial pathogen, with healthy resistant grafted plants in the background.*



breeding is focused on primary traits such as yield. Analytical or physiological breeding involves secondary traits that must be related to the yield potential or to improved behavior of the breed when grown in a stressful environment. While adaptive traits present an advantage for survival, the cultivars, livestock, and fish with these adaptations often do not possess traits with high economic value, such as high yields. As a result, producers are breeding some species to enhance their production traits but their survival traits are being lost.<sup>43</sup> This creates a major problem because adaptability is going to be increasingly important as producers continue to adapt in the face of climate change. While producers may experience a short-term economic benefit from breeding simply for high productivity, there are long-term consequences of breeding out and losing survival traits. One such consequence is a lack of genetic diversity, which can result in lower fertility and the persistence of health issues.<sup>44</sup> Another consequence is the complete loss of indigenous species.<sup>45</sup> Cultivars and breeds are local to a particular area for a reason: they have adapted and evolved to best survive local conditions. If researchers can preserve these innate traits that have allowed the local species to thrive while breeding in traits associated with productivity, they and other stakeholders can help to establish a much more sustainable food system through improved plant and animal performance.

Work on genetic improvement offers considerable opportunities for global partnerships between public research universities, low-income country institutions, and international research centers such as the CGIAR. The Green Revolution emerged from such collaborations. These partnerships can produce not only appropriate new varieties and breeds, but also be a source of human and institutional capacity development.

For this pathway, public research universities are best poised to undertake the following activities:

- Develop and train the next generation of plant, algae, and animal breeders that excel in interdisciplinary work environments and in science communication. Provide curricula that focus on integrating new technologies, advances, and conventional breeding to allow graduates to think comprehensively to solve complex food system problems.
- Develop gene databases for local plant and animal breeds through sequencing and publishing the genomes of more locally adapted cultivars and livestock, considering rights of local communities.
- Employ genetic innovations in plant, algae, and animal breeding that maximize the biologic potential of a given area or region, conserving local genetic richness.
- Use participatory research methods involving scientists, producers, and other stakeholders to be informed by public input in selecting locally relevant crop, animal, and fish varieties for the desired traits, but with emphasis on understudied species to help ensure local adoption.

- Use private/public partnerships to support the development and translation of research knowledge into innovations that are disseminated to the public to solve problems.
- Access and assemble relevant data and information using Global Open Data for Agriculture and Nutrition (GODAN) and other platforms to develop and assess the site-specific crop suitability for producers.
- Create means for promoting public input and acceptance as newly developed breeds, strains, cultivars and selections are planned and introduced. Establish mutually beneficial partnerships with foreign institutes to develop their institutional capacity and together train and engage faculty, staff, and students from the U.S. and abroad in research and international collaboration.

## Creating and Sharing Open Data for Agriculture and Nutrition

The Global Open Data for Agriculture and Nutrition (GODAN) initiative is a worldwide movement bringing together countries, academic institutions, development organizations, companies, and others to make agriculture and nutrition data available, accessible, and usable for unrestricted use worldwide to deal with world food security. Launched in 2013, the coalition now with over 500 partners, has created momentum by raising awareness about the need for open data, facilitating cooperative coalitions, and sharing best practices and instructive case studies.

In 2015 GODAN asked the Presidents United to Solve Hunger (PUSH), a consortium of universities, to become a visionary GODAN partner to tap into the university's unique role as discoverer, curator and disseminator of knowledge. Speaking at a recent gathering of university leaders, GODAN Executive Director Andre Laperriere said universities should advance a hunger-free world in four key ways.

First, universities, as research institutes, can ensure knowledge transcends the walls of the university and is available to all who need it. Second, by making data usable, for instance, by translating hard data, such as nutrition research, into facts that the average person can use daily to improve their health. Third,

by helping to connect isolated data sets to make a more complete picture, so that better policy decisions can be made. For instance, improving food security through advancing knowledge about the entire food chain—not just narrow focuses on areas such as production and yield. Finally, universities can nurture innovation—by training the next generation of researchers who will fuel the open data revolution.

One of the visionary projects GODAN hopes to inspire is a global, comprehensive assembly of agriculture and nutrition data. This data, made available through open data portals around the world with contributions by university-generated data sets, once available could provide finger-tip agriculture and nutrition information, much like how we access instant weather forecasts today.

Learn more: <http://www.godan.info/>



LOGO PROVIDED BY GODAN

## Meet the Cornell Alliance for Science

The Cornell Alliance for Science believes the best way to change minds and policies is to change the conversation. Through international training, multimedia, and outreach programs, the Cornell Alliance for Science is seeking to bring science and evidence into the contentious conversation around agricultural biotechnology.

As a global communications initiative, the Alliance strives to promote access to scientific innovation to enhance food security, improve environmental sustainability, and raise the quality of life globally.

It accomplishes its goals through a four-part strategy:

- Multimedia productions that amplify the voices of farmers, public sector scientists, and others who are working to improve seeds and livestock through genetic engineering
- International short courses that give grassroots science advocates the tools needed to successfully communicate about science and promote evidence-based decision-making
- A 12-week intensive Global Leadership Fellowship that trains science champions to conduct successful outreach around crop biotechnology and food security in their home nations
- Building a global alliance of partners who share the common mission of solving complex global hunger issues by leveraging advances in agriculture, including the creative tools and insights biotechnology can offer



PHOTO: CORNELL UNIVERSITY

*The Cornell Alliance for Science offers international training to build a global network of science champions who can successfully communicate about crop biotechnology and food security in their home countries, such as these 2016 graduates of the 12-week Global Leadership Fellows program.*

The Alliance is housed with Cornell University's International Programs-College of Agriculture and Life Sciences. It was founded in 2015 with a \$5.6 million grant from the Bill & Melinda Gates Foundation and is led by Sarah Evanega, Ph.D.

Since its inception, the Alliance has graduated two cohorts of Global Leadership Fellows representing Africa, Asia, Latin America, and the United States. The fellows have been extremely effective at sharing credible information about biotechnology in their home countries and bringing science into policy discussions around the deregulation of genetically modified crops.

The Alliance also has produced many videos and blog posts that highlight the work of public sector scientists around the globe, the performance of biotech food crops in the field, the concerns and interests of primarily small-holder farmers, and efforts to address the climate change footprint of agriculture.

Learn more: <http://allianceforscience.cornell.edu/>

*The Cornell Alliance for Science promotes science-based policies that can help Selma Selimani and other drought-stricken small-holder farmers in Tanzania access innovative crops like water-efficient maize.*



PHOTO: CORNELL UNIVERSITY

**Use new genetic technologies to tap into global genetic diversity in animals to produce breeds that are profitable, productive, sustainable, and appropriate for evolving production systems.**

The demand for meat will grow rapidly in the coming decades, particularly as wealth increases in low-income countries. Worldwide meat production has tripled in the last four decades.<sup>46</sup> Meat production will likely become more concentrated, particularly in non-ruminant production systems, such as pork, poultry, and fish. Universities and their partners can apply their expansive scientific capacities to address the emerging animal production needs that this intensification will demand, especially to ensure food safety, zoonotic and non-zoonotic disease control, profitability, and environmental responsibility.

## Local Adaption for Global Food Security

University of Missouri beef geneticist and extension specialist, Jared Decker, is working to help Missouri farmers and ranchers improve breeding and sustainability for their cattle and the environment. Decker learned from local producers about the challenges they faced with their cattle carrying fescue toxicosis, a fungus found in fescue grass across Missouri, Tennessee, Kentucky and parts of Oklahoma, Arkansas, Mississippi, Alabama, and Georgia. Decker thinks there is a genetic and environmental link to breeding cattle with resistance to this toxicity, which if identified, can lead to better breed adaptability and improved animal welfare.

Decker responded to a USDA call for proposals seeking projects related to solving local problems with crops and livestock breeding and genomics to address the global food security issue. Decker's project seemed a perfect fit to address both a local and global issue.

The traditional method for breeding cattle relies on external criteria of animal health, such as weight and robustness, but this does not account for the impact that generations of adaptation to local environment can play. Geographic and climatic environment, and even diet, may each produce genetic traits that result in cattle that are well adapted to the local environment. Understanding the 'what and why' of these traits can result in greater efficiency and profitability for producers. Working to understand the what and why is made easier with a partnership between Decker and multiple cattle

breed associations to analyze data collected by these associations over the past 30 years.

While community engagement has been an important part of the development of this research, Decker plans to continue this outreach. In collaboration with University of Missouri's agricultural education and leadership department, as well as colleagues from the University of Wyoming and Texas A&M University, Decker and his team are making sure that the outcomes of this research includes creating publicly available tools for producers and developing curriculum for youth.

Learn more: <https://cafnr.missouri.edu/2016/05/tackling-a-challenge/>



PHOTO: UNIVERSITY OF MISSOURI

*Decker's project will also include an educational component. He wants to give beef producers, farmers and ranchers as much information as possible when they make decisions about cattle.*



should manage such growth to complement, instead of undo many low-income countries' reliance on seafood as an alternative protein source to meat.<sup>47</sup> Partnerships between North American and foreign universities, particularly in low-income countries, are critical to success. Recent outbreaks of avian flu remind us of the capacity for global zoonotic diseases to harm animals, and potentially humans, worldwide. These impacts are discussed more fully in the pathway to challenge seven, ensuring a safe and secure food supply that protects and improves public health.

Local livestock breeds present a unique opportunity for dealing with a range of issues related to productivity. For example, livestock breeds indigenous to certain regions of the world have better resistance to local diseases and pests than breeds developed elsewhere.<sup>48</sup> This is often due to the simple fact that living in a region where particular diseases or pests are present forces a species to adapt to survive. Local cultivars and breeds are often more adapted to the climate of a particular area as well. For example, many native African livestock breeds have improved heat stress characteristics that provide an advantage in the harsh African climate over breeds developed in more moderate climates.<sup>49</sup>

For this pathway, public research universities are best poised to undertake the following activities:

- Develop breeds that fit within the constraints and opportunities posed by the analysis that defines and supports sustainable systems in low-, middle- and high-income countries.
- Use genomic sequencing to identify genes in indigenous breeds associated with resistance to biological and environmental stress and high production levels to ensure productivity, but also resistance to diseases that can be transmitted to humans (zoonotic diseases).
- Conduct deep sequencing of the gut microbiome of these breeds in their local environments to provide answers to the effect of feed and environment on the presence of methane-producing microbes and incorporate these findings into overall models of reducing greenhouse gas emissions.
- Determine the risks and benefits of new technologies, including genetic techniques, to provide an objective basis for the development of informed consumer decisions and policymaking.
- Conserve germplasm working together with local communities.

**Access, contribute, and assemble relevant data and information involving crop and animal germplasm, agroecosystem expertise, climate, and biotic and abiotic stress to develop and assess the site-specific suitability for producers, as well as evaluate long-term health and the environmental risks related to genetic modification.**

The growing existence and availability of site-specific data on all aspects of production and environmental parameters provides a rich new

resource for plant and animal breeding. Open access to these data for scientists could increase the capacity to tailor crop and animal varieties that are responsive to local variability. Using open data in combination with a participatory evaluation approach that includes interdisciplinary teams of scientists and public stakeholders allows for the selection of suitable crop and animal varieties for an area that provides stable yields in varied climatic condition.

For this pathway, public research universities are best poised to undertake the following activities:

- Develop gene databases for local breeds—sequencing and publishing the genome of more locally adapted cultivars, livestock, and fish through GODAN or similar approaches to allow for a more collaborative approach to researching and using local traits.
- Coordinate the information available on local plant, algal, and animal diversity in existing databases and genetic banks, but with emphasis on varieties and breeds that are locally important yet understudied, to allow integration and access for greater improvement and more effective and rapid adaptation efforts.
- Apply the newest methods of genetic analysis to a new coordinated and integrated database on crop, algal, and animal genetics to improve performance.

### **Build on new advances in photosynthesis efficiency to increase crop productivity and create more efficient renewable energy sources.**

Photosynthesis, a process by which plants and algae turn light and carbon dioxide into sugars for energy, is a fundamental process that governs plant production and is an essential first step in all plant-based food systems. Over the next 30 years, increases in production will have to fulfill both the volume and rate of human consumption but also the estimated 85 percent increase need for livestock consumption as a growing middle class desires more meat.<sup>50</sup>

Over time, plants known as C<sub>4</sub> (corn, sugarcane, sorghum, and millets) have evolved to become more efficient than their cooler climate counterparts known as C<sub>3</sub> plants (wheat, rice, barley oats, peanuts, soybeans). However, even these more efficient plant species are inefficient at fully capturing enough energy potential to grow at the rate needed to satisfy consumption rates. A typical field of corn only captures 1 to 2 percent of solar energy in a growing season, and sugar cane, one of the most efficient at capturing this energy, only captures 8 percent.<sup>51</sup> If scientists can unlock the full potential of photosynthesis efficiency in plants, more efficient crops will grow, helping to increase yield without putting more land into agricultural production, which in turn would contribute positively to sustainable intensification.<sup>52</sup>

Making gains in the efficiency of photosynthesis has benefits beyond more efficient plant growth. Practitioners can apply the knowledge of photosynthesis efficiency to the conversion of solar energy as a renewable energy source.<sup>53</sup> Photosynthesis discovery

may also lead to reducing greenhouse gas emissions by capturing carbon dioxide and converting it into products such as biodegradable plastics and liquid fuels, potentially providing alternatives to petroleum-based fuels.<sup>54</sup>

Much of this work on photosynthesis efficiency for food and energy is already in progress. One example is the *Realizing Increased Photosynthesis Efficiency* (RIPE) project at the University of Illinois, funded by the Bill and Melinda Gates Foundation. Photosynthesis and energy efficiency is also a focus of the Department of Energy-supported Berkeley Lab at the University of California, Berkeley. Much of the exploratory work in this field has focused on tobacco because it is a fast-growing crop. Recent discoveries, such as success in increasing tobacco photosynthesis efficiency by 14 to 20 percent is a critical step in unlocking the science to apply this innovation to food-related crops.<sup>55</sup>

For this pathway, public research universities are best poised to undertake the following activities:

- Determine possible points of intervention in the photosynthesis process where genetic manipulation would be most likely to have a positive impact.
- Seek public stakeholder input and understanding early on to inform research on transforming photosynthetic pathways.
- Assess how molecular changes affect efficiency of photosynthesis in laboratory plants.
- Transfer advances in non-food crops (e.g., tobacco) to food crops (e.g., rice, wheat) to advance increases in field production efficiency.
- Increase solar-to-chemical efficiency in artificial photosynthesis for alternative fuel production.<sup>56</sup>



## CHALLENGE 3 OVERVIEW

### Decrease food loss and waste through more efficient distribution systems

Most of the models that predict the need for food production increases by 2050 do not include reductions in food waste or loss in their calculations.<sup>57</sup> Researchers have estimated that reducing loss and waste to currently achievable levels would be sufficient to cut losses in half and provide enough additional food for one billion people, potentially reducing the need for increased production to estimates of 30 percent.<sup>58</sup>

Currently, significant amounts of food are lost along the food supply chain—during production, postharvest, storage, processing, distribution, and at the consumer level. This can be an unintended result of agricultural and fisheries processing; technical limitations in storage, distribution, and infrastructure; or a failure in packaging and marketing, but it also includes household-level decisions. Each year in the United States, 52.4 million tons of food is sent to landfills, while an additional 10.1 million tons remain unharvested at the farm.<sup>59</sup>

*Food loss* refers to the decrease in mass (dry matter) or nutritional value (quality) of food that was originally intended for human consumption. *Food waste* refers to food appropriate for human consumption being discarded or left to spoil. The term *food wastage* can be used to discuss the combination of food loss and waste.<sup>60</sup>

There are several methods to analyze loss and waste in the food system. Food wastage typically follows similar patterns across developed countries—with most wastage occurring at the later stages of the food chain in marketing and household consumption. In the United States and other high-income countries, 20 to 30 percent is wasted at the consumer and retail levels.<sup>61</sup> The annual economic value of food waste and food loss in the United States is \$218 billion, or 1.3 percent of GDP. In low-income countries, most of the wastage occurs during the early stages (harvest, postharvest, storage, and processing).

## Maine In-field and Market Gleaning

The USDA estimates that 15.8 percent of Maine households are food insecure, ninth in the nation for food insecurity. Meanwhile, Maine has 8,200 farming operations managing 1.45 million acres of land. For several years, University of Maine Cooperative Extension staff have been creating sustainable linkages between farms, volunteers, and food pantries/community meal sites. Statewide, staff and volunteers currently support 49 gleaning sites. Here are two of their stories:

In 2010, Hancock County Extension Hancock gathered hunger relief organizations to harvest surplus apples from a local orchard, starting a yearly tradition of gleaning and distributing an average of 5,000 pounds of apples to area food pantries and soup kitchens. In 2012, they partnered with Healthy Acadia and the city of Ellsworth to receive a grant to expand the Downeast Gleaning Initiative enabling them to hire a local gleaning coordinator and significantly increase their efforts to recover surplus crops that would otherwise go to waste. Initially designed as a one year project, it's now wrapping up its fifth season. Thanks to the hard work of two regional gleaning coordinators and more than 200 community volunteers, over 100,000 pounds of fresh vegetables, fruits, and meats have been rescued and redistributed to neighbors in need.

In 2011, Penobscot County Extension staff worked with a local farmer and volunteers to develop

and implement a farmers' market gleaning plan for the Orono farmers' market. Tip sheets and market gleaning trainings have been offered throughout the state. Since then, at least five other markets in Maine established programs that utilize volunteers and/or agency staff to collect and distribute unsold high-quality food to food security organizations. The past six years yielded more than 20,000 pounds of donations from the Orono market alone. Farmers see this as a service and often bring extra food from their farm because they can count on the volunteers to bring it to where it's most needed.

Learn more: <https://healthyacadia.org/initiatives/gleaning.html>



PHOTO: UNIVERSITY OF MAINE

*Produce gleaned from farmer's market on display in food pantry.*



Researchers estimate that 2 to 18 percent of cereal crops and up to 50 percent of fruit and vegetable crops in low-income countries are lost post-harvest. Food waste prevention can not only reduce inefficiencies, address hunger, and reduce the negative effects on the environment, but also create jobs and stimulate economies.<sup>62</sup>

Urban communities must be a part of the solution to address the challenge of localizing food systems and reducing food wastage. They offer new arable land, land-independent food production options (e.g. hydroponics, aquaponics, green roof, green walls), and opportunities to localize supply chains close to the majority of consumers.



## The Pathway to Meeting the Challenge

Conduct research to identify causes of loss and waste in food systems to design appropriate interventions to improve distribution, packaging, and other processes to reduce food wastage.

Build internal capacity to measure and analyze data, cost, and health outcomes to improve policy and behavior through addressing food waste and loss in the value chain.

Engage urban communities to develop opportunities for urban agriculture and aquaculture (e.g., aquaponics) to increase the availability of nutritious food in urban environments to promote healthy diets and to expand economic opportunities.

Generate knowledge of local food systems to re-localize those systems and revitalize communities through investment, job creation, and resilience building.

### **Conduct research to identify causes of loss and waste in food systems to design appropriate interventions to improve distribution, packaging, and other processes to reduce food wastage.**

Beyond understanding the size or cost of the problem, it is critical to understand the causes of food loss and waste to address challenges across the entire food system. Food crops have a limited post-harvest shelf life. Due to the delay between planting and harvest, producers must make decisions about demand, quantity, and market prices well in advance, often with limited information on weather and markets, particularly in low-income countries. Furthermore, former safeguards for fair food commodity prices between buyers and sellers have become deregulated, allowing agricultural commodity futures to be traded by individuals and banks with little concern for the long-term outcomes on the producer, the consumer, or the market itself.<sup>63</sup> The challenges that producers face can lead to high food prices in addition to overplanting or edible crops left in the fields.<sup>64</sup> Damage, contamination, or inefficiencies in harvest, storage, processing, and distribution are additional causes of food loss and waste at the producer level.

At the retail level, avoidance of visually imperfect food products, overstocked displays, and misleading or misunderstood food labels contribute to food waste and loss. Food logistics tend to be highly fragmented with limited incentive for retailers to change behaviors. While many solutions to reduce food wastage require

costly interventions or investments, they may take a long time to eventually return a profit. One area of renewed interest is in packaging—both in efforts that reduce staleness and others that increase shelf life.

Reducing food wastage requires a holistic approach beyond shelf life. This approach ideally would begin during post-harvest and extend to household practices. For consumers, inconsistency in labeling, negligence, or over-preparation of food, and an aversion to consuming leftovers demonstrate the lack of awareness or education, which contributes to excessive food waste and loss.<sup>65</sup>

## Students Combating Food Waste, One Dehydrator At a Time

Iowa State University College of Agriculture and Life Sciences students are up to the task of helping to feed the world.

Four students majoring in global resource systems, who called themselves the Gung-ho Globies, designed a mobile solar dehydrator for fruit and vegetables called KinoSol for the Thought For Food global challenge.

Thought For Food is an annual competition to catalyze university students from all fields of study around the world to learn more about the complex challenges of food security and to inspire them to channel their passions and creativity towards developing new ideas that make a difference. The Iowa State team was one of only 10 teams out of 336 entries chosen as finalists during the 2015 competition. And now, the team has transitioned this project into a startup business that will help battle post-harvest loss and increase nutrition for people in low-income countries.

In the fall of 2016, the student-led KinoSol team won second place and \$35,000 at the Global Citizen Waislitz Award competition in New York City. One of the student co-founders was selected as one of three finalists worldwide to present an idea that alleviates world hunger and food waste. The idea she presented outlined how a KinoSol Orendaunit—a solar-powered food dehydrator for fruits, vegetables, grains, and insects—that can be used to aid in reducing food waste, increasing nutrient availability, and improving livelihoods around the world.

KinoSol units were initially designed for rural farmers in low-income countries. Now the team is working to expand its use to urban residents to increase awareness about food waste in the United States and globally.

Learn more: <http://www.tffchallenge.com/>  
<http://www.getkinosol.com>



PHOTO: IOWA STATE UNIVERSITY

*Clayton Mooney, an Iowa State University graduate of the global resources systems program, checks on one of the prototypes of a mobile solar dehydrator. Mooney and four other Iowa State students created the dehydrator to address world hunger. The device can help small-scale subsistence farmers provide food for their families year-round.*

Improving the cold storage process and management via intelligent food logistics necessitates the use of technology to monitor each stage, including reducing harvest “cut to cool” times, targeting product specific transport, and adjusting packaging to allow visibility and monitoring of the state of the food inside could also lead to less loss.<sup>66</sup>

Universities can lead the way on research through innovation and partnership with the private sector, and they can also provide educational outreach to communities.

For this pathway, public research universities are best poised to undertake the following activities:

- Refine spoilage prevention packaging and treatments to be attuned to food type and allow for external quality measurements.
- Encourage the establishment of short-market chains that can help to reduce food loss and reduce pollution.
- Provide recommendations for optimal cold chain management especially regarding segmented food shipments.
- Conduct consumer education campaigns on *Use By* and *Best Before* dates to avoid unnecessary wastage.
- Foster organizing for collaborative research across the value chain for timely and accurate demand forecasting with special attention to communication technologies that can be scaled to large and small producers around the globe.
- Develop courses that encourage entrepreneurship to address producers’ and consumers’ needs and attract innovative students.
- Assess brand impact and consumer loyalty regarding switching products to reduce waste.<sup>67</sup>

### **Build internal capacity to measure and analyze data, cost, and health outcomes to improve policy and behavior through addressing food waste and loss in the value chain.**

The first step to reducing food wastage must be improving the collection and analysis of food waste and loss data at both local and aggregate levels, as well as along the value chain. USDA provides technical guidance on activities to reduce, recover, or recycle food waste, but aggregate tracking is not yet available. The effort is currently focused on assisting organizations to commit to food conservation efforts rather than providing increased access to information and analysis for individuals. Many of the potential solutions require better tools and increased participation to reduce waste across the food value chain.

Food wastage can also be result of food appearance and quality. Food quality encompasses the characteristics of food that make it both safe and acceptable to a consumer. This can include broad aspects of taste, appearance, texture, nutritional content, and absence of chemical or biological safety hazards.<sup>68</sup> Fruits and

vegetables are often rejected by retailers and consumers over perceived flaws and high cosmetic standards, but these foods are nutritionally adequate. Over 10 million tons of unharvested foods could be sold in a secondary market for imperfect produce, and further value-added processing could provide an opportunity for profit- or donation-driven business to avoid waste.<sup>69</sup> Similar problems exist with seafood. Less common species or over- or undersized fish or shellfish are difficult to sell to consumers because of misconceptions about these products' utility, taste, and nutritional value. Improving consumer and retailer information in both the nutritional and food safety aspects of imperfect fruit and vegetables, as well as products from fisheries and/or aquaculture, could lead to greater acceptability.

## The Harding Street Urban Agriculture Center

The Harding Street Urban Agriculture Center, a Virginia Cooperative Extension Project at Virginia State University, is an indoor farm in the middle of a food desert in the city of Petersburg. The center is an example of how urban agriculture can be used to redevelop inner city communities through agriculture enterprise. The center serves as a year-round vegetable production facility, a retail storefront, and a research center.

The center uses an innovative approach to growing referred to as controlled-environment agriculture (CEA). It has developed (patent pending) portable growth chambers that allow for 100 percent off-

grid climate-controlled environments. The entire production room uses solar panels for off-grid operation. The center also captures rainwater and condensation from the HVAC units. The center conducts research experiments with lighting, grow methods, and nutrient combinations to develop high-efficient, year-round hydroponic and aquaponic production methods that are useful for both commercial applications and everyday citizens. In addition to the indoor farm, they also developed a micro-farm, urban orchard, urban vineyard, and composting site on vacant lots near the center, which are maintained by local citizens.

The major strength of the center is the collaboration with the city of Petersburg, its Department of Social Services, and its Health Department as well as several grassroots organizations to provide outreach regarding nutrition, entrepreneurship, economic development, and agricultural literacy. Soon the center will launch a mobile market unit that will conduct "pop-up markets" throughout the community. It will also open a kitchen for value-added food processing, culinary arts, and nutrition education.

The Harding Street Urban Agriculture Project is funded by a grant from the USDA National Institute for Food and Agriculture.

Learn more: <https://www.ext.vsu.edu/harding-st-project/>

PHOTO: VIRGINIA STATE UNIVERSITY



*Former Harding Street Urban Agriculture Center director, Duran Chavis, checks the status of the greens in one of the center's growth chambers.*



For this pathway, public research universities are best poised to undertake the following activities:

- Provide improved systems for households, producers, and businesses to identify opportunities to eliminate or reduce food loss and waste.
- Refine techniques and technologies to better quantify food waste along the entire food value chain.
- Conduct research to better understand the drivers of consumer and employee behavior and develop appropriate educational interventions.
- Target communities through increased outreach and extension activities with educational materials addressing health or nutritional concerns on imperfect food products and ways to reduce household-level food loss.
- Conduct research to better understand the impact of post-harvest handling and food processing on the health functionality and overall quality of foods.<sup>70</sup>
- Actively engage existing university policy institutes to focus research and other efforts to address issues of food loss and waste in the value chain.

**Engage urban communities to develop opportunities for urban agriculture and aquaculture to increase nutritious food availability in urban environments to promote healthy diets and to expand economic opportunities.**

Why focus on urban areas? In 2007,<sup>71</sup> for the first time in human history, more people lived in cities than in rural areas. Projections for 2050 estimate an increase to at least 66 percent.<sup>72</sup> Currently, many urban areas have “food deserts” where fresh fruits, vegetables, and other healthy food are not readily available. As an example, of the over 520 food retailers in Washington, DC, 88 percent mostly sell boxed, canned, or processed foods according to a 2015 report.<sup>73</sup> In higher-income areas, there is consumer demand for small chain (farm to market) access to fresh produce, meat, and seafood. As cities grow around the world, particularly in low-income countries, urbanization presents pressing challenges to ensure food access and availability.

Public research universities, particularly in urban settings, can deepen and redirect their focus on urban agriculture, aquaculture, and food systems. They can engage urban communities to analyze the constraints, costs, benefits, and market structure of potential urban agriculture and aquaculture and provide required research to support local community development.

For this pathway, public research universities are best poised to undertake the following activities:

- Provide the knowledge necessary to foster the creation of regional food hubs that revitalize urban and rural communities, create local investment and jobs, improve nutritional health, reduce waste, and make communities nationwide more resilient.

- Identify effective intervention points, potential investments, and business models to create economic opportunities and increase availability and access to healthy foods.
- Study issues of specific concern to urban production such as mitigation of contaminated soils, roles of food policy councils, and causative links between food and nutrition assistance and health outcomes.
- Conduct research to develop new technologies and methods to make better use of food processing byproducts and discarded crop, food, and seafood residues, with special attention to how this waste could be reintegrated into animal production systems.
- Focus on the new opportunities offered by the marriage of agriculture and technology, which includes innovations of small-scale production systems.

**Generate knowledge of local food systems to re-localize those systems and revitalize communities through investment, job creation, and resilience building.**

Currently, 54 percent of the world's population live in urban areas. This number increases to 80 percent of the population in the U.S., Mexico, and Canada.<sup>74</sup> Much of the urban population is concentrated in coastal areas.<sup>75</sup> Coastal population growth and urbanization, along with an increasingly centralized large-scale food system, has increased the distance between food production (farm) and food consumption. Food travels longer distances as food production is centralized in rural and on large scales. Meanwhile, food processing is highly centralized, and nutrient density has declined. In the United States, the agricultural workforce (including fisheries) is less than 1 percent of all wage and salary workers; worldwide the most recent figures from the World Bank's World Development Indicators shows that agriculture accounts for just 3.8 percent of total workforce employment across high-income countries.<sup>76</sup> Fresher food, and engagement of a larger segment of the population in the food system, are benefits that could lead to better policy and personal food choices.

With this move to urbanization, consumer tastes are also changing, with demand for local and organic foods on the rise. To meet consumer needs, universities could create a network of engagement around urban, peri-urban, rural, and coastal food system value chains.

For this pathway, public research universities are best poised to undertake the following activities:

- Perform information gathering and analysis to determine where gaps in knowledge and research regarding local food hubs exist.
- Gather and share information, including knowledge from NGOs, food policy councils, and other entities, using the connections of Cooperative Extension and other university outreach and engagement mechanisms to help localize food systems.
- Develop new curriculum for urban students, executives, non-producers, and others to improve agricultural and food literacy.

- Work with local communities to build knowledge and capacity by revitalizing existing and establishing new knowledge and research networks through regional partnerships between rural, peri-urban, urban, and coastal public research universities to encourage two-way exchange of ideas.
- Embrace the role of the public research university as a convener that mediates urban, peri-urban, and rural dialogue as well as dialogue between food agriculture and fisheries and other nonfood agriculture communities.
- Build local and regional capacity in food production and preparation by building shared facilities in urban, peri-urban, rural, and coastal communities.
- Establish strong networks with non-agriculture and fishing communities such as architects, landscapers, urban planners, the development community, material scientists, engineers, and energy scientists.
- Facilitate education as empowerment for small producers, food processors, consumers by expanding the university's role from the classroom to the community through extension and community outreach to build educational capacity and future innovation.

## Access

The second dimension of food and nutrition security, Access, means having sufficient resources and ability to obtain appropriate foods for a nutritious and culturally appropriate diet. The FAO estimates that although world food production is currently sufficient to meet the caloric requirements of today's world population, one in nine people are still chronically malnourished.<sup>77</sup> Like the availability component, challenges around access to food and nutrition security have many contributing factors, including gender, socioeconomic status, and location. To address these and other factors, the Commission identified two areas as critical for public universities and their partners to address: the creation of an enabling environment for access and inclusion and equity. Working groups focused on these two areas developed two challenges to be addressed under the access component:



### Challenge 4

Create and share resources that serve all populations



### Challenge 5

Ensure inclusive and equitable food systems



## CHALLENGE 4 OVERVIEW

### Create and share resources that serve all populations

All people deserve access to healthy and affordable food, but access can be impeded by economic, physical, and social factors. To address these impediments, local, national, and international actors should create policy that enables access to a safe and nutritious food supply for all. Currently, the economic and social status, gender, race, ethnicity, and/or location of groups and individuals contributes to the disparity of access to a nutritious food supply. These factors are also an obstacle to the creation of an inclusive and equitable food system overall. For some, the issue is not a complete lack of access to food, but a lack of access to healthy food. For example, in higher-income countries, single parents who work two jobs and experience limited access to healthy foods are presented with food choices that are adequate for hunger, but inadequate for full child cognitive and physical development. Lack of access to healthy food often results in undernutrition and/or obesity.<sup>78</sup> In low-income countries, access is often driven by many of these same constraints; however, severe poverty and the unpredictable forces of political, climate, and social instability compound and magnify the problem.<sup>79</sup>

Likewise, rural producers may be constrained by lack of market integration and inadequate knowledge of, or ability to meet, international standards necessary to fully engage in trade in a global economy, thereby diminishing their incomes and hindering access to nutritious foods.<sup>80</sup> To increase access, public research universities should bring attention to the priorities and constraints of food and nutrition insecure populations. By focusing on these priorities and constraints, public research universities can engage with policymakers and communities to collaboratively design and build effective solutions that support evidence-based decision making.

A number of factors affect access to a healthy and nutritious food supply and therefore to food security overall. One factor is isolation from the institutions that create and disseminate relevant knowledge. Globally, there are approximately 500 million family farms occupying 80 percent of the world's farm land.<sup>81</sup> These 500 million family farms must make critical decisions regarding the management of natural resources, technology adoption and adaptation, market engagement, and consumption. Most of these farmers make decisions with little to no support from formal advisory services. Rural household surveys, like the World Bank Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA), indicate that only a small fraction of rural households report contact from extension providers and even fewer report impact from that contact. Poor extension services contribute to persistent poverty, which makes food unaffordable and inaccessible. It also contributes to low farm productivity, further diminishing access to food for consumers. Those affected by low farm productivity and diminished access to food often do not have sufficient knowledge about nutrition and are therefore unable to make informed choices with regard to the food they are able to access.



## Enhancing Food Security in the Northeast through Regional Food Systems

The northeastern U.S., comprising 12 states from Maine to West Virginia and the District of Columbia, is home to more than 21 percent of the nation's population, but only 6 percent of the nation's farmland. More than 7 million Northeast residents do not have adequate access to an affordable food supply. These circumstances prompted research into whether greater reliance on regionally produced food could improve food access in low-income communities while also benefiting farmers, actors in the food supply chain, and others in the food system.

Since 2011, with a \$5 million grant from the USDA's National Institute of Food and Agriculture, a team of researchers has been exploring this question through a project called Enhancing Food Security in the Northeast (EFSNE). The project engages more than 40 partners from 16 different disciplines at 11 universities, nonprofits, and agencies, including

Columbia University, Cornell University, Delaware State University, Johns Hopkins Bloomberg School of Public Health, Penn State, Tufts University, University of Vermont, the USDA's Agricultural and Economic Research Services, and West Virginia State University.

The project team employs a systems approach, engaging the entire food chain from production to consumption in collaboration with community leaders in nine rural and urban locations across the Northeast. A large portion of the EFSNE work occurs in specialized research teams that explore a specific segment of the food system—primarily, consumption, distribution, and production.

During this time, team members focused on outreach and education have extended project findings into communities and classrooms. The project's outreach component focuses on engaging community

members at its eight study locations. For instance, by conducting a “community readiness” study, team members identified what several of the communities have already been doing to enhance food access at the community level along with potential next steps. These team members shared their findings with community leaders at each location and collaborated with location leaders to plan and implement stage-appropriate programming.

Findings of the project's education component have been integrated into classrooms across the region. For example, Delaware State University partners developed a team-taught, experimental course that bridges nutrition and natural resources, titled “Fundamentals of the U.S. Food System and Food Security,” which was offered in spring 2016. In addition, Tufts and Penn State have augmented courses with food system topics.

Learn more: <http://agsci.psu.edu/research/food-security>



*The EFSNE project engages more than 40 partners from 16 different disciplines at 11 universities, nonprofits, and agencies.*

Farming households in Africa, South Asia, and other regions with high rates of food insecurity often lack technical knowledge that could enhance productivity, market information that could enhance their incomes, and nutritional information that could improve the health of their families. Moreover, they lack the means to communicate with the scientific community to create and disseminate vital information as well as the means of access and share information among one another. Similar issues exist within fishing households and communities in low-income countries, where a lack of education and information severely impede family wellbeing. Within food insecure populations, women and minorities tend to be especially disadvantaged and disconnected from advisory services. The use of communication tools and platforms to improve extension services, technical assistance, and advisory services could improve the dissemination of information to these populations, enhance their knowledge, and improve their ability to interact with researchers.

Existing extension systems in many countries are ineffective. They are often formed from misaligned factions of public, private, and non-governmental providers whose lack of resources, insufficient coordination, underlying gender and class dynamics, and other outdated approaches and methods hinder their ability to increase access to, and knowledge of, nutritional food for these populations



## The Pathway to Meeting the Challenge

Develop models and make recommendations for infrastructure development that improve access to food and counter risks in rural, urban, peri-urban, and coastal areas.

Expand access to knowledge through open learning, participatory research, intercultural dialogue, and outreach platforms.

Develop and apply improved communications technology to enable communities to collaboratively shape research agendas and use technologies to improve advisory and outreach services.

Develop and revise needs-based programs to train Extension personnel and administrators domestically and globally using proven outreach and engagement methods to increase access.

### **Develop models and make recommendations for infrastructure development that improve access to food and counter risks in rural, urban, peri-urban, and coastal areas**

Infrastructure deficiencies in both rapidly growing cities and isolated rural areas of low and high-income countries leave many households without access to a diverse selection of safe and nutritious foods. At a regional level, infrastructure deficiencies inhibit trade of food products and contribute to local shortages as well as local excesses and waste. It is well acknowledged that improved infrastructure can enhance access to food by allowing low-cost movement of products and people. In spite of this knowledge, policy-makers and other actors rarely consider whether particular forms of infrastructure investment would have a differential impact on food accessibility to insecure populations. Focusing

on the ways infrastructure investments could address the problems that food insecure households face in achieving food security could result in a more structured pattern of infrastructure development. Food security outcome can depend on the nature of infrastructure investment. For example, investments in port improvement will likely enhance food access at a national level, while the provision of rural cold storage and feeder roads might have a more targeted impact on access to nutritious food at the household level. Both types of investments are needed, and distinctions about forms of infrastructure are important considerations when designing interventions.

The challenge of creating infrastructure to address the issue of food security is increased by the dramatic demographic shifts currently taking place in the world, with urban populations expected to rise by 2.5 billion people, the greatest challenges exist mostly in low-income countries where there are already inadequate infrastructures and weak linkages between urban centers and rural areas of food production.<sup>82</sup> Indeed, the Global Harvest Initiative estimates that there is a \$1 trillion gap between current investments and the amount of investment that would be needed to meet the physical infrastructure needs in low and middle-income countries.<sup>83</sup>

Public research universities can help governmental actors identify forms of infrastructure development that would be most beneficial to food insecure communities. Infrastructure is, by nature, a public good. Public research universities are uniquely situated to combine a public service orientation with the technical expertise needed to address infrastructure innovations. This necessary technical expertise includes environmental and civil engineering, but also social science, food science, and other disciplines. Funding for infrastructure development will almost certainly require forms of public-private partnership. Because of their expertise, public research universities can be helpful in identifying potential partnerships and ensuring that those partnerships are in the public interest. The challenge is to promote innovations and investments that are targeted to the needs of food insecure people in both physical infrastructure and institutional infrastructure.

For this pathway, public research universities are best poised to undertake the following activities:

- Collect and analyze data that guides investment and research on alternative infrastructure systems to enhance physical access to safe and nutritious foods.
- Conduct a needs assessment based on geocoded information related to nutritional outcomes, food distribution, and market access. Such an assessment might use “big data” analytics to identify infrastructure deficiencies that can be associated with food insecurity.
- Conduct research to identify and test new forms of physical infrastructure suited to local contexts. Such new forms may be more important in information and communication technology (ICT), energy, and sanitation than in transportation.

- Research contract mechanisms that are more appropriate for low-income people to develop economically sustainable infrastructure for ICT, energy, and sanitation.
- Research the relative impact that infrastructure has on poverty and food security in order to facilitate regional trade versus the impact infrastructure support of domestic markets has on ICT, energy, or sanitation in order to set appropriate priorities in many countries.

## FeedMix App Aims to Help Small Farmers Optimize Flock Health

Providing the correct balance of nutrients can be challenging for chicken farmers who mix their own feed. Nutritional imbalance can lead to malnourished or stressed chickens. Justin Fowler, an assistant professor at the University of Georgia, recently released a mobile app that will help poultry producers mix feed ingredients to maintain a healthy flock.

Fowler developed the app after working with the emerging poultry industry in Ghana. He was one of a delegation of UGA poultry scientists who traveled to Ghana to help the Ghana Association of Poultry Farmers set up a Cooperative Extension-style continuing education program for poultry farmers.

The number of poultry farms in Ghana is growing, but most farmers only raise a few hundred birds at a time. In 2015, Ghanaian farmers produced approximately 2.1 million broilers on 1,508 farms. About 2,900 Ghanaian poultry farms raise laying hens and sell eggs, according to a 2016 study by the USAID.

Ghanaian poultry farmers who mix their own feed do so from ingredients that are very similar to U.S. producers' ingredients. The mix mainly consists of corn and soybean meal.

During Fowler's trips to Ghana, farmers often asked him about the health of their flocks to which he would respond with questions about the chickens' nutrition. "They'd tell me, 'We just make our feed ourselves; we don't know what nutrients are in it,'" Fowler said.

After those visits to Ghana, Fowler collaborated with developers to create a simple app to help producers know exactly what they are feeding their birds.

FeedMix, funded by a grant from the World Poultry Foundation, was released in August 2016.

"This app allows them to enter in what they're mixing into the feed, and it will give them information about the nutrient balance of that mix" said Fowler.

"Pretty much every farmer we talked to had a (smart) phone," Fowler said. "The advantage of this technology is that it provides immediate feedback to producers who are on a small enough scale that they may not have a good handle on exactly what kind of nutrition they are providing their flocks."

FeedMix is the second app released by the UGA poultry science department. In 2015, UGA faculty members developed CHKMINVENT, an app that allows farmers to enter local climatic conditions and other factors to calculate cooling and ventilation plans for their chicken houses. Farmers in the U.S. and across the globe have downloaded the app more than 1,000 times.

Learn more: [tinyurl.com/UGAFedMix](http://tinyurl.com/UGAFedMix)



*The FeedMix App*

PHOTO: UNIVERSITY OF GEORGIA



## **Expand access to knowledge through open-learning, participatory research, intercultural dialogue, and outreach platforms.**

Public research universities have a unique leadership role in creating and populating universally available knowledge sharing platforms. These information collection and dissemination tools can provide inclusive, equitable, and accessible information about both the drivers and causes of food insecurity, as well as best practice solutions that come from discovery and learning.

A representative population of persons impacted by food security, including women, youth, poor, and marginalized groups (WYPM) should be engaged in setting the agenda for research and should have easy access to research and information that would be helpful in overcoming food security challenges. Outreach activities should seek to understand how to effectively interpret and apply that information. According to the Human Science Research Council, the use of modern information-sharing technologies, like reliable internet access, can lead to increases in agricultural productivity among family farm households.<sup>84</sup> Using technology for knowledge sharing can make market information more accessible and offer the information resources necessary to make better choices toward increased productivity.

Although public research universities often conduct studies related to global food security, they often do not have as much impact as they could. In many cases, these studies incorporate WYPM groups as the focus of their study. However, unfortunately, the study outcomes are not always relayed back to the focus groups, thus limiting the potential impact of the studies. It is important, therefore, to develop intentional strategies, not only for the collaborative design of research, but also to include local communities and public stakeholders in the development of outreach and engagement strategies. Doing so would help to ensure that results and outcomes are shared in ways that are easily accessible and useful for eliminating food insecurity.

Opportunity exists not just for public research universities, but also for the private sector, governments, and communities to share research, knowledge, and resources related to food security. Allowing equal opportunities for all sectors to access and share vital information will promote broader use of the information that is important to food value chains. Global Open Data for Agriculture and Nutrition (GODAN), a global organization of more than 350 entities, has determined that the world would “greatly benefit” from a global data ecosystem, but that “none currently exists.”<sup>85</sup> One of the major obstacles in creating a data-sharing culture is establishing trust. It therefore is critical to engage all stakeholders to build personal trust in the early stages that will then translate into institutional trust.<sup>86</sup>

For this pathway, public research universities are best poised to undertake the following activities:

- Catalogue available outreach materials and the existing models for communication platforms. Such an inventory of content and practices would be a valuable resource for the development of new modes of public outreach and engagement.

- Examine how existing models and communication platforms can be used to encourage front-end input from target communities, thereby facilitating a move toward a more engaged model for Extension.
- Catalogue information and platforms for knowledge collection to be shared with stakeholders. Beyond the initial research to inventory materials and methods, universities should take the lead in building the platform(s) to make those materials available and to allow their curated expansion through public participation.

## AgReach – A Program for Smallholder Extension

Access to markets, better seeds, and innovative technologies are just a few components that producers need to improve production and yield higher profits. However, the poorest smallholders face many barriers to success even with the support of local agricultural extension and advisory services. AgReach, a program of the University of Illinois at Urbana-Champaign (UIUC), closes gaps in agrisystems so that smallholder farmers can thrive.

AgReach has grown out of several USAID and Feed the Future (FtF) projects, which began in 2010 with the Modernizing Agriculture and Extension Services (MEAS) project. Through collaboration with public and private institutions, governments, and nongovernmental organizations, these projects have transformed extension into more demand-driven,

gender-responsive, and nutrition-sensitive systems through building local capacity and applying research-based program designs, which ultimately serve millions of smallholder farmers.

Paul McNamara, Ph.D., economist and professor at UIUC, leads the initiative and team of 18 professionals based at UIUC and in some of the poorest countries in the world. The program also serves to connect institutions like Njala University in Sierra Leone and Makerere University in Uganda with University of Illinois' staff and students, opening communication and collaboration on international agriculture issues.

In 2016, two AgReach projects worked to build the capacity of extension workers, improve agricultural policies and practices, and evaluate programs intended to support smallholder farmers. The Integrating Gender and Nutrition within Agricultural Extension Services (INGENAES) project worked with people in eight countries including Honduras, Bangladesh, and Zambia to create more gender-responsive and nutrition-sensitive extension for men and women farmers. The Malawi Strengthening Agriculture and Nutrition Extension Services (SANE) project worked with the FtF initiative and Malawi's public extension providers to better coordinate services and close agriculture and nutrition gaps. AgReach continues to develop research-based solutions with its network of smallholder farmers, extension professionals, innovative researchers, and students to build better extension systems, and is always up for a challenge.

Learn more: <https://agreach.illinois.edu>



PHOTO: COLBY SILVERT

*Students from Tonkolili District School in Sierra Leone check for weeds in demonstration vegetable plots planted during a field day with INGENAES and WorldFish.*

- Participate in current data and knowledge sharing platform opportunities, such as GODAN.
- Seek to develop outreach, service, and engagement opportunities that develop participatory research methods and opportunities for sharing research results with underserved populations.

**Develop and apply improved communications technology to enable communities to collaboratively shape research agendas and use technology to improve advisory and outreach services.**

Since the passage of the Morrill Land-grant Acts of 1862, 1890, and 1994, Hatch Act of 1887, Smith-Lever Act in 1914, the 1966 Sea Grant College Program, and several other important legislation land- and sea-grant universities have developed cooperative extension systems so that university discoveries can be made available to a variety of stakeholders and so that individuals and groups in need can make their needs known to researchers.

Due to budget cuts, extension education and outreach services have been dramatically cut, and outreach to underserved areas of mid- and high-income countries have suffered. Systems are largely absent or poorly functioning in low-income countries. To address global food insecurity, extension systems are needed to empower producers and food insecure populations and to allow those populations to communicate with each other and with research institutions. Public research universities are in a position to leverage their experience with public outreach along with the new platforms and technologies for communication that they develop to improve extension and advisory services for food insecure populations wherever they may be.

Universities have already been working to enhance the quality of communication through community outreach and engagement with underserved and non-traditional stakeholders, like the work of the University of Illinois through AgReach (see box on page 62) and others throughout the report. The problems, however, are particularly acute in developing regions of the world. Universities can contribute by providing expertise in assessing strengths and weaknesses of existing extension systems, providing models for training trainers and policymakers, and exploring new systems that could be locally relevant, sustainable, and effective.

Beyond leveraging existing knowledge, universities are centers for creating and applying communications technologies. For example, public and extension practitioners will need to be trained how to use new communication tools. To ensure inclusive use of communications tools and platforms, it is important for universities to engage in coalition building with communities and partners from the public and private sectors.

Universities can help create new platforms on which communities can express their needs to the research sector, share their experiences, and benefit from the knowledge created by universities.

For this pathway, public research universities are best poised to undertake the following activities:

- Catalogue available extension material to be delivered along with the existing models for communication platforms. Such an inventory of content and of practices would be a valuable resource for the development of new modes of public outreach and engagement.
- Study successfully implemented U.S. and foreign extension systems as a step towards guiding/strengthening their roles in informing research and adoption by users of new methods and approaches.
- Foster collaboration between land- and sea-grant, urban-serving public universities and public university programs.
- Prioritize the creation of new communications tools for a 21st century extension and engagement system that can deliver greater food security.
- Engage in coalition building through, for example, dialogue between the academy and indigenous or disenfranchised communities.
- Conduct research to characterize the current state of the delivery of extension and advisory services and to assess its effectiveness as a platform for multi-directional communication.<sup>87</sup>
- Test and assess alternative methods of public outreach and advisory service delivery. Universities can provide evidence for what works and what does not work in terms of creating effective communication for greater food and nutrition security.

**Develop and revise needs-based programs to train Extension personnel and administrators domestically and globally with proven outreach and engagement methods to increase access.**

There are a range of needs for post-secondary training to improve extension and outreach related to food and nutrition security. Universities in the U.S. and in low-income regions could enhance extension systems by providing additional technical training for extension agents in food and nutrition systems. Further, they could offer degree programs in management and administration relevant to leadership in extension systems. Universities could also more widely offer non-degree programs for training trainers and addressing other aspects of public education. However, such curricular programs must be based on the identified needs for training Extension personnel and administrators both in North America and abroad. The training of extension agents should be particularly attuned to the needs of female agriculture workers, thereby mainstreaming the dimension of gender.

Investment in international partnerships with universities and institutions not only yields benefits overseas, but also brings benefits back to the U.S. or other investing



countries, through ensuring safe, high-quality food; expanding trade and developing business; sharing scientific knowledge and information; solving environmental problems across borders; and, preparing human capital for the global economy. Universities can promote the purpose of these partnerships to the public as the underlying driver of domestic food supply, emphasizing the international collaborations that promote problem solving for an increasingly connected world.

For this pathway, public research universities are best poised to undertake the following activities:

- Provide technical training for extension agents in food production and nutrition.
- Provide degree training in management and administration relevant to extension systems leadership and non-degree programs for training trainers and addressing other aspects of public education.
- Develop appropriate curricular programs based on needs identified by Extension personnel and administrators in in North America and abroad.



## CHALLENGE 5 OVERVIEW

### Ensure inclusive and equitable food systems

Public research universities, as the discoverers, analyzers, and curators of agriculture, food systems, fisheries, aquaculture, and nutrition information, have a unique leadership role in creating knowledge that will ensure equitable access to sufficient food and nutrition security for all people. Opportunity exists for public research universities, in partnership with the private sector and local governments, to share research and knowledge resources related to food and nutrition security. Allowing equal opportunities for all sectors, especially small and entrepreneurial producers, to access and share vital information will promote broader use of information that is important to the food system. The time is right to create such a platform and universities, as the discoverers, analyzers, and curators of information and data, should be the natural leaders in this effort.

Addressing the issue of inclusion and equity in the charge to create food and nutrition security globally demands an examination of affect the gender composition has on the global food scene. Women play a major role in increasing the performance of the agricultural sector and eradicating hunger, particularly in low-income countries where women account for 43 percent of the agricultural workforce.<sup>88</sup> Therefore, closing the gender gap in agricultural productivity by giving women the same access to resources as men could help reduce the number of undernourished by as much as 100 to 150 million people.<sup>89</sup>



## The Pathway to Meeting the Challenge

Identify the forces in food production systems that impact producers and their workers to ensure policymakers fully understand and address their needs.

Measure and address the drivers/causes of inequity in access to food through inclusive, equitable, and accessible creation and dissemination of information related to domestic and global food security.

Expand inclusion on campuses and with the public through discovery, engagement, and learning.

Enhance the role of women in agriculture, and related areas, by promoting girls' and women's education and access to resources.

Invest in human and institutional capacity-building efforts of constituencies, allowing them full participation in science, education, and policy making to ensure food and nutrition security, which is particularly necessary in low-income countries.

### **Identify the forces in food production systems that impact producers and their workers to ensure policymakers fully understand and address their needs.**

The nature of production systems are a product of societies they serve, and forces outside the control of the producer often have an impact on consumers within those societies. Universities are a place where the social and biophysical sciences reside in tandem. The challenge is one of helping consumers understand that there are tradeoffs involved with meeting nutritional, health, sustainability, environmental, animal, and social welfare goals and in providing producers with information to mitigate risks and to facilitate informed decision making.

Labor-intensive food production and processing, such as the processing of dairy, meat, seafood, and horticultural crops rely on sources of labor from outside the United States. Typically these laborers originate from populations that are so poor that they are willing to work under conditions that U.S. citizens are unwilling to accept. Despite growing interest in sustainable production among U.S. citizens, still only a very small percentage of the U.S. population owns farmland. And without access to land and the means of sustainable production, producers, workers, and consumers alike have little input into their food system. The same holds true for sustainable fisheries and access to boats and equipment for production, harvesting, and distribution.

Producers can increase their security in the event of catastrophic climate or environmental failure, but the ability to do so relies on adequate local weather data to calculate payouts through agricultural index-based insurance markets. Universities can also contribute to the climate modeling to build the index and facilitate the development of infrastructure to capture real-time information. In addition, universities can assist in helping to identify and quantify some of the risks involved so that policymakers and individual consumers can make informed choices regarding the food they eat and the products they purchase.

For this pathway, public research universities are best poised to undertake the following activities:

- Analyze the benefits and burdens of the food system on all people, places, and enterprises to be a resource for policy- and decision-makers.
- Prioritize the study of barriers to full participation in the global agricultural trade, especially for low-income countries, and identify interventions for capacity building through university partnerships.

## How Researchers Developing New Insurance Products Are Reducing Poverty in Africa

Droughts in eastern Africa have become increasingly severe, with devastating results for farmers and pastoralists. During 2011, livestock pastoralists in Kenya lost on average one-third of their animals to severe drought. Some families manage these losses by selling off assets and others reduce how much they eat. Both of these can keep families trapped in severe poverty.

“We know that risk is a driver of poverty,” says Michael Carter, director of the Feed the Future Innovation Lab for Assets and Market Access at UC Davis with collaborators at Cornell and the International Livestock Research Institute. They have spent the past decade developing ways that pastoral households can manage this risk.

Their solutions are based on index insurance, which is a more affordable alternative to traditional insurance. Index insurance bases payouts for losses on measures of related environmental factors, such as rainfall or vegetation coverage. If a measure fails to reach a certain threshold, the policy automatically makes a payout regardless of actual losses. This increases transparency on both sides, and eliminates the need—and cost—of investigating individual claims.

The Index-Based Livestock Insurance project (IBLI) in Kenya, and more recently Ethiopia, uses advanced satellite technology to build an index based on an area’s vegetation coverage. When vegetation coverage fails to reach a certain threshold, the payout helps farmers to recover losses. This project has changed how many pastoral households in eastern Africa deal with drought. The IBLI team

recently found that the insured households are up to 36 percentage points less likely to expect to reduce meals than those without insurance. They are also half as likely to expect to sell livestock after a drought.

“The government of Kenya is at the cusp of doing some very interesting and innovative things,” says Carter, “and that’s based in part on what’s been happening under the IBLI project.” Building on the team’s work, the government of Kenya is scaling up the IBLI innovations by launching the Hunger Safety Net Program and the Kenya Livestock Insurance Program to address chronic poverty in the country.

Learn more: <https://basis.ucdavis.edu/index-insurance-innovation-initiative-i4>



*A child sits with goats at a market in Ethiopia.*

PHOTO: AMA INNOVATION LAB

- Educate actors on existing inequities and promoting public discourse and policy to further just and equitable food systems for all people in the food system.
- Propose alternative economic models that promote equitable distribution of wealth, access to healthy food and conservation of biological and cultural diversity.
- Conduct research on risk markets for producers and interventions that can lower risk, particularly for those entering the market.
- Analyze the cost and benefits of immigration policy on the agricultural workforce.
- Provide better training in sustainable agriculture and food systems by developing new interdisciplinary programs that better integrate the natural and social sciences aspects of agriculture and food systems.
- Adopt new teaching models based upon problem-based learning, projects, and phenomenon learning.
- Conduct barrier assessments for small/young farmers to start businesses and/or uptake new technologies that would create more sustainable systems.

**Measure and address the drivers/causes of inequity in access to food through inclusive, equitable, and accessible creation and dissemination of information related to domestic and global food security.**

Universities have the opportunity to address the causes of food and nutrition insecurity through capacity building, technical research, technical assistance, and facilitation of communication. Not only does disseminating this knowledge via knowledge platforms serve to solve problems, knowledge sharing also allows for more informed policymaking.

Access to food can be affected by the policy environment. For example, openness to international trade can have both positive and negative impacts on local food prices. Likewise, regulations governing transportation and processing of food impact local availability and access. Policies governing access to credit and agricultural/fisheries inputs also affect production and incomes. In addition, policy may inhibit access to food in the areas of governance of land tenure, biotechnology and biosafety, gender equity, research and extension, and ocean spatial planning. The capacity of policymakers and the public to assess policy options often determines the quality of public policy and the degree to which the policy environment promotes food security and avoids unintended negative consequences.

Policy research can identify unintended consequences of policies, determine who wins and who loses as a result of policy interventions, and assess the degree of benefits and costs from policy alternatives. As disinterested, neutral parties, universities can be an important source of credible technical analysis to inform policy debates.

For this pathway, public research universities are best poised to undertake the following activities:

- Train future policymakers and policy analysts who are well-versed in policy research, including methods of welfare analysis and impact evaluation, and who can work collaboratively with scientists and stakeholders.
- Offer degree programs and lead short courses for public sector and NGO staff in low-income countries to enhance their capacities to conduct and interpret policy analysis.
- Provide policy briefs to explain both the implications of research and the implications of policy for public audiences. Such communication is critical to raising the quality of the policy environment and its contribution to inclusive access.
- Conduct domestic and international policy analysis.

### **Expand inclusion on campuses and with the public through discovery, engagement and learning.**

Traditionally, the mission of public research universities has been to teach, research, and be of service to communities. However, in reality, most are more focused on research than on teaching, community extension, and outreach services. This is partly because incentives, such as promotion, tenure, and salary prioritize research and publication, over teaching or service. Additionally, budgets for extension and outreach programs have been cut significantly in the recent past.

Consequently, universities may have limited engagement with some of the stakeholder groups that are most impacted by food insecurity—women, young, poor, and marginalized populations. These factors affect not only those engaged in the conversations around teaching, research, and service, but also those impacted by it.<sup>90</sup> Ensuring that universities engage all stakeholders in tackling food insecurity necessarily involves two parallel and complementary foci: changing the face of the university and changing the impact of the university.

True equity and inclusion must begin within the university—from admissions and hiring practices to ensure that the voices of women, youth, the poor and other marginalized groups are being heard at all levels—and extend into true partnerships within the community. Diversifying both the student body and the staff/faculty is essential to bringing stakeholder voices into the conversation around how to address food insecurity.<sup>91</sup> Increasingly, universities are seeing the value that a diversified campus brings. Data from the 1995 Faculty Survey conducted by UCLA's Higher Education Research Institute (HERI) showed that having diverse faculty provided new viewpoints and new answers to old questions.<sup>92</sup>

Lack of diversity among university student bodies, and in particular the failure of U.S. universities to attract minority students from underrepresented populations, is also partially to blame for the predicted shortage of qualified graduates for jobs in the agricultural and related sciences, including fisheries and aquaculture. Minority college enrollment increased dramatically from 2002 to 2012, but the percentage of minority graduates of programs in the agricultural and related



sciences increased from only 16 to 17 percent.<sup>93</sup> U.S. institutions must develop innovative programs to attract and train minority students. Attracting more minority students can be achieved by diversifying curriculum and faculty, raising awareness of educational and career opportunities, and reaching out to this untapped pool of students.

## Building on a Legacy

### *Serving Small Farmers in Alabama and Beyond*

The Carver Integrative Sustainability Center (CISC), launched in 2010 at Tuskegee University, is a regional, national, and international leader in agricultural and environmental sustainability focusing on challenges of socially disadvantaged and minority communities and small farmers in the South and in low-income countries. CISC builds upon the legacy of research and service initiated at Tuskegee University by George Washington Carver in 1896.

More than 40 faculty and staff from six of the university's eight schools and colleges participate in eight transdisciplinary teams to support goals and progress around four pillars of sustainability: ecological, economic, social, and health/wellness. These teams engage representatives from the university, community-based organizations (i.e., Federation of Southern Cooperatives, various farmer and farmers market associations throughout the Alabama Black Belt, economic development organizations, county commissions and various faith-based organizations), as well as U.S. Department

of Agriculture agencies (i.e., Natural Resource Conservation Service, Forest Service, Farm Service Agency, and Rural Development).

CISC successes include adaptive irrigation and solar energy technologies that have enhanced small farmer production efficiencies as well as the development of small to large producer and landowner clusters to increase marketing opportunities, profitability, and economic development in poor and rural communities. A transdisciplinary team of research and Extension experts have targeted the benefits of orange-flesh sweet potato from a whole plant perspective. Human disease due to a lack of nutrients (i.e., anemia and Vitamin A deficiency) can be mitigated by the nutrients found in orange-flesh sweet potato. Initiating the project in Ghana, the team focused product enhancement across the value chain (production, processing, and preparation) to increase intake. The effort proved successful, generating a sweet potato flour used in breads that were well received. The team is working toward similar success in the United States to promote sweet potato use by poor communities.

Tuskegee University believes strongly in equality of opportunity and recognizes exceptional talent is often hidden in students whose finest development requires unusual educational, personal, and financial reinforcement. Tuskegee serves the global society as well as the regional and campus community and beyond by developing outreach programs that are compatible with the university's educational mission, improve understanding of community problems, and help develop relevant alternative solutions.

Learn more: <http://www.tuskegee.edu/academics/colleges/caens/cisc.aspx>



*Regional clusters of small and large scale farmers get first-hand experience on a commercial grower's operation at a field day sponsored by the National Black Growers Council.*

For this pathway, public research universities are best poised to undertake the following activities:

- Engage stakeholder groups in identifying barriers to admission and success, as well as barriers to hiring and retaining faculty.
- Change the make-up of the hiring committees to ensure that they reflect diversity.
- Increase the recruitment and retention of students of color, poor students, and other historically marginalized groups through strategic enrollment management designed to address identified barriers.
- Increase diversity among faculty members through actively recruiting from diverse populations and improve retention by actively addressing identified barriers.
- Mobilize alumni to expand the pool of qualified student, faculty, and staff applicants.
- Create policies that provide the same kind of incentives and bureaucratic exceptions for diversity hiring as is done for premiere hires.
- Engage stakeholders in a review of curriculum, with a focus on diversifying the perspectives presented. University curriculum must also be adjusted to ensure that not only the people being taught, but the content taught is inclusive.
- Engage faculty in a review of tenure and promotion criteria to support and reward work that impacts local and global food insecurity.
- Create a community of practice that connects researchers and extension faculty with community workers on the frontline of hunger and malnutrition.
- Engage more student experiences in connection to global food security. Students and the broader community still experience food insecurity due to financial constraints and the increased cost of attending higher education.<sup>94</sup>
- Endorse food security as a community priority, beginning with campus leadership.

### **Enhance the role of women in agriculture, and related areas, by promoting girls' and women's education and access to resources.**

Women grow more than half of the world's food. They comprise 43 percent of the agricultural labor force globally and up to 70 percent in some countries.<sup>95</sup> Yet they are unable to access productive resources at rates equivalent to men, leading to lower crop yields and lower incomes. Increasing access to economic resources has a profound effect on household health outcomes and educational attainment. In 2011, the FAO estimated that more equitable distribution of resources to women could increase their yields by 20 to 30 percent, raise the agricultural output in their country by 2.5 to 4 percent, and reduce the number of hungry people in the world by 12 to 17 percent.

Limited access to resources is a consequence of many factors and usually stems from confinements created by gender roles.<sup>96</sup> Women often lack decision-making authority, have intense workloads for care and household

responsibilities, limited educational opportunities, and lack role models within the agricultural sector to provide them with direct training. Further, agriculture is often seen as a masculine subject of study so female students do not participate as frequently and, when they do, they often do not have the opportunity for higher-level learning. In 2016, UNESCO reported that female graduates in agricultural science have been increasing steadily in sub-Saharan Africa, with eight countries

## Equality for Women Farmers Will Help Feed the World

In regions across the globe, women in agriculture have less access to resources and opportunities than their male counterparts. The U.S. Agency for International Development (USAID) estimates that closing the gender gap by ensuring women have the same access as men to resources would increase yields by 30 percent, feeding an additional 150 million people.

Mississippi State University is one of five universities involved in a five-year project, led by the University of Illinois, aimed at enabling small-scale farmers to meet the rising demand for soybeans and to feed their families. Kathleen Ragsdale, Ph.D., associate research professor at Mississippi State's Social Science Research Center, and other collaborators, are evaluating gender empowerment using the Women's Empowerment in Agriculture Index (WEAI). Ragsdale is co-principal investigator on the project alongside Jill Findeis, Ph.D., professor of agricultural and applied economics at the University of Missouri.

"We are assessing gender equity between women and men farmers within and across the same households, villages, and regions in rural Ghana and Mozambique, as well as the role of women as soy producers," Ragsdale said. "Our overarching goal is to understand gender

inequalities in agricultural sectors in Sub-Saharan Africa in order to help transition rural women farmers, their families, and their communities toward better food security, health, and economic development."

Ghana is situated in western Africa and is about the size of the state of Oregon. It has a population of about 27 million, with 75 percent of the population living in the southern portion of the country. Northern Ghana is considered a low-income, food-deficient area. The region has some of the highest rates of malnutrition in the country, with four out of ten children malnourished.

Mozambique is home to 24.5 million people. It is one of the most impoverished countries in the world, ranking on the United Nations Development Programme's 2014 Human Development Index at 178 out of 187 countries.

"This research is important because women farmers in Sub-Saharan Africa—who produce approximately 80 percent of the food in this region—have different priorities, power over decision making, and access to resources than men," Ragsdale said.

Learn more: <http://soybeaninnovationlab.illinois.edu/>



PHOTO: NINA FURSTENAU

*Fridah Mubichi, project member, facilitates focus groups in rural Mozambique.*

reporting a share of women graduates of 40 percent or more: Lesotho, Madagascar, Mozambique, Namibia, Sierra Leone, South Africa, Swaziland, and Zimbabwe. However, the UNESCO report added that women are still poorly represented in the agriculture extension services.<sup>97</sup> Extension agents, who are typically male, are often unaware of the challenges women face in agriculture and the services they provide are attuned to the needs of men rather than for producers of all genders.<sup>98</sup> Gender roles may also discourage women from seeking assistance from male extension agents, thereby continuing the cycle.<sup>99</sup>

Empowering women for market-level integration and primary and secondary school enrollment has been a prominent goal for NGOs and extension agents, but universities can also take a role in encouraging women to continue their studies and receive advanced degrees. This can provide the diversified workforce necessary for extension agents to work effectively with female producers and, in turn, increase the available knowledge-specific barriers women face. Having women who are versed in the rigors of field work and the effect of policy on the most vulnerable can lead to reforms of the resource-access landscape. This, in turn, will likely favor the access and availability of food for households in both urban and rural environments.

Promoting inclusion of youth and women's voices in policy discussions can facilitate greater understanding and serve as a step towards removing the barriers blocking to entry that women face in agriculture and related fields. Actions resulting from these policy discussions can revitalize an aging workforce by spurring renewed interest in traditional farming methods and promoting an environment that enables innovation.<sup>100</sup> Universities can further facilitate these discussions by researching the barriers that exist with regard to: women seeking to enter the agriculture field, training youth in the agriculture field, and promoting access to information through ICT /open access platforms.

For this pathway, public research universities are best poised to undertake the following activities:

- Identify, recruit, and train women in the agricultural sciences.
- Create curricula that educate male extension agents on the specific barriers women face in agriculture, resource access, and social roles to better prepare them to meet the needs of all people.
- Analyze the barriers women face when choosing their major for higher education.
- Promote diversity at all levels in agriculture departments in higher education.

**Invest in human and institutional capacity-building efforts of constituencies, allowing them full participation in science, education, and policy making to ensure food and nutrition security, which is particularly necessary in low-income countries.**

This challenge addresses three interrelated issues, all of which are critical to building long-term effective research and implementation initiatives. First, a disconnect exists between the stated goal of public research universities in

long-term sustainable Human and Institutional Capacity Development (HICD) and the almost universal funding model of short-term project-based research and development projects. Second, the short-term project approach hinders the development of sustainable research relationships between public, land and sea -grants, urban serving universities and minority serving institutions (MSIs) both domestically and in in-country partner universities in low-income countries. Third, there continues to be a lack of funds to support the incorporation of non-researchers, particularly from disadvantaged or underrepresented communities, who use participatory research methods and evidence-based implementation approaches to address food security issues.

To address these three distinct issues, funding mechanisms need to be reoriented to emphasize longer-term, holistic partnerships between researchers at research-intensive and minority-serving U.S. institutions, in-country institutions overseas, and end-users in communities where food security issues need to be addressed. There is also need for investment in the human capital of the United States and North America. In particular, funding is needed to internationalize campuses, prepare students to work on global food security issues, and provide opportunities for short- and long-term study abroad.

This challenge acknowledges the experiences of food insecure community members as the bedrock of a generation of valid research topics, outcomes, and effective implementation strategies. Given the cultural and physical distance between even the most sensitive and experienced U.S.-based public and land-grant researchers, and the rapidly changing conditions in food insecure locations, it is essential that more inclusive, equitable, and durable partnerships be formed in which repeated exchange of ideas and knowledge can unfold. Short-term, project-based funding schemes deprive targeted communities—and the research and development experts working alongside them—of autonomy, self-determination, and respect. Moreover, many public university researchers are frustrated by these limitations, which prevent them from understanding their partners and end-users' wants and needs, as well as the lack of support they need to implement research outcomes.

In a 2014 review of Feed the Future programs, the Board of International Food and Agriculture Development (BIFAD) recommended that creating long-term partnerships between U.S. universities and those in low-income countries are the “key instruments for developing sound and sustainable” capacity building. BIFAD added that U.S. universities can “help model enabling environments and relationships to engage with the public.” To establish long-term relationships with higher education institutions in low-income countries, U.S. public, land-grants, and minority-serving institutions need support. Such support necessarily also involves creating incentives for collaborative work among researchers, scholars, and outreach specialists.<sup>101</sup>



# The Legacy of Norman Borlaug and Investing in Human Capital



*Norman Borlaug (fourth right) in the field showing a plot of Sonora-64, one of the semi-dwarf, high-yield, disease-resistant varieties that was key to the Green Revolution, to a group of young international trainees near Ciudad Obregón, Sonora.*

Norman Borlaug (1914–2009) was an American agronomist, researcher, humanitarian, and Nobel laureate who took on the challenge of ending world hunger and increasing agricultural productivity.

As part of his team of “hunger fighters,” he collaborated with Mexican scientists and farmers at the International Maize and Wheat Improvement Center (CIMMYT), the second Consultative Group for International Agriculture Research (CGIAR) center established by the Rockefeller Foundation, to breed a shorter and stronger stemmed wheat variety that responded to increased water and fertilizer. This allowed the variety to be used worldwide and remain structurally intact. He also worked with the first CGIAR center, the International Rice Research Institute (IRRI), to develop high-yield rice breeds that were resistant to heat and disease and resulted in increased yields across the Asian continent as part of the Green

Revolution of the 1960s. Both improved grain varieties led to a decrease in chronic food shortages.

While his work effectively increased yields, Borlaug envisioned himself as a humanitarian-scientist, improving the livelihoods of communities and promoting self-sufficiency to combat hunger. He famously said during his acceptance speech for the Nobel Peace Prize, “Never think for a minute that we are going to build permanent peace in this world on empty stomachs and human misery. It won’t happen, and the sooner our leaders at all levels of society reflect on that, the better.”

Today, his memory lives on through the Borlaug Leadership Enhancement in Agriculture Program Fellowship Program. The Borlaug LEAP program awarded fellowships to promising graduate students to engage mentors from U.S. universities and the CGIAR system. From 2005–2016, 170 fellowships (143 Ph.D. and 27 master’s degrees) were awarded, 97 percent to students from sub-Saharan Africa. Designed with input from renowned scientist Norman Borlaug, the program aimed to mentor a new generation of agricultural scientists and educators who can sustain scientific innovation for development. The program focused on exposing students to new ideas and different types of organizations through internships at U.S. universities and CGIARs. All 15 CG centers and 44 U.S. universities have participated in the program.

Funded by USAID with significant contributions from U.S. universities, Borlaug LEAP was managed by the CA&ES International Programs Office of the University of California, Davis. All participating organizations waived all indirect costs.

## ***Notable Borlaug LEAP Alumni include:***



H.E. Gerardine Mukeshimana, currently serves as Rwanda’s Minister of Agriculture. Her Borlaug LEAP fellowship strengthened her

doctoral research on the common bean by including field trials at CIAT in Colombia and in her home country of Rwanda. As Minister of Agriculture, she is leading the modernization of food and nutrition security in Rwanda including cross-cutting issues affecting the agriculture sector.



Peter Aikpokpodion, Ph.D. led the cocoa transformation agenda at Nigeria’s Ministry of Agriculture until May 2015. He brokered several innovative

public-private partnerships and facilitated private sector investment. Currently a professor at University of Calabar, Nigeria, his research has resulted in the development and official release of eight new cocoa hybrids in Nigeria and the unraveling of the genetic diversity of Nigeria’s cocoa field gene-banks and farm plantations.



Charity Mutegi, Ph.D. was honored with the Borlaug Field Award at the 2013 World Food Prize for her aflatoxicosis research. She is currently the

East Africa Aflasafe Coordinator at IITA. Mutegi’s fellowship in 2006 was her first opportunity to visit the United States and led to her establishing a network of international colleagues. During her fellowship, she worked with professors at Penn State University and researchers at ICRISAT.

For this pathway, public research universities are best poised to undertake the following activities:

- Expand education of women, youth, poor people, and marginalized groups in agriculture, nutrition, and related areas.
- Increase exchange programs between universities to cultivate and nurture long-term researcher-to-researcher and scholar-to-scholar relationships between U.S. and low-income country universities to build sustainable capacity.
- Encourage global learning opportunities for all students, including opportunities for short- and long-term study abroad, research and service-learning opportunities, as well as through technology such as the Center for Collaborative Online Learning (COIL) at the State University of New York (SUNY) for those students who are unable to go abroad.
- Encourage adoption of “sandwich” training programs, where foreign graduate students conduct research in their home countries and have an advising team that engages faculty members from the host country, as well as an in-country institution.
- Recruit developing universities around the globe to participate in knowledge sharing platforms such as GODAN, by submitting data and best practices as well as gaining access to data about agriculture and nutrition.

## Utilization

The third dimension of food and nutrition security, Utilization, refers to the appropriate use of food, which is based on knowledge of basic nutrition and care, as well as adequate water and sanitation to prevent foodborne disease. The FAO identifies food utilization as: “Sufficient energy and nutrient intake by individuals is the result of good care and feeding practices, food preparation, diversity of the diet, and intra-household distribution of food.”<sup>102</sup> To address these and other factors, the Commission identified two areas as critical for public universities and their partners to address: nutrition, human development, and health; and food safety, sanitation, and public health. Working groups focused on these areas developed two challenges to be addressed under the utilization component:



### Challenge 6

Address the dual burdens of undernutrition and obesity to ensure full human potential



### Challenge 7

Ensure a safe and secure food supply that protects and improves public health



## CHALLENGE 6 OVERVIEW

**Address the dual burdens of undernutrition and obesity to ensure full human potential**

According to the FAO, “food insecurity exists when people do not have adequate physical, social or economic access to food.”<sup>103</sup> A broader definition of food security reads: “food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life.” Food insecurity creates hunger, undernutrition, and higher risk of “overnutrition”—or, unbalanced nutrition with excessive caloric intake—leading to increased incidence of all forms of malnutrition.<sup>104</sup> Consequently, food insecurity profoundly affects nutritional status as well as health, social, and economic outcomes.

Many argue that what people eat is a personal choice and that consumer demand, including their culinary preferences, dictates much of what is produced. A more nuanced perspective suggests that demand can be shaped by many forces.<sup>105</sup> Within the framework of the definition of food security, access and utilization are linked.

The relationship between access and utilization is key to defining demand, which, in turn, affects production. Therefore, the science of nutrition must be integrated with components of access, utilization, and human behavior to comprehensively address the issues of over and undernutrition domestically and globally.

What individuals eat impacts society. At the individual level, one’s diet early in life sets the trajectory for cognitive and physical development that affects their productivity, health, and wellbeing throughout their lifetime.<sup>106</sup> The costs of malnutrition are staggering and reflect a growing double burden of both under and overnutrition. Recent reports on U.S. death rates show an increase for the first time since 1993, the vast majority of this increase is due to chronic disease, much of which is related to diet.<sup>107</sup>

The loss in human capital due to malnutrition is one of the hidden drags on economic development in high, middle, and low-income countries.<sup>108</sup> In Ethiopia, for example, undernutrition costs an estimated 16.5 percent of GDP and Asia and Africa lose 11 percent of GDP every year due to poor nutrition. In China, overnutrition will lower GDP 8.73 percent by 2025.<sup>109</sup> Obesity is estimated to cost \$1.4 trillion per year in the U.S. and \$2.0 trillion globally.<sup>110</sup>

Poverty is closely linked to obesity rates.<sup>111</sup> Poverty affects where people live, their access to quality food choices—fresh fruits and vegetables are often more expensive than fast food—, and, the time they have to prepare healthy foods. For example, in single-parent households, more often unhealthy choices are served because the parent doesn’t have sufficient time to prepare healthy meals. Many factors affect the nature of demand, which is shaped by the interaction of many external factors that impact access, utilization, and personal choice.

## Impacts of Nutrition on Human Capital Development

Children in low-income countries often suffer from high rates (40 to 60 percent) of micronutrient (MN) malnutrition that saps their cognitive and physical development. Based on survey work conducted in the 1980s by the USAID-funded Nutrition Collaborative Research Support Program (CRSP) (the precursor the current Feed the Future Innovation Labs), showing the value of animal source foods, a major source of bioavailable MN in child cognitive and physical development, the Global Livestock CRSP in the mid-1990s initiated a study to determine if the survey results were valid. The Child Nutrition Project (CNP) led by UCLA conducted a controlled interventions trial in rural Kenya that showed that a small quantity of meat fed on school days resulted in a significant increase in IQ scores, school performance, and leadership in playground activities. Researchers were then challenged as to how to get meat in the diets of children.

In response, a new project Enhancing Child Nutrition through Animal Source Food Management (ENAM) was awarded by the Global Livestock CRSP in 2002 to Iowa State University, McGill University (Canada), and University of Ghana to assess how to improve

children's diets in Ghana. Using the assessment results, ENAM combined formation of women's groups, led by Ghanaian women and training in nutrition, income generating skills, and microfinance to overcome the identified constraints to diet improvement (poverty, access to services, and nutrition knowledge). This sequence of long-term research investments by USAID shows the profound impact of research continuity and long-term commitment to critical areas of human capital development.

The results were remarkable. The women earned money, repaid their loans, and changed the diets of their children. In the end, a pool of \$12,000 was used over a quarterly cycle with full repayment. The results attracted the attention of local banks which then took over the project. Over the 16 months following the project, the local banks dramatically increased both the number of benefiting women (184 to 2,257) and the circulating microcredit loan portfolio (\$48,000 to \$1,242,000).

To spread the message, the Nigerian film industry, Nollywood, was engaged. It is viewed across Africa on TV and through DVDs. One of Nollywood's most renowned directors made a love story, "Hidden

Hunger," about the ENAM project that had embedded in it the message about nutrition and child cognitive development. Estimates suggest it was viewed by 2 to 3 million Africans.

The legacy of the CRSP system continues through the Feed the Future Innovation Labs, including the FfF Innovation Lab for Nutrition, led by Tufts University. They seek to discover how integrated interventions of agriculture, nutrition and health can achieve large-scale improvements in maternal and child nutrition.

Learn more: <http://www.vimeo.com/14063199>  
<https://feedthefuture.gov/lp/feed-future-innovation-labs>

PHOTO: SUSAN JOHNSON, GLOBAL LIVESTOCK CRSP



*The ENAM project activities targeted groups of mothers with small children (ages 2 to 5). The project succeeded in economically empowering women and improving the nutritional status of children. A system of peer educators was used to provide both nutrition and business education.*

It is well recognized that current analysis of food systems must consider both under and overnutrition. This is especially true given the high prevalence of both conditions globally and given that both conditions can occur within the same individual. Poor dietary quality, like the over-consumption of starchy or processed energy-dense foods that are low in micronutrients required for healthy, normal human development and prevention of metabolic diseases, are often to blame. In both North America, and across the globe, efforts to address food insecurity frequently fail to assess or target the real nutritional, health, social, and economic needs of populations, assuming instead that increasing the quantity of food will result in improved nutrition.

The underlying goal in these challenges presented below is to improve the integration of discovery, engagement, and learning to better evaluate and understand the food needs and nutrition gaps of specific populations, as well as plan and deliver more effective interventions to improve both food and nutrition security.



## The Pathway to Meeting the Challenge

Integrate resources through partnerships to understand the food and nutrition needs of populations and deliver scale-appropriate accessible, acceptable, and sustainable solutions to ensure nutritious diets.

Use systems thinking to perform public engagement and outreach that encourages the consumption of healthy foods, which is further informed by inter-connections among sociocultural, behavioral, and other determinants of food choice, as well as food systems constraints.

### **Integrate resources through partnerships to understand the food and nutrition needs of populations and deliver scale-appropriate accessible, acceptable, and sustainable solutions to ensure nutritious diets.**

Programs to improve nutritional status and food security have been implemented worldwide for decades,<sup>112</sup> yet there are still gaps in what is known about the nutrient and food needs of specific populations, namely: urban and rural poor, subsistence farmers, migrants and the homeless, those living in areas with a high prevalence of infectious disease, women of reproductive age, adolescent girls, and the elderly, who represent an increasing proportion of the population. Without data and analysis on these groups, solutions to food and nutrition insecurity will not effectively meet their nutritional needs both collectively and as individuals. Moreover, if their food and nutrient needs are not met, these populations will be unable to realize their full potential.

University discovery and learning is required in several areas in order to support improved interventions. These areas include: nutritional status and food security across seasons; food and nutrient intake versus nutrient requirements of target groups; understanding the functional impacts of intervention (e.g. reduced mortality and morbidity, better child development); cultural practices, beliefs, and acceptability of changes in the food supply; cost of resources needed to support different intervention strategies; and the usual factors on which successful



agricultural interventions depend (e.g. water, climate, soils, marketing). There is great opportunity for universities to improve the knowledge base in all these areas.

There is increasing recognition of the frequent mismatch between program delivery and nutritional needs. With this recognition has come the development of a limited number of tools and models to improve decision-making. Optifood,<sup>113</sup> linear programming software, is one such example. Optifood has been tested in Southeast Asia, Latin America, and Africa and aims to help design strategies for nutrition and micronutrient interventions. Another recent conceptual

## Nutritionally Yours

Louisiana's Southern University and A&M College includes the three arms of land-grant mission: teaching, research and extension. Nutritionally Yours encompasses the signature Extension nutrition programs: Supplemental Nutrition Assistance Education Program (SNAP-Ed), The Expanded Food and Nutrition Program (EFNEP), Creating Healthy Enjoyable Foods (C.H.E.F) Camp and the Growing Healthy Initiative, all of which serve thirteen parishes across the state of Louisiana. Programming for Nutritionally Yours aims to educate the citizens of Louisiana about the positive benefits of making healthy nutritional choices, how to expand their food dollar and how to prepare food safely.

Southern's model demonstrates the cultivation of organic partnerships with public, private and grass roots community organizations through outreach. Parish advisory council meetings are among the ways they facilitate those partnerships. These councils provide an opportunity to hear the immediate concerns and challenges that citizens face. From parish to parish, advisory councils across the state shared a common sentiment. In many cases, they expressed a desire to make healthy food selections, but often had limited access to fresh fruits and vegetables. The United States Department of Agriculture's Food Access Research Atlas revealed that the majority of the nutrition education sites in the program were located in urban and rural food deserts.

A majority of the educational sites are school based, which highlights the fact that children are growing up in food deserts. Southern University partnered with several schools across the state to providing a series of nutrition education lessons to students from Kindergarten through 12th grade. In keeping with

the SU Land Campus's mission and federal nutrition program goals and objectives, Southern provide this direct and indirect nutrition education using a policy, systems, and environmental change (PSE) approach.

Policy, systems, and environmental change (PSE) approaches seek to go beyond programming into the systems that create the structures in which clientele live, work and play. Program evaluation indicates that providing nutrition education using a PSE approach increases nutrition knowledge and encourages behavioral change.

Learn more: <http://www.suagcenter.com/>



*Stephanie Elwood, Extension Associate teaching the students at Bridge Academy how to grow a plant the correct way and how to eat healthy as part of the Growing Healthy Initiative.*

development is bio-economic optimization modeling, which considers both the biological impact (e.g. nutritional status, function, disability, adjusted life years) and economic resources needed to determine which combination of interventions will be most efficient.<sup>114</sup> The likely impact of local agricultural changes on food security has also been modeled by researchers at the University of California, Davis with national food balance sheets in Bangladesh, Senegal, and Cameroon, suggesting which crops should be increased and the gaps that would likely remain to be filled by other strategies.<sup>115</sup> For fisheries in low-income countries, existing trends suggest that there is likely to be greater food insecurity and conflicts as a result of declining fishery resources, changing consumption patterns, increasing reliance on fishery resources for coastal communities, and inescapable poverty traps creating by low net resource productivity and few alternatives.<sup>116</sup>

Effectively engaging in research at the community level requires building relationships of trust between the researchers and the community. The importance of this relationship is further explored in the Institutional Transformation section of this report. Many North American universities are located in urban or rural areas where food insecurity and both under and overnutrition problems are common, yet faculty and students working on international nutrition and food security are often disconnected from the locally affected communities. Developing community trust and an understanding of the inner workings of cultural and societal norms requires significant time. Providing a platform for more efficient and effective researcher engagement requires a strong extension presence in the community.

The recommendations of this Commission regarding nutrition, human development and health support and build upon the recommendations from the *Healthy Food Systems, Healthy People* report issued by APLU in 2016.

For this pathway, public research universities are best poised to undertake the following activities:

- Leverage partnerships, extension services, and stakeholders to better evaluate and understand the food needs and nutrition gaps of specific populations, both domestically and globally, in order to plan and deliver more effective interventions to improve health outcomes.
- Aggregate what is already known about successful and unsuccessful programs that exist across North America to encourage healthy eating, including programs that study the effects of junk food and publicity on health, so that interdisciplinary teams can develop and pilot new methodologies and strategies to improve health outcomes.
- Develop new biomarkers to better predict chronic disease predisposition, which can in turn help to tailor individual nutrition programs to better address these diseases.<sup>117</sup>
- Forging partnerships with health care and public health professionals to enhance understanding of the role of nutrition and lifestyle strategies in improving health and lowering the risk of chronic disease.<sup>118</sup>

## Making the Healthy Choice the Easy Choice

### *University of Minnesota Extension SNAP-Ed Creates Greater Impact through Partnerships*

When clients visit the ECHO Food Shelf in Mankato, Minn., they enter a place subtly structured to help them make nutritious choices.

Some of what clients encounter is visual—an appealing setting where fresh fruits and vegetables are displayed prominently, for instance. Other features are practical. Text messages encourage clients to pick up produce while it's fresh. Volunteers use “healthy nudging”—helpful encouragement and preparation tips that promote vegetables and whole-grain foods, without any “shoulds” or judgment. All result from a partnership between ECHO and the University of Minnesota Extension’s Supplemental Nutrition Assistance Program-Education (SNAP-Ed).

SNAP, previously known as food stamps, helps low-income individuals and families buy food. Recipients include the elderly, families and veterans. Many are employed but still need some assistance to put nutritious food on the table, and they may visit a food shelf because SNAP benefits are not enough to meet all of their food needs. SNAP-Ed results in clients making healthy nutritional choices wherever they are. Both SNAP and SNAP-Ed are funded by the U.S. Department of Agriculture (USDA).

Rachel Jones, Extension SNAP-Ed educator, leads Mankato-area SNAP-Ed programs that equip volunteers with approaches to “nudge” clients toward healthy choices. “We want to make healthy choices the easiest choices,” she says.

Deisy De Leon Esqueda, director at ECHO, says it makes a difference when Jones teaches volunteers just how to do that. “Our volunteers have contact with many families walking through the door every day,” says De Leon Esqueda. “For every volunteer trained by Extension, we reach many more clients with messages about how to be healthier, while treating them with respect and dignity.”

Extension leaders began reframing statewide SNAP-Ed programs in 2015 to align with the USDA’s expanded direction. Providing education and research-based information to groups that work



PHOTO: UNIVERSITY OF MINNESOTA

*University of Minnesota Extension SNAP-Ed educators like Rachel Jones (foreground) extend nutrition education to families by training food shelf volunteers and other partner organizations. Also pictured: Deisy De Leon Esqueda, director at ECHO Food Shelf in Mankato, Minn. (back), and volunteers.*

directly with SNAP recipients enables Extension to have a lasting influence on the wide scope of issues that impact nutrition.

### **Impacts**

University of Minnesota Extension SNAP-Ed helps nearly 40,000 people make healthy food choices via 281 partnerships. Other programs offered through Extension health and nutrition include:

- Expanded Food and Nutrition Education Program (EFNEP), assisting metro-area families
- Volunteer-based programs to boost shopping and meal preparation skills
- Diabetes prevention classes for high-risk groups
- Outreach to school nutrition services

Learn more: <http://www.extension.umn.edu/family/health-and-nutrition/partner-with-us/snap-ed/>

- Develop better tools for rapid nutrition assessment of population groups.
- Conduct case studies on interventions to provide an analysis of what design and implementation characteristics prove effective in improving nutritional status.
- Develop and test tools for modeling the impact of individual interventions and then evaluate the optimal mix of effective interventions for target communities.
- Identify what cultural, policy, systems, and food environment changes can positively affect consumers to make healthy dietary choices, particularly for children and adolescents, leveraging and expanding partnerships, extension services, and stakeholders to better evaluate and understand the food needs, constraints on utilization and nutrition gaps of specific populations to plan and deliver more effective individual and community interventions.
- Determine the impacts of interactions among nutrient intake, physical activity, and educational interventions on chronic disease prevention and treatment.<sup>119</sup>
- Incorporate food systems level modelling of nutritional interventions into the nutrition curriculum.
- Collaborate across academic colleges of agriculture, human sciences, medicine, nursing, and public health to develop curricula and other learning experiences that enhance workforce understanding of, and scientific skills related to, food and nutrition impacts on human health and chronic disease.

**Use systems thinking to perform public engagement and outreach that encourages the consumption of healthy foods, which is further informed by inter-connections among sociocultural, behavioral, and other determinants of food choice, as well as food systems constraints.**

Identifying additional barriers to healthy eating is the best way to promote healthy eating and will provide necessary and important insights that support action programs aimed at improving food and nutrition security.

The universe of literature discussing how behavior affects food choice is growing rapidly.<sup>120</sup> Integrating many disciplines in this research can provide a new, more effective approach to food behavior change. Local groups interested in improving eating habits can act as a resource and assist in the implementation and evaluation of local projects. Policy analysis and research is also needed to determine how current policy fosters the availability and affordability of unhealthy food over healthy food, and what policies could be developed to make healthy food more available and more affordable.

In the long term, it is essential for society to understand the value of nutrition and its role in the health, economic productivity, and social stability of a nation. Nutrition education that emphasizes the importance of access to, and availability of, a nutritional food system is a critical part of changing the drivers of consumer demand that in turn affect the structure of food systems.

For this pathway, public research universities are best poised to undertake the following activities:

- Aggregate what is already known about successful and unsuccessful programs that exist across North America to encourage healthy eating so that interdisciplinary teams can develop and pilot new methodologies and strategies.

## Beyond the U.S., Mexico, and Canada

### *From Measuring Problems to Solving Problems*

Universities around the world are engaging with their local communities, not just APLU members. Zamorano University in Honduras was established to 1942 to offer young people the opportunity to become professional leaders with skills and values capable of transforming companies and organizations to respond to current challenges in Latin America and the world. Zamorano students recently experienced this mission in action and learned how their work can have impacts on the local community.

In 2013, several students participated in a study organized by Adriana Hernandez Sant, Ph.D, where they were provided with the resources to carry out research on the state of nutrition in the nearby town of El Jicarito.

Students formed teams and studied the nutrition of El Jicarito's residents in five age groups in the town: newborn—3 years old, 6–12 years old, teenagers, adults, and over 65 years old. They found that little to no research existed on levels of nutrition in rural Honduran communities. In several cases, these thesis projects were the first time these groups of people participated in nutrition related exploration. Due to the lack of existing research, the students created their own research tools, consisting of questionnaires, health evaluations, weekly meetings, and food logs. Questionnaires created by the students were filled out by each participant along with a nutrition test, blood test, BMI exam, and attendance at regular meetings.

While El Jicarito is located near Zamorano and many of its residents are employed by the campus, gathering participants was no easy feat. These students had no previous contact with members of this community, but made contacts with school principals, mayors, and clinics to earn trust and assure a three- to four-month long commitment to the study.

The students found some stunning results—young children were predominantly anemic and their mothers were found to be consuming the proper number of calories, but lacking the proper nutrients. Young children and teenagers were consuming excessive amounts of vitamin A and sodium. Adults were had excess levels of sodium, but lacked vitamin A and calcium.

It is the hope and goal of Zamorano students and faculty to continue the work started with these research projects to provide additional research and education in a way that makes an impact on the local community and continues to build the relationship between Zamorano and El Jicarito.

Learn more: <https://www.zamorano.edu/en/academic-departments/food-science-and-technology/infrastructure/human-nutrition-laboratory/>



PHOTO: ZAMORANO UNIVERSITY

*Students interview youth about their food consumption using familiar foods and quantities.*



- Determine the components of food choice and develop methods for modification of human behavior related to choice to improve diets.
- Identify and conduct rigorous evaluation of cases of successful behavioral modification, like, for example, the success in reducing smoking in U.S. populations, in order to apply similar practices to nutritional interventions.
- Engage other food system leaders and businesses, health and public health professionals, economic developers, planners, and other non-traditional partners to address the issues of food choice.
- Incentivize and build skillsets of consumers in food systems thinking and analysis for food choice behaviors.
- Analyze the connections between availability, access, and utilization at the population, landscape, and regional scales, for populations, as well as individuals.



## CHALLENGE 7 OVERVIEW

### **Ensure a safe and secure food supply that protects and improves public health**

Proper food safety and sanitation practices are public health concerns that must be addressed in order to achieve food and nutrition security. Food safety will continue to be an increasingly critical area of concern as the food supply chain becomes even more global. In the United States, an estimated 1 in 6 (48 million) Americans become ill, another 128,000 are hospitalized, and 3,000 die of foodborne diseases like Norovirus, *Salmonella*, and *Listeria monocytogenes* each year.<sup>121</sup> In low-income countries, an individual's ability to absorb and utilize nutrients from food is affected by a number of non-food related factors, including safe water, sanitation facilities, and hygiene (commonly referred to by the acronym WASH).

It is important to be able to quantify and predict the risk of unsafe food. The growing world population, along with increasing consumer demands for a variety of foods, present a very complex supply chain where foods and ingredients come from different countries, fields, bodies of water, and farms—all of which are subject to different food safety programs, infrastructures, and potentially hazardous contaminants—thus creating vulnerability to outbreaks around the world.<sup>122</sup> A number of organizations, including the WHO and the FAO, are currently building networks to facilitate the flow of information and increase collaboration among different countries. Changing climate conditions, such as changes in rainfall patterns, affect food safety by impacting the resistance, dissemination, and persistence of bacteria, viruses, parasites, and fungi, and their respective foodborne diseases.<sup>123</sup>

It is clear that the challenge of keeping food safe in a highly interconnected and globalized world must be addressed in a way that is collaborative and coordinated and that includes research institutes,



governments, industry, and the public.<sup>124</sup> This requires committed resources, improved communications, and directed efforts to assure safety and sustainability in the convergence of animal, human, and environmental health.<sup>125</sup>

## The Pathway to Meeting the Challenge

Collaborate to improve understanding of the animal-human-environment health continuum through the ONE Health initiative.

Develop more effective preventative controls through developing and testing technologies that assess critical points, mitigate risks in the food chain, and allow the timely detection of potential foodborne illness outbreaks, particularly in fresh produce and raw seafood.

Improve surveillance of antibiotic use, develop tools for source attribution, improve management practices, and find effective alternatives for treating antibiotic resistance.

### **Collaborate to improve understanding of the animal-human-environment health continuum through the ONE Health initiative.**

The concept of ONE Health recognizes that the health of humans is linked to the health of animals, as well as the prevalence of pathogens in the environment. The underlying philosophy is that the health of the global population can only be addressed by undertaking a coordinated, interdisciplinary, and preventative approach. This is especially relevant to the spread of multiple drug-resistant pathogens that can arise in one geographic region and then spread across the globe. This synergy will advance health care for the 21st century and beyond by accelerating biomedical research discoveries, enhancing public health efficacy, expanding the scientific knowledge base, and improving medical education and clinical care.

Of particular concern in the ONE Health environment is the transfer of pathogens between humans and animals. Zoonosis is the transfer of pathogens from animals to humans, and has represented a significant public health concern since early civilization. There is also increasing concern over zoonanthroponosis, which can result in virulent pathogens being passed to and then disseminated via animals.<sup>126</sup> The World Bank has estimated that various zoonoses have cost global economies more than \$20 billion USD in direct costs, and \$200 billion in indirect costs between 2000 and 2010.<sup>127</sup> It is estimated that there are zoonotic origins to 65 percent of recent major disease outbreaks, this includes recent outbreaks of Ebola, H1N1 (swine flu), mad cow disease, and avian influenza.<sup>128</sup>

Zoonotic diseases are in part increasing due to an expansion of the meat production industry to satisfy the increasing global protein demand. To meet the growing demand, the number and intensification of animal production systems has increased. The consequence of current trends is that zoonotic diseases are likely to become more significant in the near future, with virulent pathogens becoming rapidly and more widely disseminated. It is critical to monitor zoonotic diseases with a ONE Health approach and identify practices that can reduce the risk.<sup>129</sup>

The ONE Health initiative involves the collaborative efforts of many partners, including universities. Universities play a key role in scientific innovation, education, training, and in developing guidelines for consistent practice. Other partners include physicians, osteopathic physicians, veterinarians, dentists, nurses and other scientific-health and environmentally related disciplines, including the American Medical Association, American Veterinary Medical Association, American Academy of Pediatrics, American Nurses Association, American Association of Public Health Physicians, the American Society of Tropical Medicine and Hygiene, the Centers for Disease Control and Prevention, the United States Department of Agriculture, and the U.S. National Environmental Health Association.

## ONE Health – Ohio to Ethiopia and the World

Society's challenges and our complex, interconnected communities demand new models of inter-professional collaboration and institutional teamwork. A ONE Health approach encompasses education, surveillance, farm management, environmental stewardship, and health care to address issues related to antimicrobial resistance, foodborne illness, and the spread of zoonotic agents.

The Ohio State University's Global One Health initiative is the result of a deliberate strategy to improve lives by recognizing connections and breaking down silos, internally and externally. Ohio State's collaborations incorporate a One Health philosophy that integrates individuals and organizations for optimizing the health of humans, animals and the environment.

Global One Health at Ohio State began in response to consultations with Ethiopian universities, regional and U.S. federal institutes, to build a partnership integrating academicians and practitioners from Ohio State and select East African countries to leverage their knowledge, skills and resources to directly and indirectly contribute to improving biologic and economic health in developed and underdeveloped countries.

Faculty and staff teach, conduct research, strengthen relationships, and exemplify Ohio State's commitment to innovation on a global scale. Task force members come from multiple colleges and non-academic offices throughout Ohio State, including all seven health science colleges, agriculture, arts and sciences, business, education and human ecology,

engineering and social work, distance education and outreach and engagement. Today, Global One Health connects Ohio State to Ethiopia, Kenya, Tanzania, Brazil, Mexico, Thailand, China and India in a coordinated, multidisciplinary approach to improve health, build capacity, and provide learning opportunities for students across the globe.

This partnership is led by Wondwossen Gebreyes, DVM, Ph.D., a professor of molecular epidemiology, director of Global Health Programs at Ohio State's College of Veterinary Medicine, executive director of Global One Health at the Office of International Affairs and recipient of the 2015 APLU Malone Award for International Leadership.

Learn more at <https://globalonehealth.osu.edu>



*Ohio State and Addis Ababa doctors review a scan.*

PHOTO: THE OHIO STATE UNIVERSITY

The recommendations of this Commission regarding an integrated, ONE Health approach build upon the recommendations from the *Healthy Food Systems, Healthy People* report.

For this pathway, public research universities are best poised to undertake the following activities:

- Develop a better understanding of the biology and relative importance of each key host species and its relationship with biodiversity at local and landscape levels.
- Develop innovative genetic and genomic tools to differentiate infectious agents, across both species and strain level.
- Implement new strategies for tracking hosts, including detailed information of social networks plus spread barriers and routes of dissemination within and between species.
- Develop predictions and model gene flows across multiple hosts and build a network to improve the understanding of the transmission process through the implementation of mathematical modeling and statistical analysis.
- Develop policies to expand and implement the tracking and assessment of the factors and mechanisms of human and animal disease processes control, including managing the release of wastewater to estuaries and coastal waters where seafood is produced and harvested.
- Collaborate with partners in low-income countries on technical assistance that will prevent the transmission of food safety threats moving across borders.
- Continue research on the human microbiome to better understand the role of microbiota in human health and disease.
- Collaborate to develop consistent curricula for veterinary practitioners around the globe.

**Develop more effective preventative controls by developing and testing technologies that assess critical points, mitigate risks in the food chain, and allow the timely detection of potential foodborne illness outbreaks, particularly in fresh produce and raw seafood.**

Foodborne illness outbreaks result from a number of events that combine to form the “perfect storm.” With centralization of production and more effective surveillance, the ability to detect outbreaks has increased significantly within the last three years.<sup>130</sup> Still, the ability to prevent pathogens entering into, and disseminating through, the food chain remains inadequate.

For the last 30 years, the underlying philosophy of the food safety system has been that pathogens acquired at the primary production stage can be removed post-harvest during processing. Yet particularly in the case of fresh produce and raw seafood, this approach has proven to be ineffective due to limited efficacy of the post-harvest wash process for produce or the lack of any economically viable post-harvest processing methods that would be able to eliminate pathogens from raw seafood without changing texture and/

or flavor.<sup>131</sup> Moreover, some of the foodborne pathogens in raw seafood, like *vibrio* spp., are considered part of the normal microbiota of shellfish.<sup>132</sup> Consequently, it is becoming clear that preventative approaches are required at the primary production stage, which includes identifying events and conditions that would raise the risk of contaminated product reaching the consumer.

## Food Research Institute Celebrates 70 Years of Food Safety Innovation

The oldest U.S. academic program focused on food safety, the Food Research Institute (FRI) was founded at the University of Chicago in 1946.

At that time, botulism and salmonellosis were known but poorly understood foodborne illnesses. Many otherwise well-known diseases were only alleged to be foodborne, and the causes of many known foodborne illnesses had yet to be established.

With the advocacy of UW-Madison professor E. Michael Foster, the Institute moved to the University of Wisconsin- Madison's campus in 1966. Ever since, FRI has served as a portal to UW-Madison's food safety expertise for food companies in Wisconsin, the U.S. and worldwide. Once the academic Department of Food Microbiology and Toxicology, today the Institute is an interdepartmental entity, with faculty from the Departments of Bacteriology, Animal Sciences, Food Science, and Plant Pathology in the College of Agriculture and Life Sciences, the Department of Medical Microbiology and Immunology in the School of Medicine and Public Health, and the Department of Pathobiological Sciences in the School of Veterinary Medicine.

In keeping with the Wisconsin Idea, FRI's reach extends well beyond campus boundaries through industry partnerships, especially with its 40 sponsor companies. The Applied Food Safety Lab and laboratories

of FRI faculty collaborate with food processors to identify safe food formulations and processing techniques. The Institute also provides outreach and training to both food companies and the greater scientific community through meetings, short courses, conferences and symposia.

"FRI is an outstanding example of how a public-private partnership can benefit the academic mission of UW-Madison and the needs of the Wisconsin food industry," FRI Director Chuck Czuprynski, Ph.D. said.

During the past 70 years, FRI has made many insights into the causes and transmission of foodborne diseases. Early on, FRI research established

methods to identify and detect staphylococcal enterotoxins. FRI faculty are leaders in mycotoxin research and have made important contributions to understanding of the shedding of *E. coli* O157 by cattle, survival of *Salmonella* in stressful conditions and the role of *Listeria* in foodborne disease.

Looking to the future, FRI research is investigating novel mechanisms to prevent foodborne pathogen growth in meat and dairy products, interaction of plant pathogens and pests with human foodborne pathogens, food-animal antibiotic alternatives, and the role of the microbiome in health and disease.

Learn more: [fri.wisc.edu](http://fri.wisc.edu)



PHOTO: UNIVERSITY OF WISCONSIN

*Lab workers and undergraduates at FRI inoculated apples with Listeria in a study that revealed the cause of a 2014 Listeria outbreak in caramel apples.*



Fresh produce and raw seafood remain the commodity groups that are responsible for the most foodborne illness outbreaks within North America. In most cases, foodborne illness outbreaks linked to fresh produce and raw seafood are detected long after the contaminated product has been consumed or discarded. Short shelf life and complex distribution chains make it more difficult to identify outbreaks and trace them back to the contamination source. A classic example of such a scenario is the 2011 outbreak of *Listeria monocytogenes* in cantaloupes.<sup>133</sup> In that case, the trace-back investigation isolated five different *Listeria monocytogenes* strains from patients, homes, retail locations, and the cantaloupe packing house and farm cooler at the originating farm. The pathogen contaminated the surface of the cantaloupes and was subsequently spread to crates, transport trucks, and other facilities.

Identifying genetic, biological, and other critical points within the food chain, it is possible to develop algorithms. From that point, scenario models can be constructed to predict the probability of outbreaks based on the environmental inputs, climatic conditions, post-harvest handling, and consumer handling. Moreover, scenario models will enable virtual assessment of policies and interventions related to the probability of reducing outbreaks. With advances in data acquisition occurring in near real-time, it is feasible to monitor the food chain with greater frequency and greater detail than ever before.<sup>134</sup> Combining newly acquired data with historical data, makes it possible to identify critical points in the food chain, create means of monitoring, and establish critical limits through scenario simulations.

For this pathway, public research universities are best poised to undertake the following activities:

- Develop enabling technologies that span the development of diagnostics, data acquisition frameworks, and advances in data processing.
- Develop sensors that can be used within the field to capture data or facilitate laboratory testing to predict potential pathogen risks.
- Work to correlate the incidence of pathogens in animal production, prevalence in crop production centers and in soil and water (including ocean) environments.
- Determine how pathogens spread through the environment in relation to climatic conditions; human practices of waste management; farming, ranching, and fishing practices; scales of production; soil and water characteristics; and resident microflora.
- Identify genetic and physiological markers that identify pathogens with the ability to persist in the environment and interact with growing plants and filter feeding shellfish.
- Investigate how post-harvest handling and packaging affect the virulence and persistence of foodborne pathogens in foods.
- Develop quantitative risk assessment models that enable prediction of foodborne illness outbreaks taking into account pathogen type, climatic conditions, intrinsic conditions, pathogen resistance, and consumer susceptibility.

- Educate consumers and health practitioners on pre-existing health conditions that enhance the risk for food-borne illnesses.

**Improve surveillance of antibiotic use, develop tools for source attribution, improve management practices, and find effective alternatives for treating antibiotic resistance.**

As shared in the opening of the *Addressing Antibiotic Resistance* report, jointly produced by APLU and The Association of American Veterinary Medical Colleges (AAVMC),

“... antibiotics have enabled millions of people to live longer and more productive lives. They have dramatically lowered child and infant mortality rates and helped to significantly increase life expectancy. Antibiotics have also significantly reduced morbidity and mortality in animal populations and have improved gains in productivity. At the same time, there is a growing concern among scientists and healthcare workers that the effectiveness in treating infections with antibiotics is becoming compromised by increasing drug resistance.”<sup>35</sup>

Antibiotic resistance is a multidimensional and urgent worldwide problem. Due to extensive use of antibiotics, various organizations, such as the National Antimicrobial Resistance Monitoring System (NARMS) and the WHO Advisory Group on Integrated Surveillance of Antimicrobial Resistance (AGISAR), screen and track for resistance of microorganisms to specific antibiotics, as well as carry out significant resistance investigations.<sup>36</sup> For example, AGISAR collaborated with the FAO to initiate integrated foodborne pathogen and antimicrobial resistance examinations in Asian and African poultry, beef, pork, and aquaculture value chains.<sup>37</sup>

A range of common microorganisms and their resistance to traditional antibiotics is well documented. The growing antibiotic resistance of microorganisms, for both human and animal health, makes clear why a ONE health approach is needed to address these global issues.

The recommendations of this Commission with respect to nutrition, human development and health, support and build upon the recommendations from the *Addressing Antibiotic Resistance* report issued by APLU and AAVMC.

For this pathway, public research universities are best poised to undertake the following activities:

- Expand the development of epidemiology tools for source attribution and biomarkers.
- Implement the use of whole-genome sequencing, and other novel approaches to strengthen surveillance programs by the development of affordable diagnostics to facilitate data collection.
- Delineate modes of transmission of resistant organisms.

- Assess the relative importance of overuse and misuse of antimicrobial agents in human and animal settings: developing and carrying out risk assessment and prediction models on the overuse or misuse of antibiotics;
- Develop rapid care and diagnostically innovative therapeutic approaches.
- Implement innovative strategies to minimize the use of bactericides throughout the pre-supply chain and supply chain.
- Consider existing networks and coordinate a single network for collaboration, including universities, research institutes, and regulatory agencies to share and coordinate efforts.
- Use a systems approach to consider the roles of production scale, management practices, biodiversity in managed ecosystems, and ecological contexts in new strategies to avoid antibiotic misuse.




*Cows from the Thompson Research Center will be featured in Decker's project on page 44.*





*Extension Agent Lara Miller (white shirt at far left) instructing teachers and educators on how to use a seine net to collect and identify basic marine life as part of an Extension outreach program.*



A photograph of a man, David Reif, smiling and looking towards a woman, Dahlia Nelson, who is partially visible on the right side of the frame. The man is wearing a green and grey argyle sweater over a white t-shirt. The woman is wearing a white lab coat. They appear to be in a collaborative space, possibly a laboratory or office, with a blurred background showing other people and equipment.

*David Reif and  
Dahlia Nelson, right,  
members of the  
Bioinformatics cluster  
at North Carolina State  
University, talk in a  
collaborative space  
developed for their  
cluster.*

PHOTO: MARC HALL



## PART II

# Institutional Transformation for Public Research Universities to Meet the Challenges

## Introduction

Public research universities have long been powerful, problem solving institutions. Particularly in the field of agriculture, land-grant universities have solved problems in the production sector by making improvements in areas like agronomy, plant disease, and soil management. Many of the problems of the past fit comfortably within the disciplinary boundaries that define university departments, like addressing significant plant diseases or producing new varieties of plants with higher yields. Public research universities, with their disciplinary strengths, continue to make notable accomplishments that improve productivity, yields, and increase food supply.

Yet today, the challenges of ensuring food and nutrition security, as this and other reports detail, are more complex. Greater investments are needed to produce more food and fiber, but such production must also be done with greater efficiency, less impact on the environment, methods that support long-term productive capacity, and with underlying policy support. Such challenges demand approaches that engage a wide range of biophysical and social science actors who can productively interact to create solutions.

There are many examples of efforts to build interdisciplinary structures within universities such as the Biodesign Institute at Arizona State University, which addresses global challenges in healthcare, sustainability, and security and the California Institute for Quantitative Biosciences (QB3) at UC Santa Cruz, Berkeley and San Francisco, which uses quantitative tools to integrate bio-physical science in order to understand how biological systems work. In food systems, similar institutional approaches have been developed at several public research universities. However, more are still needed.

The university community, both public and private, maintains a strong interest in domestic and global food and nutrition security challenges; often private and public universities partner productively on these and other efforts.

This report challenges universities to evaluate

what has been done in the past to identify what works best and develop new ways to align their operations and resources to tackle the critical, complex, and wicked problems that are key to food and nutrition security. This section and its recommendations draw heavily on the work of the commission and the working group reports, as well as the excellent National Academy of Science 2014 report: *Convergence: Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering and Beyond*.

Undoubtedly, public universities face demands from many sources: students and communities, government and civil society, and political and economic entities. They also face external constraints, like competition, rather than

## Breaking Down Silos

In her book, *The Silo Effect: The Perils of Expertise and the Promise of Breaking Down Barriers*, Gillian Tett draws from example primarily of the business and financial sectors (including GM, Sony, and UBS) on how silos can hinder our work and our thinking and makes the following conclusion:

“...if there is one message from this book, it is that our world does not function effectively if it is always rigidly streamlined. Living in specialized silos might make life seem more efficient in the short-term. But the world that is always divided into a fragmented and specialist pattern is a place of missed risks and opportunities.....or to put it another way, in today’s complex twenty-first century world we are all faced with a subtle challenge: we can either be mastered by our mental and structural silos or we can try to master them instead. .... the first step to mastering our silos is the most basic one of all: to think how we all unthinkingly classify the world around us.”

Tett points out that breaking down barriers runs into resistance within institutions. “The people running institutions also face pressure to make these as efficient as they can by cutting waste. Specialization and focus is considered desirable in the modern world. That makes it hard to justify time consuming activities that do not deliver instant results....” Silos are not going away because they are fundamental and necessary structures of organization but we need to understand the forces that build barriers and be creative in how to cross fertilize between our



PHOTO: ISTOCK/ SHAUNL

disciplinary strengths to capture the opportunities and challenges of our complex world. That is the transformational challenge that our institutions face and are working to address. What can we do to mitigate the problem? Tett gives the following advice:

1. It pays to keep the boundaries of teams in big organizations flexible and fluid.
2. Align rewards and incentives with collaboration. Get away from “eat what you kill incentive structure.”
3. Information flows should be open and people should be capable of not only access but interpretation of information. There is a need for “cultural translators” in such a structure.
4. People should be able to reimagine the taxonomies they use to reorganize their world and experiment with alternative structures and operations.

collaboration, for funding. Other constraints are created internally through organizational structures and administrative policies that emphasize advancing a discipline rather than addressing complex problems faced by communities at home and abroad.

Universities are one of the world's most powerful public resources available to address the challenges identified in the previous section of this report. We must encourage their engagement and welcome them to transform the university system in ways that utilize their interdisciplinary expertise so that they may have a significant impact on the food and nutrition security problems of today and the future.

## Today's Public Research University Environment

Much like the food system, the university discovery, engagement, and learning system is a complex, interagency, multidimensional process influenced by history, established processes, and longstanding institutions. As with most institutions, universities are highly responsive to their resource base. Funding and constituencies determine a great deal of their structure and their behavior. With regard to the university resource base, several notable trends have developed in recent decades.

First, while funding is not the only issue, it is a critical one in today's environment. Fiscal support from states has declined dramatically to a level that is on average below 25 percent of the state universities' budgets. Several large research universities, such as UC San Diego, UCLA, University of Michigan, The Ohio State University, and Colorado State University, received less than 10 percent of their university budget from state funding.<sup>138</sup> This funding situation has influenced public research universities to implement an array of fiscal strategies. Most relevant to this report has been a greater reliance on federal research funding. Much, but not all, of that funding, like that from the National Science Foundation (NSF) and the National Institutes of Health (NIH), is more appropriate for basic science that does not connect easily to local community interests. Similarly, funding from the United States Department of Agriculture (USDA) is fragmented and focused on specific areas, although USDA's National Institute for Food and Agriculture (NIFA), through the Agriculture and Food Research Initiative (AFRI), has begun efforts to address food system level issues.

Second, obtaining large external grants, mainly through federal and private sector funding, has become an important measure of faculty success and a basis for promotion. Furthermore, many of the funding streams from the federal government are influenced considerably by well-meaning interest groups, and may be narrowly defined, short-term in focus, and strongly defended. This reinforces the departmental disciplinary science, but also sustains weaknesses in addressing system-level challenges, as discussed herein. This environment does not bode well for an incentive structure that aims to connect faculty to communities and

support integrative research. Since faculty members design and develop their courses in large part based on their research experience, education tends to have a strong disciplinary focus. The curriculum is more likely to reflect federal funding priorities than those of an increasingly diverse university constituency.

Third, the student and the local community populations have become more diverse, both ethnically and demographically. As the student and community populations diversify, and their food system issues become more local, education and engagement efforts need to become more connected to their needs. As noted earlier, diversifying the student body brings new stakeholder voices into the conversation around how to address food insecurity. Overall, universities benefit from the new viewpoints and novel answers to old community questions that a diversified campus brings.

## Engaging Local Stakeholders to Create Data Hubs

Local stakeholders have been formally influencing the research and engagement agenda at the University of North Dakota (UND) for nearly 10 years through the Community Connect forum, journal, and website. Area stakeholders have been heavily engaged in shaping has been precision agriculture and the use of unmanned aircraft systems (UAS), more commonly known as drones.

In 2012, the Unmanned Aircraft Systems Research Compliance Committee (UASRCC) was created to apply community standards to its evaluation of UAS research. The committee consists of 15 members representing the community, UND faculty and staff, local government, as well as local public safety departments such as fire and police. All UND UAS related research must be reviewed and approved by the committee before implementation. The committee's work is vitally important to the UAS field because of the need to engage the public in determining the ways this technology can be used efficiently and ethically.

In early 2017, through a grant funded by National Science Foundation to create the Digital Agriculture Spoke for the Midwest Big Data Hub, UND hosted producers, agronomists, agricultural UAS providers, and data experts from research universities, including Iowa State University, Kansas State University, and the University of Nebraska, Lincoln. This forum provided the opportunity for community members and businesses to communicate their needs.

As a relatively new innovation with the potential to dramatically influence agriculture production, a major livelihood of North Dakotans, it is vital for researchers to work with local communities to set trajectory for research in order to address community needs and concerns.

The big data spoke will provide data to producers, landowners, governments and other entities in the region gathered from sensors in farm and related equipment, aerial imagery, survey data, management and policy models and other sources.

Learn more: <http://und.edu/news/2016/09/big-data-hub.cfm> and <http://midwestbigdatahub.org/about/working-groups/digital-agriculture-spoke/>



PHOTO: JACKIE LORENTZ,  
UNIVERSITY OF NORTH DAKOTA

*UND Assistant Professor of Computer Sciences Travis Desell (center), along with UND High Performance Computing Specialist Aaron Bergstrom (left) and Ron Marsh, chair of the UND Department of Computer Sciences, gather recently in UND's High Performance Computing facility.*

## DISCOVERY

One of the reasons the challenge approach has been widely used is that it identifies a problem of relevant scale and importance that the public can understand and support. As this report recognizes, these challenges tend to be complex and inter or trans-disciplinary. Their solutions require teams with strong disciplinary skills, who also can integrate and coordinate across disciplines. The great strength of the challenge approach is that by focusing on the problems and processes underlying the problem, it is easy to define the required expertise of the transdisciplinary team and link them conceptually to the components of the solution. The challenge approach keeps the team focused on solutions. Research studies have found that teams formed in this manner are more productive, creative, innovative, and able to address complex problems than individual researchers.<sup>139</sup> The University of Minnesota has taken on this approach at the institutional level—an approach that the Commission encourages other institutions to pursue (see box on page 100). The University of Minnesota devoted significant time and resources to identify the challenges and now continues to experiment with ways to form interdisciplinary teams and delineate approaches to address local, national and global challenges. This is just one example of a public university that is making the transition to the challenge approach to solving problems.

The complex nature of the grand challenge of achieving food and nutrition security could be better navigated through this type of approach, but academic institutions, and scientific discipline areas, need to better promote and reward this type of science. The transition to this approach is not easy. Even when engaged in research in the ONE Health arena, which by nature is transdisciplinary, researchers still tend to organize themselves into discipline-specific silos, forming robust internal communities that rarely interact with one another.<sup>140</sup> While bringing scientific depth to the table is key, when done well, “team-science” or “team-based research”, leads to more frequent citations and higher impact research than that of individual authors.<sup>141</sup>

Beyond academic silos, research on complex sustainability problems requires input from a variety of stakeholders, including those most directly affected, as well as science, business, and government.<sup>142</sup> To integrate these stakeholders in a way that strengthens and suits their needs, universities should work to facilitate cooperation and collaboration. Universities must recognize that there are multiple communities of knowledge to draw upon for partnership: scientific, international, and sectorial.<sup>143</sup> Ideally, within each of these contexts, co-design of research agendas and co-production of knowledge among all stakeholders, including academia, community, and international partners is important for the production of knowledge and solutions that are useful to many fields and institutions. Universities must ensure that there are clear points of contact for stakeholders to engage with the university and that university resources are aligned to nurture such relationships. For academics, the challenge must be to improve skills necessary to work and collaborate horizontally, across disciplines, without losing the vertical depth of knowledge and practice. This will require and ability to communicate effectively across the biophysical and social sciences as well as between scientists and the public.



## Pursuit of Grand Challenges at the University of Minnesota

How does a public, tier-one research university muster its vast research and publicly engaged strengths to address some of the most persistent and vexing problems facing the world's societies?

The University of Minnesota has laid out a multiyear process to engage broad, interdisciplinary teams of faculty to generate ideas, propose research that includes the engagement of external partners and students, and inspire the institutional pathways that lead to solutions and new mechanisms of enhancing interdisciplinary research.

The University of Minnesota has identified five Grand Challenges, through a campus community-based process. The five interrelated Grand Challenges are: (1) Feeding the World Sustainably, (2) Assuring Clean Water and Sustainable Ecosystems, (3) Fostering Just

and Equitable Communities, (4) Enhancing Individual and Community Capacity for a Changing World, and (5) Advancing Health through Tailored Solutions.

The deliberate process that resulted in identification of these Grand Challenges, based on University of Minnesota strengths, was a faculty-based, multi-step process over nearly 12 months. The objective of addressing Grand Challenges was a key element of the University's Twin Cities Campus Strategic Plan, which was approved by the Board of Regents in October 2014. The plan envisioned "marshaling the University's research and creative capacity to address grand challenges critical to our state, nation, and world."

Specific to Grand Challenges research, Provost and Executive Vice President Karen Hanson convened a Strategies Team of 30 faculty to help shape



CREDIT: GRAPHIC FROM THE UMTC OFFICE OF THE EXECUTIVE VICE PRESIDENT AND PROVOST AND USED WITH PERMISSION.

*The Grand Challenges Research Initiative of the University of Minnesota Twin Cities is one component of Driving Tomorrow, the UMTC's ten-year strategic plan to accelerate advancement of academic excellence.*

## ENGAGEMENT

A strong theme of the *Challenge of Change* process has been recognition that the complex challenges posed by food and nutrition security, both domestically and globally, require greater engagement with stakeholders and local communities. Such problems require a new "social contract for science," one "defined by the problems it address [es] rather than by the disciplines it employs,"<sup>144</sup> one that is grounded in collaboration among diverse stakeholders, values community and practitioner knowledge, and is responsive to dynamic webs of interrelationships and non-linear behavior across human and natural systems.<sup>145</sup>



Challenges, involvement of scholars who can work in the intersecting spaces among the other four challenges is essential.

Following a peer-review process, Provost Hanson announced in September the Grand Challenges Research awards—an investment of \$3.6 million supporting 29 interdisciplinary teams over two years. The strategy will ultimately help clarify how interdisciplinary teams come together and collaborate, and the extent to which they

opportunities. More than 100 faculty responded with brief ideas. The idea phase was followed by campus community forums in October 2015, which engaged over 450 faculty, students and staff members around emerging key ideas. The Strategies Team issued a report to the Provost in January 2016 that identified the five interrelated Grand Challenges.

In April 2016, faculty members were invited to submit interdisciplinary proposals that included the potential for supplemental International Enhancement Grants. The initial call for proposals employed a two-track strategy. One was an open call to all faculty with the provision that proposed interdisciplinary teams were to include principle investigators who had not collaborated previously; the other was a centrally constructed set of five interdisciplinary faculty teams—one team for each Grand Challenge area—composed of scholars who had limited or no contact previously. The assumption was that, to make real change in one of the Grand

need support in identifying research team members from across the physical and biological sciences, the social sciences, arts and humanities.

The Grand Challenges research process was very deliberate and guided by the goal of institutional culture change—ensuring that faculty, students, and staff members have new opportunities and are supported as they achieve excellence in their work.

From identifying the university's five Grand Challenges to awarding funds for interdisciplinary research, the University of Minnesota is focused not only on the highest quality interdisciplinary research that distinguishes their institution, but also on changing the way they do business—creating another pathway for interdisciplinary interactions, while acknowledging existing interdisciplinary efforts and the strength of their disciplinary research.

Learn more: <http://strategic-planning.umn.edu>

While all service, outreach, and engagement activities are important, university “engagement” is distinguished. The Kellogg Commission on the Future of State and Land-grant Universities noted the need to expand understanding of public service and outreach to include “engagement,” through which there is a reciprocal and mutually beneficial exchange of knowledge, needs, and assets between the university and its partners. The report states that the university’s role is *“not to provide the university’s superior expertise to the community, but to encourage joint academic-community definitions of problems, solutions, and definitions of success.”* Engagement frequently happens before and during the undertaking of the teaching/learning and research/

discovery missions of the university—working with stakeholders as full partners in identifying and solving complex challenges.

By contrast, public service and outreach tend to be undertaken after the path of a particular teaching/learning or research/discovery effort has been determined. In public service and outreach, we work to transfer knowledge to our stakeholders and partners rather than co-create it as in engagement.

## APLU Commission to Examine “The New Engagement”

APLU is undertaking an effort to examine how best to catalyze, accelerate, and scale institutional commitment to engagement with external stakeholders. Realizing how critical it is that universities work as partners in communities, business and industry, government, and non-profit organizations to solve complex societal and economic challenges, APLU is establishing a Commission on The New Engagement. The Commission will examine the progress that has been made in advancing engagement, and also identify levers for extending and deepening the commitment of public research universities to engagement.

American public universities by many counts are the most successful institutions of higher education in the world. But these institutions face many challenges, including the need to be more engaged in problem solving in their communities, states, and beyond.

Through engagement, universities can make a difference in helping to solve seemingly intractable societal challenges. The contributions of public research universities to societal challenges are, of course, substantial, but we must do more. We must increase our engagement efforts to fully demonstrate to our stakeholders the problem-solving value of our enterprises in learning and discovery. To become full partners in this work, a new commitment to university engagement is needed.

Engagement has increased in recent years, but much more needs to be done. The Kellogg Commission on the Future of State and Land-grant Universities reshaped thinking and had an impact on the ways in which many universities understood and undertook their outreach and “engagement” efforts. Leaders of public and land-grant universities and many others believe engagement is important for their institutions.

Universities now broadly understand “engagement” to mean efforts that include *mutual benefit* for both the university and its community and other partners. Reciprocity in partnership development—rather than partnerships based on the university simply delivering its educational offerings or discoveries into the community—has become a central principle in how universities see engagement.

Engagement must become a more visible aspect of what we do, it must permeate the culture of the institution, and it must be undertaken more often to inform our teaching, learning and discovery rather than solely as an addendum to these core missions. We must do more in partnering with our communities and stakeholders to introduce students to the world of work, engage them in research so that they might better understand its importance and perhaps themselves contribute to scientific progress.

Learn more: <http://www.aplu.org/NewEngagement>



*Iowa State University Extension and Outreach weed scientists and field agronomists educate farmers about dealing with weeds that have grown resistant to simple management systems.*

PHOTO: IOWA STATE UNIVERSITY EXTENSION AND OUTREACH

Importantly, public service and outreach are also valuable strategies for realizing the goals of this Commission, as is evidenced by references to public service and outreach efforts to address challenges herein. It is important, however, to clearly distinguish these different forms of service, outreach, and engagement.

In 2014, the National Science Foundation released a call for Sustainability Research Networks that were expected to bring together interdisciplinary and multi-institutional teams of researchers, educators, managers, policymakers and other stakeholders to conduct collaborative research that addresses fundamental challenges in sustainability, including food insecurity and food system sustainability.<sup>146</sup> And yet, food security research has a long way to go in developing and advancing systems that truly integrate perspectives from across disciplines and from diverse stakeholders in ways that support communities to identify, build, and sustain pathways that will build their food and nutrition security.

Building trusting relationships with communities requires long-term, intensive interactions. This requirement is often a disincentive for many faculty members, especially early in their careers, to participate in research and engagement activities with local communities. Extension has often built the bridges that ultimately create the relationship that facilitates tenured faculty interaction in this space. The decline in fiscal support for extension has greatly reduced the reach of the university into local communities and has contributed to the reduction in community outreach and engagement. These trends further distance universities from the communities they wish to serve.

The same applies for international work. Often the short-term nature of funding for international development work leaves little time for building relationships and trust; nor does the short-term nature of this work allow for the building of local capacity and infrastructure to carry on the work that has been implemented when the outside funding ends.

## LEARNING

All students, including those in North America, should be engaged in interdisciplinary work early on, through theories, concepts, and applications, as a means to provide a perspective that connects their disciplinary expertise to the wider framework within food systems.<sup>147</sup> This training is often referred to as “T” training, where the depth in a discipline is the stem of the “T” and the knowledge and skills that cut across relevant disciplines, are the top of the “T”. Many organizations recommended flexibility professors design interdisciplinary programs or courses that provide the foundational knowledge and theoretical language to communicate with potential collaborators in other disciplines.<sup>148</sup>

In public research universities, teaching faculty have research as a core component of their responsibilities. Naturally, the nature of their research often strongly effects the courses they design and develop. Creating a challenge approach to research is likely to make the curriculum more attractive and relevant to students. While courses

## Hiring Teams, Not Individuals

Faculty cluster, or cohort, hiring is the practice of hiring faculty into multiple departments or schools around interdisciplinary research topics. The cluster is superimposed across multiple disciplines, transcending institutional barriers to collaboration and intellectual exchange that are often ingrained. Some cluster hiring programs also aim to increase faculty diversity, not just in terms of race, ethnicity, and gender, but also in terms of perspective, ideology, and methodology.

The University of Wisconsin-Madison pioneered the practice in the late 1990s, to advance research, the state economy, and to break down barriers across campus. Since then, faculty cluster hiring programs have been implemented at other universities with many more in development. Universities nationwide have modeled this approach with both success and challenges. In the report *Faculty Cluster Hiring for Diversity and Institutional Climate* by Urban Universities for Health, Coalition of Urban Serving Universities, APLU, and The Association of American Medical Colleges, eight best practices emerged for universities to consider as they develop their own faculty cluster hiring programs:

- Make diversity goals explicit and develop supporting strategies to achieve those goals
- Work to ensure early buy-in from deans and department heads
- Engage faculty early in the process and follow the lead of the faculty

- Establish and articulate expectations for cluster hires from the very beginning
- Give cluster hires credit for work they perform as part of the cluster in the tenure and promotion process
- Establish infrastructure to support interdisciplinary collaboration
- Communicate the value of the program to stakeholders across the institution
- Develop a plan for sustaining the program throughout leadership changes.



PHOTO: BECKY KIRKLAND

*The tangible landscape tool allows researchers working with the Geospatial Analytics cluster to quickly create, analyze and manipulate 3D-scale models.*

in agronomy struggle to attract students, courses in food security attract hundreds.<sup>149</sup> Problem-oriented courses can be magnets for students to become interested in fields related to food and nutrition systems.

Several approaches have been recommended to enhance transdisciplinary research and interdisciplinary education. Cluster hiring of faculty with related disciplines within a field, combined with coordinated team teaching, creating and enhancing organized



### ***Working Together to Solve Real-World Problems***

At North Carolina State University, 20 clusters in the Chancellor's Faculty Excellence Program (CFEP) support collaboration across 10 colleges and the addition of more than 75 new faculty members. Launched in 2011, CFEP brings together the brightest minds in a range of academic disciplines and gives them the support to tackle global issues. The Emerging Plant Disease and Global Food Security cluster will create new knowledge and tools to better understand and counter emerging infectious plant diseases caused by pathogens and pests. The application of their work will lead to better collection, analysis, synthesis, and knowledge sharing.

The clusters program is essential to accomplishing the goals of NCSU's strategic plan: supporting student success by exposing them to an innovative, interdisciplinary culture; enhancing scholarship and research through investments in faculty and infrastructure; and boosting interdisciplinary research to address society's grand challenges.

Projects launched by cluster faculty have drawn millions of dollars in external research funding. The CFEP spurs development of new graduate academic programs, attracts top faculty and graduate students from around the world, generates partnerships with government and industry, and fosters a spirit of collaboration across the university's 10 colleges.

Learn more: <https://facultyclusters.ncsu.edu/clusters/>

### ***Catalytic Hiring to Solve Global Challenges – New Thought for Food***

Ohio State has built networks within the university to tackle the globe's most pressing challenges and focus on their role in addressing them in departments across campuses, colleges, research institutes, and centers. Since 2008, their strategic planning efforts have focused around four areas called Discovery Theme. One of two focus areas under the Food Production & Security theme is the Initiative for Food and AgriCultural Transformation (InFACT). This effort draws participation from over 100 faculty members in over 20 different departments representing 10 colleges and over 20 interdisciplinary centers.

The initiative began as a grassroots collaboration among 50 faculty who created a compelling vision to find solutions to some of our most complex challenges. In response to a University call for proposals, and a rigorous review process, they developed the top rated plan which including 30 catalytic hires across the University for a transdisciplinary approach to research, teaching, and outreach. Hiring is clustered in five areas: climate resilient production; health and nutrition; policy and planning; business and entrepreneurship; and culture, art and design. The initiative is expected to create both conceptual and physical models of secure, resilient, and sustainable agriculture and food systems that assure the health and well-being of a growing world population in the face of unprecedented environmental change and constraints.

Learn more: <http://discovery.osu.edu/focus-areas/infact/>

research units, and supporting knowledge tools that facilitate the university's investment in partnerships are all productive approaches. Likewise, promoting the practice of providing off campus internships and engaging those with expertise outside of academia as professors of practice to conduct courses can expand the learning experience. Flexibility and stable funding is needed to create collaborative courses, hire faculty in clusters, and support professors in creating interdisciplinary courses.<sup>150</sup>

# Partnerships for Discovery, Engagement, and Learning

The urgency for change will require new and enhanced models of partnership between universities and the private sector in order to address many of the challenges identified in this report. Public, land, sea, and urban-serving universities with historically strong partnerships with the private sector are actively seeking new ways to align their agendas with private sector partners with the ultimate goal of addressing food and nutrition security in the broader context of the challenges identified in this report. Many private sector companies are orienting their research and development towards more sustainable practices that minimize environmental and climate change impacts, as well as heeding the call by consumers for more nutritious and sustainably grown foods. U.S. private sector investment in research and development in agriculture has grown since 2000, and now exceeds what is federally funded.<sup>151</sup> Although this financing can be focused on shorter term, for-profit benefits, there are many possible intersections for collaboration with universities.

Universities have partnered with many non-governmental organizations (NGOs), local governments, and other partners to engage communities in food and nutrition security development activities, both domestically and internationally. Particularly in low-income countries, even under intense resource constraints, these relationships have historically been an effective means to work at the community level in the absence of strong in-country extension resources. Built on their complementary strengths, universities and NGOs are natural partners with considerable opportunity for collaborations that are efficient and effective.

The Consultative Group on International Research (CGIAR) has been another long-term and effective university partner. Established during the Green Revolution, the CGIAR system, consisting of 15 research centers around the globe, engages over 8,000 scientists, researchers, and others working to reduce poverty, enhance food and nutrition security, and improve natural resources and ecosystem services. Hundreds of universities engage in partnerships with the CGIAR system, including many collaborative research activities.<sup>152</sup> The in-country presence of CGIAR complements the scientific strengths of the university community. Working with the CGIAR, North American universities have not only assisted low-income countries, but have also brought back important research innovations to their own states and country (see Better Bread story on page 107).

This report concludes that there are limited incentives for food and nutrition security discovery, engagement, and learning efforts that are summative, cross-cutting, and with a long-term focus, which are critical to food and nutrition security.

- “Summative,” refers to efforts to summarize the lessons of a wide range of research in food and nutrition security and disseminate and translate those lessons to a broad range of stakeholders. Knowledge, data, best practices, and models exist for food and nutrition security innovations, but there are also knowledge and data gaps.

These gaps need to be identified, prioritized, and shared in order to drive the next generation of food and nutrition security discovery, engagement, and learning. Then, the necessary work must occur to help funders, universities, and communities work together to tackle the gaps and share the most successful models.

- "Cross-cutting," refers to the meaningful integration of disciplinary expertise with public and private sector practitioner perspectives. For example, accounting for human dimension and programmatic issues will enhance the success of a program.<sup>153</sup> Much of the focus of existing

## Better Bread

### *How Researchers are Using Genomics to Predict Bread Quality and Accelerate Wheat Variety Development*

With funding from USAID's Feed the Future Initiative, a team of breeders and geneticists at Kansas State University's Feed the Future Innovation Lab for Applied Wheat Genomics and the International Maize and Wheat Improvement Center (CIMMYT), are using DNA markers to predict important traits for bread wheat, such as dough strength and loaf volume.

Historically, the main focus of wheat breeding has been grain yield and the selection of varieties with the best performance and disease resistance. Quality traits, such as those used for bread, are usually evaluated at the end of the selection cycle due to high cost and the large quantity of grain needed for testing. Kansas Hard Red Winter wheat, for example, needs to have a stronger dough strength as it mostly goes to industrial bakers and needs to be able to withstand industrial processing. The typical wheat breeding cycle takes eight to 10 years—a lengthy amount of time to wait before being able to test for the quality of bread.

The team used wheat quality data generated in the test baking lab at CIMMYT and built algorithms using DNA marker information for predicting quality traits in new generations of wheat varieties. Using the prediction algorithms, they have been able to advance wheat quality screening by at least a year and predict over 10 times more candidate varieties than can be tested in the quality lab.

From all this data, decisions can be made on whether the wheat line is good enough to keep—but this question cannot be addressed until six to eight years into the breeding cycle.

Accurate processing and end-use quality prediction models, such as genomic selection, will allow breeding programs to target specific varieties before investing time and resources into varieties that will not pass the final test.

Researchers estimate that making these adjustments could increase the selection gains for quality two or three times above what is currently possible. The results also show that wheat breeding programs can use genomic selection for wheat quality, along with their traditional breeding pipeline, to more effectively and efficiently use resources throughout the whole breeding program.

Learn more: <http://www.k-state.edu/media/newsreleases/jun16/betterbread63016.html>



PHOTO: KANSAS STATE UNIVERSITY FEED THE FUTURE INNOVATION LAB FOR APPLIED WHEAT GENOMICS

*For each breeding line, a quantity of wheat grain is milled and baked into a small experimental loaf, from which total volume is measured as one assessment of the performance of that line.*

efforts in the food and nutrition security space has been on agricultural science innovation, but innovations in other spheres (e.g. social science in its broadest sense) can and must contribute to solving the challenge.<sup>154</sup> Often, there is sufficient technical knowledge about an innovation or practice, but adoption fails. We cannot innovate ourselves out of future food and nutrition security challenges without understanding the social factors influencing the populations that will ultimately be responsible for carrying out these innovations.

- “Long-term,” refers to research, or discovery, that takes a long-term perspective on solving problems and on transdisciplinary science, along with research that includes plans for learning and engagement related to the dissemination of findings. Research is a programmatic activity; it can take years to form meaningful partnerships, determine community needs and perspectives, and generate new knowledge in cycles of basic research, implementation, and innovation. The continued focus on short-term solutions and short-term funding will guarantee long-term problems.

## Recommendations for Institutional Transformation of Public Research Universities

The members of the Commission and working groups, in consultation with experts in matters related to institutional transformation, identified four areas where universities can address institutional barriers to meeting the Grand Challenge to sustainably feed an expanding population and improve prospects of food and nutrition security for all.

- |   |  |
|---|--|
| 1 | Elevate Food and Nutrition Security to a Top Priority                        |
| 2 | Align University Resources and Structures for Transdisciplinary Approaches   |
| 3 | Enhance and Build University-Community Partnerships                          |
| 4 | Educate a New Generation of Students to be Transdisciplinary Problem Solvers |

### 1 ELEVATE FOOD AND NUTRITION SECURITY TO A TOP PRIORITY

Building consensus for both domestic and global food and nutrition security requires: engaging the appropriate partners from the public and private sectors; collecting strong evidence of the importance of food and nutrition security on an appropriate scale; and, proving that universities can align their resources to effectively address food and

nutrition security challenges and, with their partners, communicate effectively to gain wide support for these efforts among communities, governments, and donors.

The Challenge of Change initiative is a powerful call for a consensus on food and nutrition security and a unique opportunity to convene the necessary stakeholders to galvanize support for addressing the challenges and activities identified in this report. Because of their collective strength in the discovery, engagement, and learning involved in addressing these challenges, universities can act as leaders in the call for consensus and action. Accomplishing this will require universities to coordinate with partners in the private sector, NGOs, and other communities.

## 2

## **ALIGN UNIVERSITY RESOURCES AND STRUCTURES FOR TRANSDISCIPLINARY APPROACHES TO SOLVE FOOD AND NUTRITION SECURITY CHALLENGES**

In the United States, spending on agriculture and food research and development has grown only 2.4 percent per year between 1960 and 2013, while the rest of the world saw more substantial growth at 3.2 percent per year. Overall, U.S. leadership in public funding for agricultural research and development has been overtaken by countries outside of North America. For example, China, Brazil and India spend a combined \$2.35 for every dollar invested by the U.S. in agricultural research and development.<sup>155</sup>

While funding levels are not the only issue impacting future success, they are, when combined with institutional transformation, critical to making significant scientific progress. If the United States wants to continue to lead in agriculture, more investment needs to be made to adopt and implement the challenge approach. In the absence of more flexible and longer-term investment, greater coordination and reorganization of funding is possible within the funding agencies that will address critical constraints on both domestic and global food systems. The organization of government funding dictates the nature of the interaction with universities and their partners. In order to solve complex problems, a comprehensive review of the structure of research and development funding flows is necessary. Government must take a leadership role in allocating resources to build and support the challenge approach. Coordination and reorganization at the national level is also critical to setting the stage at all other levels for a productively advancing a transdisciplinary approach.<sup>156</sup> Such a review should not be seen as a threat, but as an opportunity to improve the knowledge produced and to make our universities more effective problem-solving institutions for food and nutrition security.

As stated in other sections of this report, universities have a strong disciplinary focus. Maintaining and enhancing the quality of disciplinary science is critical, but as outlined above, experimentation to integrate and scale up university expertise to solve challenges through a transdisciplinary approach is already underway. The discipline focus results from an alignment of resources, organizational structure, outside processes (e.g., funding streams from state



and federal levels and the private sector to some degree), and internal processes (e.g., promotion and tenure and funding streams within universities).

Financial, promotional, and other incentives systems are often a top constraint for unleashing the university's potential. These incentives must be realigned not only to meet academic standards, but to also address challenge efforts. To be able to meet the seven food and nutrition security challenges outlined in the previous section, as well as other complex issues facing humanity, it will be key for universities to examine their policies and look beyond the traditional measure of advancing their disciplines and instead focus on what will benefit society the most, as defined by the communities they serve.<sup>157</sup>

## Auburn University's War on Hunger

### *PUSHing Toward a Food Secure World*

In 2004, Auburn University was invited by the UN World Food Programme (WFP) to create a replicable model to educate and mobilize college students in the fight against hunger. In partnership with WFP, Auburn designed a whole-of-university approach that included a grassroots student action and advocacy platform, as well as an academic agenda of teaching, research, and outreach. The Auburn War on Hunger Model led to the 2006 formation of Universities Fighting World Hunger (UFWH), a global movement of higher education institutions around the world.

Powered by UFWH, in February 2014, more than 70 presidents and senior leaders from 30 universities assembled at Auburn to determine how their respective institutions could join with others to accelerate the global effort to end hunger and malnutrition. The *Presidents' Commitment to Food and Nutrition Security* emerged out of this meeting, emphasizing that a lack of access to sufficient, nutritious food destabilizes countries, endangers national security, compromises individual and economic productivity, and robs our youngest generation of opportunities for a healthy, prosperous future.

The Presidents' Commitment now serves as a blueprint for universities to take collective action in achieving zero hunger campuses, communities, and nations by focusing on teaching, research, outreach, and student engagement. Signatories to this document have coalesced under the banner of Presidents United to Solve Hunger (PUSH). To date, PUSH consists of nearly 90 higher learning

institutions across five continents, with support from more than 20 partner institutions, government agencies, and international organizations.

Members of the PUSH consortium have been engaged in work related to food and nutrition security on their respective campuses for many decades. Through the presidents' pledge, however, university leaders now have a mandate to bring collective action and new energy to this issue by sharing knowledge and best practices, engaging faculty across disciplines and institutions, creating public and political will, and developing a new generation of enlightened global citizens.

Learn more: <http://wp.auburn.edu/push/>



Mississippi State president Mark Keenum speaking at UN Headquarters about how universities can help combat famine during the 2016 GODAN Summit.

PHOTO: PUSH

To address barriers to transdisciplinary research, universities must:

- **FOSTER STRONG COMMITMENT FROM UNIVERSITY LEADERSHIP**

The recommendations for university transformation in this report will not happen without support from university leadership across all levels. These recommendations challenge our institutions to make changes that will require difficult choices that run up against long-established policy, but that are critical if public research universities are to be globally relevant and engaged in this critical issue facing the world. This report argues that the problem of food and nutrition security is of a magnitude that requires making tough decisions and taking bold action. In fact, refusing to act to address food insecurity is a decision. University leadership should recognize both the need and the opportunity. Institutional changes laid out here are likely to enable public institutions to solve other emerging problems facing humanity beyond food and nutrition security. It may well be that the future economic growth of the U.S. and North America rests in the ability to effectively conduct transdisciplinary convergent research and development.<sup>158</sup> For academia, well-targeted transdisciplinary research will be key to the globally engaged and relevant university of the future.

- **REWEIGH TENURE REQUIREMENTS TO PROMOTE COLLABORATION, SERVICE, COMMUNITY ENGAGEMENT, AND PROBLEM SOLVING<sup>159</sup>**

Administrative policies outlining the requirements for tenure and promotion may differ considerably across universities. Faculty members are well aware of the expectations of their workplace. If department policies do not incentivize collaborative research, community engagement, or problem solving, then faculty are less likely to participate. This opportunity cost is especially relevant for un-tenured or young academics who may or may not be interested in engaging in transdisciplinary work. Early decisions can set the trajectory for the rest of one's career, which could lead to contributions in food and nutrition systems research. To combat the costs of engaging in this work, universities could rethink the traditional points/metric system, which predominantly rewards single authorship in a single disciplinary research.<sup>160</sup> Research has found that by broadening the definition of success beyond traditional metrics like primary authorship or project leadership, to include credit for co-authorship, data production, outreach, education, and ongoing mentoring or administrative activities, participation in transdisciplinary research increased at all career stages.<sup>161</sup> Creating clear departmental expectations for individuals and teams will be instrumental to successful collaboration both internally and externally. Support for this transdisciplinary work could be embedded in the promotion and tenure process, not just facilitated by it.

- **IMPROVE HIRING PRACTICES TO PROMOTE DIVERSITY AND INCREASE COLLABORATIVE ACTIVITIES**

A diverse staff not only broadens an institution's perspective, but also enhances the institution's ability to connect with increasingly diverse communities.

*Revolutionizing the Role of the University: Collaboration to Advance*

*Innovation in Higher Education*, a report from APLU's Coalition of Urban Serving Universities, argues that to address homogeneity among faculty, students, and staff, there must be understanding of the underlying drivers against diversity, such as high cost and debt for students, unexamined or biased hiring practices, and a less diverse public image because of the restrictive policies for hiring and promotion.<sup>162</sup> Universities in both rural and urban areas could facilitate an environment of greater diversity by both providing courses that teach to the relevant needs of underserved populations and including members of these groups in the research process, especially for international partnerships. This could be achieved by reviewing the hiring committee's understanding of the characteristics of desired faculty.

- **BUILDING AND REWARDING PROJECT MANAGEMENT AND COMMUNICATION SKILLS**

Administrative and managerial skills training would enhance work across multiple institutions, departments, and disciplines. Administrative employees should be trained in management skills for complex budgets, staffing, interdepartmental and institutional regulations, and timelines, especially as collaborations among many investigators may increase coordination costs. Faculty who take on team leadership and management responsibilities should receive credit and rewards for their team's successes. Trained and experienced project managers may also be a valuable addition to university administrative structures, allowing faculty to focus on the discovery, engagement, and learning dimensions of team leadership.

- **ADAPTING FUNDING PROCESSES TO MEET THE NEEDS OF EVOLVING APPROACHES**

Changing the structure of research will require universities to find creative means to bridge barriers between units within their institutions, between universities and other partners, and across international borders. These requirements are a challenge in themselves, calling for additional resources, new policies, and institutional flexibility. The challenge is particularly evident in the international environment where low-income country, funding agency, and university fiscal and reporting policies often conflict. Because the transaction costs are often high, universities need to build the structure and be willing to support the training and support of staff who have the skills to operate effectively in these areas as well as ensure compliance.

- **REVIEW THE CLIMATE AND OPENNESS TO ALTERNATIVE DISCIPLINARY PARTICIPATION**

If the work requires engaging across science, policy, economics, and social expertise, departments and disciplines must rethink the traditional attitudes they have towards qualitative data, methodological preferences, standards of assessment, and knowledge. Working with social sciences and other disciplines requires understanding additional theories and methods, which leads to an opportunity to rethink the scientific value of research. Universities have a role in this knowledge creation process, which includes how knowledge is recorded, organized, and valued. Researchers may need training and sensitization on communication and scientific cultures to facilitate effective teamwork.

Because of the difficulty of reviewing transdisciplinary work, researchers may also face delays in journal publication. To decrease the time needed to review transdisciplinary research for publication, journals and professional societies could broaden their perspective and valuation of this type of work. Funding agencies likewise could restructure and seek proposals outside of conventional research within disciplines to support transdisciplinary efforts. Funding for the early stages of research is most important for building transdisciplinary research teams, as universities and scholars will invest their own resources, namely their time and attention, when it is feasible. Support of open access journals, which lower the costs of publications and expand the opportunity for system-level publications, could be an important outlet for transdisciplinary science.

Internal Review Boards (IRB) should also be flexible and adapt to the changing dynamics for this transdisciplinary research style. Progress can be impeded if research teams are required to go through multiple IRBs. Review groups could standardize their questions and areas of concern to avoid irrelevant questions or lack of awareness of the critical areas for review.<sup>163</sup>

### 3

## ENHANCE AND BUILD UNIVERSITY-COMMUNITY PARTNERSHIPS

As declining levels of state support for public education continue, local advocacy for public higher education is a critical component of the future of the public university system and the nature of its function. Rebuilding the relationship between universities and their communities is a function of the quality and relevance of the work universities do, how it is communicated, and the impacts it has on individuals and society. Several developments, including shifting sources of fiscal support, have changed the relationship between universities and the communities they serve. As noted above, greater emphasis on federal and other outside funding of research along with declining resources for extension, outreach, and community engagement have contributed to the current transition away from the engaged university. If Universities are to “meet the needs of today and tomorrow, instead of yesterday”<sup>164</sup> a foundation needs to be built on the practice of community engaged scholarship (CES). CES establishes a reciprocal partnership between faculty members and the community and integrates the three pillars of learning, discovery and research. This scholarship is the foundation of the public research university.

To address barriers to community engagement, universities must:

- **MAKE COMMUNITY ENGAGEMENT A FUNDAMENTAL COMPONENT OF CHALLENGE DESIGN**

While science has been successful at focusing on the reductionist approach to very specific problems, the ability of the public to understand and connect with discovery has diminished. This disconnect does not foster continuous, positive two-way interaction with the public and local communities. However, food and nutrition security issues are undoubtedly community issues.

To fully understand the forces shaping food

systems from field to fork to function, communities must be involved in the design and implementation of research. Greater support for extension, outreach, and engagement in all aspects of the food system should be a goal.

- **DEVELOP STRONGER RELATIONS WITH NGOS AND OTHER DOMESTIC AND INTERNATIONAL PARTNERS FOR WORK ON GLOBAL FOOD AND NUTRITION SECURITY**

Universities should engage in discussions with NGOs and international research institutes to explore partnership arrangements, build relationships, and develop and understanding as to how they might complement each other's work. This dialogue should be a precursor to exploring funding

## The Good Living

### *Incorporating Biological and Cultural Diversity for New Undergraduate Programs*

The Universidad Veracruzana serves the educational needs of five regions within the state of Veracruz through four campuses serving nearly 80,000 students. The Universidad Veracruzana, along with other public universities in Mexico, are finding ways to address challenges such as climate change, declining fresh water supplies, and food insecurity through new transdisciplinary programs that train students.

Indigenous areas of Veracruz are rich in biological and cultural diversity. With this richness of diversity in mind, the Universidad Veracruzana Intercultural (UVI) is reviewing existing undergraduate programs and developing new ones. The UVI is unique in that the campuses serve the indigenous zones of Veracruz State.

Using feedback from stakeholders including employers, graduates, and experts from different institutions, a team of 18 research-professors from different scientific areas (social, anthropological, economic, agronomic and biological) are working together to design an undergraduate program called *Agroecology and The Good Living*. This program will be guided by the concepts of agroecology, multiculturalism, systems theory, food sovereignty, and participatory research.

This new program is based on the consideration that contemporary agroecology has evolved to integrate concepts and methods of the social, biological, and agronomic sciences in order to allow

a better understanding of agriculture as a complex phenomenon carried out in different ecological and cultural contexts. It must be an integral, interdisciplinary, and transdisciplinary science that includes engaging local communities, including indigenous and low-income populations, as a structural part of the research, teaching and service processes. Planning for the program will continue in 2017 and this new program is expected begin accepting students in 2018.

Learn more: <https://www.uv.mx/uvi/>



PHOTO: UNIVERSIDAD VERACRUZANA INTERCULTURAL

*New degree programs at UVI will provide opportunities for students to learn from members of the indigenous community, such as Doña Francisca (pictured above), who preserves and passes down knowledge about creating handicrafts from local cotton varieties.*



opportunities. A thorough understanding of the operating processes, constraints, and cultures of the partners will also be fundamental to successful partnerships. This relationship building takes time, but it will serve as a solid foundation for effectively integrating all capable partners to succeed in the food and nutrition security space.

## 4

### **EDUCATE A NEW GENERATION OF STUDENTS TO BE TRANSDISCIPLINARY PROBLEM SOLVERS**

Universities need curricula that combine disciplinary strength with transdisciplinary awareness. They need to produce students with skills that are relevant to solving both local and global economic and social challenges and who have the interpersonal skills to promote team science. As discussed above, since faculty members at universities are largely influenced by the research they conduct, their courses will reflect their research experiences. The same is true for the internationalization of curricula. Encouraging international research and other activities for faculty is key to internationalizing the courses they teach. In order to achieve transdisciplinary curriculum with local, national, and global perspectives that address critical challenges facing humanity, faculty research must have those same characteristics.

To address barriers to transdisciplinary education universities must:

- **FOSTER A CURRICULUM THAT BALANCES DISCIPLINARY EXCELLENCE WITH STRONG INTERDISCIPLINARY FOCUS**

One of the strongest conclusions of the Challenge of Change initiative is the recognition that there is a lack of systems-level understanding and a lack of critical thinking about the transformative global solutions needed to create food and nutrition security. There was strong agreement among participants in the initiative on the most fundamental means to address this lack of understanding: ensure students are exposed to food systems as a component of their education. Given the importance of food and nutrition for an individual's existence, exposure to systems thinking, while certainly important for students in agriculture, should also be available in related disciplines and as a part of general education. University administration and departments should ensure such transdisciplinary curriculum is supported and that the faculty who design and implement such courses are rewarded.

- **COMBINE DOMESTIC AND INTERNATIONAL APPROACHES TO FOOD SYSTEMS**

In today's world of global interactions, universities need to be globally connected to engage the ideas, technologies, and solutions emerging across the globe. Today, even domestic food systems are international in scope. What we eat comes from across the world and what producers grow is exported globally. USDA/ERS estimates that 20 percent of U.S. consumption by value is imported while exports of food were \$144 billion in 2013.<sup>165</sup> Global food insecurity can have significant domestic impacts. Migration and instability occur when people cannot afford adequate food, or a poor agricultural sector

provides no opportunity for livelihood, especially in countries with predominantly rural economies and populations. The absence of good nutrition diminishes child cognitive development for a lifetime and creates vast losses in human capital, which keeps nations poor. A university education needs to prepare students for work in a global economy. They need to be prepared to help North American businesses expand into new global markets. In addition, they should build a skill set enabling them to help build the capacity of emerging low-income country agriculture systems and markets to help developing economies emerge and future markets grow.

## A Living Laboratory for Food Systems Thinking

The University of Vermont—a leader in food systems research, teaching, and outreach—is the first and only institution in the U.S. to offer undergraduate, master's, and doctoral degrees in food systems. The program prepares students to address some of the most challenging problems within food systems, from building climate change resilience and reducing food waste, to exploring equitable distribution and fair labor practices.

The University of Vermont's food systems programs are deep and broad. Courses are taught by faculty and staff who are actively involved in food systems research and the development of food systems curricula. The curriculum is designed to engage students through a diversity of research methods, transdisciplinary approaches, systems thinking, and community engagement. It also provides the opportunities for diverse internship, service-learning, research, and community partnerships, which allows students to acquire knowledge and develop skills at multiple scales.

As part of UVM's efforts to create an integrated, cross-university food systems initiative, UVM a strategic plan was developed during 2016 that highlights that highlights the connectivity and collaborations important to continue their leadership in addressing the most pressing problems facing the global food system. The strategic plan emphasized five domains: trans-disciplinary research, intra-university connectivity, external partnerships, students, and community.

As a land-grant institution in a small state, UVM recognizes that the solutions they develop, now and in the future, should be shared with neighboring communities, states, and low-income countries. These efforts must be effectively communicated to campus stakeholders to ensure that the community remains well-informed. UVM believes success in the field of food systems depends upon productive and mutually beneficial relationships with external partners, including other educational institutions, government agencies, and organizations in the nonprofit and private sectors.

Learn more: <https://www.uvm.edu/foodsystems>



PHOTO: UNIVERSITY OF VERMONT

*Farmer Training Program at UVM Catamount Farm.*

## Follow the Tomato

While many college students might not think twice about where the food on their plate comes from, one class at The Ohio State University engages students to learn the origins of their food through community service.

Follow the Tomato, a service-learning course offered through the College of Social Work, is a class offered to students interested in learning about food security issues and the social, economic, health, and environmental consequences related to the food system.

Although the curriculum is outlined to meet the criteria of social work majors, the course is intended for students of all majors and backgrounds.

“There are a lot of people interested in these issues around food,” said Michelle Kaiser, an assistant professor in the College of Social Work who adapted the course from a first-year seminar taught at Warren Wilson College in North Carolina. “Whether it’s farmworker justice issues, whether it’s food waste and compost, whether it’s ‘I just want to get out and dig in the dirt and garden,’ we really wanted to honor all of the diversity of both academic perspectives and personal reasons and values to get involved with learning more.”

Franklinton Gardens, a nonprofit urban farm, is the course’s main community partner. The farm grows 10,000 pounds of produce annually. The organization distributes the food grown to different outlets in the neighborhood, including food pantries and home produce deliveries.

Franklinton Gardens and a network of other organizations in the neighborhood, such as LifeCare Alliance and Gladden Food Pantry, work with Follow the Tomato to identify several themes to focus on during the semester, as well as service projects to go along with them.

“The whole purpose for students to understand is that while they’re benefitting from this experience, we always have to remember the purpose in going back to our community partners,” Kaiser said.

For the class’ final project, students work together to create short videos on their experiences and infographics for the community partners. Students then present their finals at a luncheon to those they interact with during the semester to enjoy a meal prepared with locally grown ingredients and to reflect on the students’ experiences.

Learn more: <http://engage.osu.edu/?q=newslist-items/tomato.html>



PHOTO: THE OHIO STATE UNIVERSITY

*Students load boxes of food from a local food pantry that they helped deliver to low-income homebound seniors and persons with disabilities.*



*Uttam Kumar of CIMMYT testing the Field Book app  
at the USAID Kansas State University Feed the Future  
Innovation Lab for Applied Wheat Genomics trials,  
Borlaug Institute of South Asia, Ludhiana, India.*



PHOTO: HALEY AHLERS, KANSAS STATE UNIVERSITY

## PART III

# Conclusions and Next Steps

Food is central to the human existence. Its production and consumption provide the energy and nutrients to produce the human capital that fuels creativity, cultures, and economies. Constraints and shocks to food and nutrition security anywhere in the food system affect all aspects of life, and they are not inconsequential. Highly functioning, robust food systems produce productive human capital and vibrant societies, while poorly functioning food systems create food insecurity that can ignite social and political instability. Increasing the efficiency of agricultural systems has always been a source of economic growth that promotes the transition from agrarian, low-income economies to robust emerging markets. But the lack of opportunity in the agricultural sector and spikes in food prices can drive migration patterns, which contributes to instability. Whether it is productive agriculture that lifts people out of poverty and food insecurity, or failing food systems that drive instability, food is fundamental to the functioning of the world.



PHOTO: UNIVERSITY OF FLORIDA/IFAS PHOTOGRAPHY

*Attendees at UF/IFAS's Bee College at the Whitney Lab in Marineland, Florida learn about honey beekeeping.*



## THE GRAND CHALLENGE

### Sustainably feed an expanding population and improve prospects for food and nutrition security for all

#### The 7 Challenges for Public Universities to Address to Help Achieve Global Food and Nutrition Security

##### Availability



##### Challenge 1

Increase yields, profitability, and environmental sustainability simultaneously



##### Challenge 2

Develop the varieties and breeds needed for sustainable food systems



##### Challenge 3

Decrease food loss and waste through more efficient distribution systems

##### Access



##### Challenge 4

Create and share resources that serve all populations



##### Challenge 5

Ensure inclusive and equitable food systems

##### Utilization



##### Challenge 6

Address the dual burdens of undernutrition and obesity to ensure full human potential



##### Challenge 7

Ensure a safe and secure food supply that protects and improves public health

Beyond the specific challenges, pathways, and activities identified in this Challenge of Change effort, what actions need to be taken concerning domestic and global food security?

# Conclusions for Public Research Universities

- **ELEVATE FOOD AND NUTRITION SECURITY TO A TOP PRIORITY**

Public research universities are uniquely positioned to provide leadership and to assist in implementing solutions to the grand challenge of sustainably feeding an expanding population and improving prospects for food and nutrition security for all. Contributing to the “public good” is a core value of public research universities. They have a full range of relevant expertise and a long track record of success in discovery, engagement, and learning efforts related to domestic and global food and nutrition security issues.

- **ALIGN UNIVERSITY RESOURCES AND STRUCTURES FOR TRANSDISCIPLINARY APPROACHES**

While this Commission recognizes there are many public research university examples of successful work on food and nutrition security, our institutions need to do much more. The Commission recommends more universities become deeply engaged and make appropriate changes to reduce barriers. Such changes, often needed to encourage transdisciplinary science, may involve changes in organizational structure, resource allocation, and incentive criteria for faculty promotion and tenure. It is clear transdisciplinary science, also referred to as convergent science, is critical in solving these challenges. This conclusion is in line with those from the National Academies report, *Convergence: Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering and Beyond*, which encourages universities to develop policies, practices, and guidelines to support and evaluate convergent and disciplinary research. Note that a number of other recent commissions from NAS, NIH, and NSF have issued reports recognizing transdisciplinary science as a promising means to solving complex problems.

- **ENHANCE AND BUILD UNIVERSITY-COMMUNITY PARTNERSHIPS**

The Commission and its Working Groups all emphasized the need to engage communities and governments, the public and private sectors, and others in the identifying both problems and possible solutions. Meaningful engagement with community partners requires time and significant effort to build necessary trust. This type of commitment is common among extension staff, but is often not incentivized for young faculty. Strengthening the engagement component of the university produces valuable outcomes for communities domestically and globally, increases the relevance of research, and builds greater public support for the university.

- **EDUCATE A NEW GENERATION OF STUDENTS TO BE TRANSDISCIPLINARY PROBLEM SOLVERS**

Universities must place an emphasis on producing graduates who understand food system concepts, have a good understanding of how their specialty or discipline relates to other components of the system,

and have the skills to work across disciplines in a team. Achieving this will require hiring faculty with interdisciplinary experience, assessing existing transdisciplinary efforts across campuses for best practices, developing a knowledge base for wide use, and creating a curriculum with interdisciplinary components.

## Conclusions to Achieve Global Food and Nutrition Security

- **BROADEN THE FOCUS BEYOND YIELDS**

There was much discussion during the course of this initiative about the need for increased production versus greater efficiencies along the rest of the food system. While there is discussion on the level of increase required in food production in the coming decades, it is sure to be a significant amount. Given the large gap between the amounts of food currently being produced, the likely impact of climate change on food production, and the estimated demand by 2050, there is much to do—not only to meet projected needs, but also to ensure increases are not achieved at the expense of the natural resource base on which food production depends. There is no question that greater efficiencies need to be made throughout the food chain. Yet it is clear that significant increases in production will also be required.

- **CHANGE THE FOOD SYSTEM'S INCENTIVE STRUCTURE**

Changes are needed in incentive structures throughout the food system. Food systems are created through the interaction of a series of individual components that are responsive to social, political, and environmental influences. To understand how to change systems, we must understand the structure, dynamics, and incentives—economic, political and cultural—within the systems sought to be changed. Existing relationships have fostered long-term fiscal and political investments, shaped human behavior, and influenced social norms.

Changing systems to meet future demands requires designing new incentive structures, including market forces affected by research on outcomes, regulations, or guidelines that promote food and nutrition security. Across high-, medium-, and low-income countries, education about food systems, its function, and outcomes, will be critical for change.

- **DEVELOP THE CAPACITY OF UNIVERSITIES IN LOW-INCOME COUNTRIES**

Helping low-income countries better address their own challenges will be critical in the global food security picture. This is perhaps most important in Africa, where half of the population growth between now and 2050 will occur. In-country universities are critical for the education of the vast number homegrown scientists, engineers, entrepreneurs, teachers and others needed to build sustainable food and nutrition systems. Primary and high school graduates are necessary, but are not sufficient to

build countries alone. If well-educated, the emerging youth bubble will be a force of economic and social growth, but if not, will be source of social and political instability.

- **LEVERAGE TECHNOLOGY, BIG DATA, AND INFORMATION SCIENCE**

While the challenges of food and nutrition security are global, many production issues are local. The use of new sensor technologies, geographic information systems, and the rapidly increasing power of information storage and processing can be powerful contributors to sustainable production. Likewise, data from social media, purchasing patterns, and other online sources hold potential to understand the structure, behavior, and function within food systems. This convergence of technologies will cause information science to play a major role in future research on food and nutrition systems. All of this is important, in various ways, to low- and high-income countries.

## Next Steps

The challenges of food and nutrition security are embedded in complex systems, which require transdisciplinary science to achieve solutions. These conclusions, central to this report, are consistent with the National Academies of Science *Convergence: Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering and Beyond* report, NSF's Innovations at the Nexus of Food, Energy and Water Systems (INFEWS) initiative, NIH's National Nutrition Research Roadmap, and recent APLU efforts such as *Healthy Food Systems*, *Healthy People* and *Addressing Antibiotic Resistance in Production Agriculture*.

These themes take into account a new understanding and wide acceptance that transdisciplinary efforts are needed to solve pressing global issues, like food and nutrition security. The report also emphasizes the need for greater community engagement to identify and define research issues, and actively interact with communities throughout the entire research process. Accordingly, this report is different from past reports. Earlier reports might well have recommended a narrowly designed “top 10” challenges, focused solely on hard science and production agriculture.

With complex systems, the need for transdisciplinary science, and community engagement in mind, this report lays a new foundation for action and recommends the following next steps:

### 1. APLU ACTION

The Commission recommends APLU play an important role in fostering discovery, engagement, and learning activities among public research universities, which should include individual institutions, groups of universities, and their partners in order to achieve domestic

and global food and nutrition security. This will require a major, sustained effort by APLU. The Commission recommends APLU and its members further develop recommendations for reducing institutional barriers to transdisciplinary research. This would include identifying and learning from promising approaches already being undertaken at public research universities, designing mechanisms to remove barriers, and making recommendations based on best practices. APLU should discuss and report on these activities at its annual meeting and other appropriate venues.

The Commission recommends APLU, in close coordination with its members, develop and undertake advocacy efforts in support of this report, including making funding recommendations, as appropriate.

## **2. U.S. “WHOLE-OF-GOVERNMENT” ACTION**

With enactment of the Global Food Security Act (GFSA) in July of 2016, Congress required the administration to develop a “whole of government approach” to combat global food insecurity and authorized appropriations for such programs for fiscal years 2017 and 2018. The pending reauthorization of the legislation provides an opportunity to build on the progress already made as a result of GFSA and act on the recommendations of the Commission. Similarly, with the Farm Bill due for reauthorization, Congress will have the opportunity to expand the U.S. Department of Agriculture’s commitments to global food security and expand the Department’s partnership with U.S. universities. Hence, there is an opportunity to coordinate both international and domestic food and nutrition security efforts.

APLU and its member universities advocate to policymakers for a “whole-of-government” approach within the federal government. A whole-of-government effort would encourage multiple federal departments and public agencies to work across their portfolios to achieve a significant goal. Such an approach would help to focus existing resources and should allocate new resources, given the critical importance of domestic and global food security.

Historically, such whole-of-government efforts have often been coordinated by the White House Office of Science and Technology Policy (OSTP). This approach should be replicated to achieve the domestic and global food security recommendations of this report. Undoubtedly, an OSTP process would also involve significant leadership from USDA and USAID, as well as deep engagement by several other government agencies, including the National Science Foundation, Department of Defense, Department of Energy, the National Institutes of Health, and others.

An explicit goal of the whole-of-government approach—in collaboration with the university community and stakeholders, including the private sector—must be to mobilize private sector and foundation resources to address the challenges. Given current federal budget constraints, it is important to make the case for resources to tackle these consequential issues. The report does not quantify the amount of those resources, but it is clear the need will be substantial for this huge and complex set of challenges.



### **3. MEXICAN, CANADIAN, AND U.S. GOVERNMENT JOINT ACTION**

The Commission also recommends the governments of the United States, Mexico, and Canada together sponsor collaborative research partnerships with universities and their partners to advance the recommendations of this report.

The Commission recommends the Canadian and Mexican governments work, as appropriate, with their universities and research entities to advance the recommendations of this report in their respective countries.

A substantial amount of current research in the region is bilateral, but more trilaterally funded competitive grants, which would require involvement from universities in each of the three countries, would provide even greater impact.

### **4. PUBLIC RESEARCH UNIVERSITY ACTION**

Many universities have already identified their own “grand challenges” or in some way have established campus-wide research goals. No doubt this is an important process for universities, especially in these days of tightening budgets. In connection with current processes, public universities and their partners are encouraged to identify challenges and related activities in this report that they might undertake. As noted above, APLU has an important role in fostering this work.

Undoubtedly in that process, universities will further define or focus the challenges and activities set forth in this report. The Commission also recognizes public research universities alone will not solve the global food and nutrition security crisis. As universities work on the challenges, it will be important to partner with public and private entities in agriculture, public health, nutrition, health care, and beyond.

*In Iowa, 4-H leadership accelerators use their culture, history, and traditions to explore healthy living, STEM, citizenship, leadership, communication, and the arts.*



PHOTO: IOWA STATE UNIVERSITY EXTENSION AND OUTREACH

# Definitions

**ACCESS** – having sufficient resources and means to obtain appropriate foods for a nutritious and culturally appropriate diet. (FAO)

**AGRICULTURAL SYSTEM** – the integrated components and operations of producing food, feed, and fiber raw materials from domesticated plants and animals. (Healthy Food Systems, Healthy People)

**AVAILABILITY** – sufficient quantities of food are obtainable on a consistent basis from either domestic production or importation. (FAO)

**ECOSYSTEM SERVICES** – the many life-sustaining benefits we receive from nature—clean air and water, fertile soil for crop production, pollination, and flood control. These ecosystem services are important to environmental and human health and well-being, yet they are limited and often taken for granted. (Environmental Protection Agency)

**FOOD INSECURITY** – a condition that exists when people lack access to sufficient amounts of safe and nutritious food, and therefore are not consuming enough for an active and healthy life. This may be due to the unavailability of food, inadequate purchasing power, or inappropriate utilization at household level. (FAO)

**FOOD LOSS** – all of the food produced for human consumption but not eaten by humans. Food loss is defined as “the decrease in quantity or quality of food.” Food is lost throughout the supply chains—from primary production to final household consumption level. Significant loss occurs in industrialized regions as well as in low-income countries where food is lost during the early and middle stages of the food supply chain with lower levels of waste at consumer level. (FAO)

**FOOD SECURITY** – a condition that exists when all people at all times have both physical and economic access to sufficient, safe and nutritious food that meets their dietary needs for an active and healthy life. (FAO)

**FOOD SYSTEM** – the integrated components and operations of producing consumable food from plant and animal agricultural products for sustenance to satisfy biological and sociological needs and provide nutrients for maintaining human health. (Healthy Food Systems, Healthy People)

**FOOD WASTE** – a part of food loss, referring to the discarding or alternative (non-food) use of food that is safe and nutritious for human consumption along the



entire food supply chain, from primary production to end household consumer level. Food waste is recognized as a distinct part of food loss because the drivers that generate it and the solutions to it are different from those of food losses. (FAO)

**HIGH-VALUE FOOD PRODUCTS (HVPS)** – consumer- oriented agricultural products that are high in value, often but not necessarily due to processing. HVPs can be divided into three groups: 1) semi-processed products, such as fresh and frozen meats, flour, vegetable oils, roasted coffee, refined sugar; 2) highly processed products that are ready for the consumer, such as milk, cheese, wine, breakfast cereals; and 3) high-value unprocessed products that are also often consumer-ready, such as fresh and dried fruits and vegetables, eggs, and nuts. In recent years HVPs have accounted for a greater percentage than bulk commodities of the total value of U.S. agricultural exports. (Congressional Research Service)

**HUNGER** – an individual-level physiological condition that may result from food insecurity (USDA). The FAO defines hunger as being synonymous with chronic undernourishment. (FAO)

**INTERDISCIPLINARY** – combining or involving two or more academic disciplines or fields of study. (Merriam-Webster)

**MALNUTRITION** – all forms of poor nutrition caused by a complex array of factors, including dietary inadequacy (deficiencies, excesses or imbalances in energy, protein, and micronutrients). Malnutrition includes both undernutrition and overnutrition. (Partnership for Maternal, Newborn & Child Health)

**NUTRITION SYSTEM** – the integrated components and operations of providing essential nutrients e.g. protein, carbohydrates, fat, fibers, vitamins, and minerals; and other bioactive compounds, required to maintain human health and prevent chronic diseases. (Healthy Food Systems, Healthy People)

**ONE HEALTH INITIATIVE** – a movement to forge co-equal, all-inclusive collaborations between physicians, osteopathic physicians, veterinarians, dentists, nurses and other scientific health and environmentally related disciplines, including the American Medical Association, American Veterinary Medical Association, American Academy of Pediatrics, American Nurses Association, American Association of Public Health Physicians, American Society of Tropical Medicine and Hygiene, Centers for Disease Control and Prevention, Department of Agriculture, and National Environmental Health Association. (Healthy Food Systems, Healthy People)

**OVERNUTRITION** – a condition resulting in overweight and obesity, defined as abnormal or excessive fat accumulation that may impair health. (Partnership for Maternal, Newborn & Child Health)

**STABILITY** – a condition that exists when people's food intake is adequate one day, but varies and there is inadequate access to food on a periodic basis, risking deterioration to

nutritional status. Adverse weather conditions, political instability, or economic factors (unemployment, rising food prices) may have an impact on food security status. (FAO)

**SUSTAINABLE INTENSIFICATION** – increasing agricultural yields from the same area of land while decreasing negative environmental impacts of agricultural production and increasing the provision of environmental services. (CGIAR)

**TOTAL FACTOR PRODUCTIVITY (TFP)** – the ratio of agricultural outputs (gross crop and livestock output) to inputs (land, labor, fertilizer, machinery, livestock). TFP increases when output rises and inputs remain the same. (Global Harvest Initiative).

**TRANSDISCIPLINARY RESEARCH** – research efforts conducted by investigators from different disciplines working jointly to create new conceptual, theoretical, methodological, and translational innovations that integrate and move beyond discipline-specific approaches to address a common problem. (Harvard University)

**UNDERNUTRITION** – a condition that includes being underweight for age, too short for age (stunted), too thin relative to height (wasted) and functionally deficient in vitamins and minerals (micronutrient malnutrition). (Partnership for Maternal, Newborn & Child Health)

**UTILIZATION** – the appropriate use of food based on knowledge of basic nutrition and care, as well as adequate water and sanitation to prevent foodborne disease. (FAO)

**WHOLE GENOME SEQUENCING** – a process that reveals the complete DNA make-up of an organism, enabling us to better understand variations both within and between species. (FDA)





*Local wheat farmer in Delta Junction, Alaska discussing agronomic production and the challenges of climatic changes.*



# Commission, Working Groups, and Invited Expert Memberships

## Commission Executive Committee

**CHAIR: Randy Woodson**, *Chancellor,  
North Carolina State University*

**James Borel**, *Executive Vice President, DuPont (retired)*

**Helene Dillard**, *Dean, College of  
Agricultural & Environmental Sciences,  
University of California, Davis*

**Gebisa Ejeta**, *Distinguished Professor, Department  
of Agronomy, Purdue University*

**Dan Glickman**, *Executive Director,  
Congressional Program, Aspen Institute*

**Mark Keenum**, *President, Mississippi State University*

**Alan Leshner**, *Chief Executive Officer Emeritus,  
American Association for the Advancement of Science*

**Lou Anna Simon**, *President, Michigan State University*

## Commission Members

**Jay Akridge**, *Dean of Agriculture, Purdue University*

**Jeff Armstrong**, *President, California Polytechnic  
State University, San Luis Obispo*

**Kathryn Boor**, *Dean, College of Agriculture  
and Life Sciences, Cornell University*

**Wayne Caldwell**, *Interim Dean of Ontario  
Agricultural College, Professor in Rural Planning  
and Development, University of Guelph*

**Thomas Coon**, *Vice President, Division  
of Agricultural Sciences and Natural  
Resources, Oklahoma State University*

**Nancy Creamer**, *Director, Center for Environmental  
Farming Systems, Department of Horticultural  
Science, North Carolina State University*

**Kimberly Espy**, *Senior Vice President for  
Research, University of Arizona*

**Shenggen Fan**, *Director General, International  
Food Policy Research Institute*

**Susan Fritz**, *Executive Vice President and  
Provost, University of Nebraska*

**Olga Garcia**, *Research Professor, Human  
Nutrition Research, College of Natural Science,  
Autonomous University of Queretaro*

**June Henton**, *Dean, College of Human  
Sciences, Auburn University*

**Walter Hill**, *Dean, College of Agriculture, Environment,  
& Nutritional Science, Tuskegee University*

**Mike Hoffmann**, *Executive Director, Cornell Institute  
for Climate Smart Solutions, Cornell University*

**Casey Hoy**, *W.K Kellogg Endowed Chair in  
Agricultural Ecosystems Management,  
Ohio State University*

**Kelechi Kalu**, *Vice Provost, International Affairs, University of California, Riverside*  
**Kendall Lamkey**, *Chair, Department of Agronomy, Iowa State University*  
**Steve Leath**, *President, Iowa State University*  
**Vic Lechtenberg**, *Special Assistant to the President, Purdue University*  
**April Mason**, *Provost, Kansas State University*  
**Bruce McPheron**, *Executive Vice President and Provost, Ohio State University*

**Olive Mugenda**, *Vice Chancellor, Kenyatta University*  
**Katherine Ozer**, *Executive Director, National Family Farm Coalition*  
**Per Pinstrup-Anderson**, *Professor Emeritus and Graduate School Professor, Division of Nutritional Sciences, Cornell University*  
**Jeff Riedinger**, *Vice Provost, Office of Global Affairs, University of Washington*  
**Sally Rockey**, *Executive Director, Foundation for Food and Agriculture*

## Working Group Members

### SUSTAINABLE PRODUCTION SYSTEMS

**CHAIR: Kendall Lamkey**, *Chair of the Department of Agronomy, Iowa State University*  
**Justine Beaulieu**, *Faculty Assistant/Food Safety Educator, University of Maryland*  
**Carlos Ávila Bello**, *Vice Chancellor, Universidad Veracruzana*  
**Stanford Blade**, *Dean, Faculty of Agricultural, Life & Environmental Sciences, University of Alberta*  
**Rachel Bezner Kerr**, *Chair of the Department of Agronomy, Cornell University*  
**Richard Conant**, *Professor, Department of Ecosystem Science and Sustainability, Colorado State University*  
**Layne Coppock**, *Professor of Environment & Society, Utah State University*  
**Casey Hoy**, *W.K Kellogg Endowed Chair in Agricultural Ecosystems Management, Ohio State University*  
**Karin Wittenberg**, *Dean, Faculty of Agricultural and Food Sciences, University of Manitoba*

### PLANT AND ANIMAL PERFORMANCE

**CHAIR: Ermias Kebreab**, *Professor, Sesnon Endowed Chair, Deputy Director – Agricultural Sustainability Institute, University of California, Davis*  
**Cynthia Baldwin**, *Professor of Veterinary and Animal Sciences, University of Massachusetts*  
**Conrad Bonsi**, *Associate Director, George Washington Carver Agricultural Experiment Station, Tuskegee University*  
**John Foltz**, *Special Assistant to the President for Agricultural Initiatives, University of Idaho*  
**Kulvinder Gill**, *Professor, Department of Crop and Soil Sciences, Washington State University*  
**Raj Lada**, *Professor, Department Head, Department of Plant, Food and Environmental Sciences, Faculty of Agriculture, Dalhousie University, Dalhousie University*  
**Catarina Loredó Osti**, *Professor, Universidad Autónoma de San Luis Potosí*  
**Morven McLean**, *Executive Director, International Life Sciences Institute Research Foundation*  
**Paul B. Thompson**, *W.K. Kellogg Chair in Agricultural Food and Community Ethics, Michigan State University*  
**Michelle Wander**, *Professor, Natural Resources and Environmental Sciences, University of Illinois*

## SUPPLY CHAINS, DISTRIBUTION, LOSS, AND WASTE

**CHAIR: Sabine O'Hara**, Dean, College of Agriculture, Urban Sustainability & Environmental Sciences, University of the District of Columbia

**Anne Cafer**, Assistant Professor of Sociology, University of Mississippi

**Cheryl T. Coleman**, Director, Resource Conservation and Sustainability Division, Environmental Protection Agency

**Hunter Francis**, Director, Center for Sustainability, College of Agriculture, Food and Environmental Sciences, California Polytechnic State University

**Miguel Gomez**, Associate Professor, Charles H. Dyson School of Applied Economics and Management, Cornell University

**Prasanta Kalita**, Director, ADM Institute for the Prevention of Postharvest Loss, University of Illinois

**Rebeca López-García**, Principal, Logre International Food Science Consulting

**Monica Munn**, Sr. Strategy Associate, Rockefeller Foundation

**Jitendra Paliwal**, Professor, Department of Biosystems Engineering, University of Manitoba

## KNOWLEDGE AND EDUCATION

**CHAIR: Jack Elliot**, Head, Department of Agricultural Leadership, Education, and Communications, Texas A&M University

**Teshome Alemneh**, Associate Vice President for International Research and Development, Indiana University

**Maryah Fram**, Associate Professor, College of Social Work, University of South Carolina

**David Gray**, Dean, Faculty of Agriculture, Dalhousie University

**Tom Kelly**, Executive Director, UNH Sustainability Institute, University of New Hampshire

**Maria Lapinski**, Professor, Department of Communication, Department of Ag-Bio Research, Michigan State University

**Christine M. Porter**, Associate Professor & Wyoming Excellence Chair in Community & Public Health, University of Wyoming

**Jeffrey Wichtel**, Dean, Ontario Veterinary College, University of Guelph

## FOOD SAFETY, SANITATION AND PUBLIC HEALTH

**CHAIR: Maria Rubino**, Associate Professor, School of Packaging, Michigan State University

**Alejandro Echeverry**, Assistant Professor, Texas Tech University

**Azadeh Namvar**, Research Associate, University of Guelph

**Chika Okafor**, Biomedical and Diagnosis, University of Tennessee

**Don Schaffner**, Extension Specialist in Food Science and Distinguished Professor, Rutgers, the State University of New Jersey

**Stuart Styles**, Director, Irrigation Training and Research Center, Cal Poly San Luis Obispo

**Siyun Wang**, Assistant Professor, Faculty of Land and Food Systems, University of British Columbia

**Keith Warriner**, Professor, Department of Food Science, University of Guelph

## NUTRITION, HUMAN DEVELOPMENT AND HEALTH

**CHAIRS: Lindsay Allen**, Director, USDAARS Western Human Nutrition Research Center (WHNRC) and **Olga Garcia**, Professor-Researcher, Human Nutrition Research, Universidad Autónoma de Querétaro

**Kate Clancy**, Food Systems Consultant; Senior Fellow, MISA, Visiting Scholar, Center for a Livable Future, Johns Hopkins School of Public Health

**Vic Knauf**, *Chief Scientific Officer, Arcadia Biosciences*  
**Kathleen Ragsdale**, *Associate Research Professor, Social Science Research Center, Mississippi State University*  
**Felicia Wu**, *John A. Hannah Distinguished Professor, Michigan State University*  
**Zhaoming Xu**, *Associate Dean, Graduate Studies; Program Director, Food, Nutrition and Health, University of British Columbia*

## INCLUSION AND EQUITY

**CHAIR: Paula Hunker**, *Director of Strategy and Policy for the Hunger Solutions Institute, Auburn/PUSH*  
**Anna Hankins**, *National Family Farm Coalition*  
**Keltie Jones**, *Assistant Dean, Students; Faculty of Agriculture, Dalhousie University*  
**Ruth Mendum**, *Associate Director for Gender Initiatives, Pennsylvania State University*  
**Emmanuel Rodrigo Marín Orozco**, *Career Coordinator for Agribusiness, Universidad de Guadalajara*  
**Deborah Rubin**, *Co-Director, Cultural Practice*  
**Alisha Vincent**, *Director McGovern Center, Dakota Wesleyan University*  
**Robert Zabawa**, *Research Professor, Agricultural and Resource Economics, Tuskegee University*

## Invited Experts

**Adegbola Adesogan**, *Director, Feed the Future Innovation Lab for Livestock Systems, University of Florida*  
**Deandra Beck**, *Associate Dean for Research, International Studies and Programs International Center, Michigan State University*  
**Doug Buhler**, *Director of MSU AgBioResearch and Assistant Vice President of Research and Graduate Studies, Michigan State University*  
**Grace Burton**, *Government Relations Officer, Chicago Council on Global Affairs*  
**Saharah Moon Chapotin**, *Deputy Assistant to the Administrator, USAID*

## ENABLING ENVIRONMENT FOR ACCESS AND SOLUTIONS

**CHAIR: Alex Winter-Nelson**, *Professor, Department of Agricultural and Consumer Economics, University of Illinois*  
**Steve Bosserman**, *President, Bosserman and Associates*  
**Graham Cochran**, *Professor and CFAES Interim Senior Administrative Officer, Ohio State University*  
**Rick Foster**, *W.K Kellogg Professor in Food, Society and Sustainability, Michigan State University*  
**Sonya Jones**, *Associate Professor, Arnold School of Public Health, University of South Carolina*  
**Danielle Nierenberg**, *Cofounder & President, Food Tank*  
**Marcela Rosas Nexticapa**, *Faculty of Nutrition, Universidad de Veracruzana*  
**Nick Younginer**, *Postdoctoral Fellow at Center for Research in Nutrition and Health Disparities, Arnold School of Public Health, University of South Carolina*

**Timothy Dalton**, *Director, Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet, Kansas State University*  
**Andrew Dill**, *Director of Federal Relations, University of Georgia*  
**Barbara Ekwall**, *Senior Liaison Officer, Food & Agriculture Organization of the United Nations (FAO)*  
**Cary Fowler**, *Former Executive Director, Global Crop Diversity Trust*  
**Keith Fuglie**, *Chief of the Resource, Environmental and Science Policy Branch at the Economic Research Service, USDA*



**Andrew Gilboy**, *Senior Partner,*  
*Associates for Global Change*

**Marta Gomez-Chiarri**, *Professor and Chair,*  
*Department of Fisheries, Animal and Veterinary*  
*Sciences, University of Rhode Island*

**Otto Gonzales**, *Director of the Center for*  
*International Programs, USDA-NIFA*

**Garrett Graddy-Lovelace**, *Assistant Professor, School*  
*of International Service, American University*

**Ian Gray**, *Vice President for Research and*  
*Graduate Studies, Michigan State University*

**Austin Humphries**, *Assistant Professor*  
*Fisheries, Animal and Veterinary*  
*Sciences, University of Rhode Island*

**David Hoisington**, *Program Director,*  
*Feed the Future Peanut and Mycotoxin*  
*Innovation Lab, University of Georgia*

**Daniel Karanja**, *Executive Director, Partnership*  
*to Cut Hunger and Poverty in Africa*

**Jonathan Lynch**, *Professor of Plant Nutrition,*  
*Pennsylvania State University*

**Jianghong Meng**, *Professor & Director, Joint*  
*Institute for Food Safety and Applied Nutrition*  
*(JIFSAN), University of Maryland*

**Richard Mertens**, *Associate Director for*  
*Federal Relations – Agriculture and Natural*  
*Resources, Texas A&M University*

**Rajul Pandya-Lorch**, *Chief of Staff and*  
*Head 2020 Vision Initiative, International*  
*Food Policy Research Institute*

**Sue Peterson**, *Director of Government*  
*Relations, Kansas State University*

**Max Pfeffer**, *International Professor*  
*of Development Sociology and Senior*  
*Associate Dean, Cornell University*

**Vara Prasad**, *Professor of Crop Ecophysiology*  
*and Director of the Sustainable Intensification*  
*Innovation Lab, Kansas State University*

**Barbara Schneeman**, *Higher Education*  
*Coordinator, USAID (retired)*

**Susan G. Schram**, *Independent Consultant*

**Anne Simmons-Benton**, *Executive Director,*  
*International Development, Arizona State University*

**Samara Sit**, *Assistant Dean and Director of*  
*Communications, Cornell University*

**Catherine Woteki**, *Former Under Secretary for*  
*United States Department of Agriculture's (USDA)*  
*Research, Education, and Economics, USDA*

**Margaret Zeigler**, *Executive Director,*  
*Global Harvest Initiative*

## Staff

**Samantha Alvis**, *Director, International*  
*Development and Programs*

**Montague Demment**, *Vice President,*  
*International Programs*

**Hanan Saab**, *Assistant Director for International Issues*

**Ian Maw**, *Vice President, Food,*  
*Agriculture & Natural Resources*

**Wendy Fink**, *Director of Food,*  
*Agriculture & Natural Resources*

**Shanaz Waise**, *Staff Associate, International Programs*

Special thank you to our research intern and assistants: Stefan Broecker, Karly Kiefer, and Shannon Patty-Stoddard.





*Ohio State student Korbin Smith and Gondar University faculty interview a farmer about his understanding of rabies, a serious problem in Ethiopia.*

PHOTO: THE OHIO STATE UNIVERSITY



# Notes

- 1 Food and Agricultural Organization (FAO). (2015). The state of food insecurity in the world. Retrieved from <http://www.fao.org/3/a4ef2d16-70a7-460a-a9ac-2a65a533269a/i4646e.pdf>
- 2 Food Security Information Network. (2017). Global report on food crises 2017. Retrieved from [http://www.fao.org/fileadmin/user\\_upload/newsroom/docs/20170328\\_Full%20Report\\_Global%20Report%20on%20Food%20Crises\\_v1.pdf](http://www.fao.org/fileadmin/user_upload/newsroom/docs/20170328_Full%20Report_Global%20Report%20on%20Food%20Crises_v1.pdf)
- 3 Barrett, C. (2013). Food or consequences: Food security and its implications for sociopolitical stability. In C. Barrett, ed., *Food security and sociopolitical stability*. (pp.1–34). Oxford: Oxford University Press.
- 4 United States Department of Agriculture, Economic Research Service. (2016). Food security in the U.S.: Key statistics and graphics. Retrieved from <https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/key-statistics-graphics/>
- 5 Feeding America. (2016). Map the meal gap 2016: Highlights of findings for overall and child food insecurity. Retrieved from <http://www.feedingamerica.org/hunger-in-america/our-research/map-the-meal-gap/2014/map-the-meal-gap-2014-exec-summm.pdf>
- 6 United Nations. (2015). World population projections. Retrieved from <http://www.un.org/en/development/desa/news/population/2015-report.html>
- 7 Chopra, M., Gailbraith, S., & Darnton-Hill, I. (2002). A global response to a global problem: The epidemic of overnutrition. *Bulletin of the World Health Organization*, 80, 952–958.
- 8 United Nations. (2015). Sustainable development goals: 17 goals to transform our world. Retrieved from <http://www.un.org/sustainabledevelopment/hunger/>
- 9 Alexandratos, N. & Bruinsma, J. (2012). *World agriculture towards 2030/2050: The 2012 revision*. Rome: FAO.
- 10 UNICEF. (2016). *UNICEF Data: Monitoring the situation of women and children, child survival. Current status + progress*. Retrieved from <https://data.unicef.org/topic/child-survival/under-five-mortality/>
- 11 United States Department of Agriculture, Economic Research Service. (2016). Agricultural trade. Retrieved from <https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/agricultural-trade.aspx>
- 12 FAO. (2008). An Introduction to the basic concepts of food security. Retrieved from <http://www.fao.org/docrep/013/al936e/al936e00.pdf>
- 13 Integrated Food Security Phase Classification (IPC). (n.d.). IPC action plan and focus areas (2014–2018). Retrieved from <http://www.ipcinfo.org/ipcinfo-about/ipc-action-plan-2014-2018/en/>
- 14 Association of Public and Land-grant Universities (APLU). (2001). Returning to our roots: Reports of the Kellogg Commission on the Future of State and Land-grant Universities. Retrieved from <http://www.aplu.org/projects-and-initiatives/economic-development-and-community-engagement/Kellogg%20Commission%20on%20the%20Future%20of%20State%20and%20Land-Grant%20Universities/>
- 15 APLU. (2016). Healthy food systems, healthy people. Retrieved from <http://www.aplu.org/projects-and-initiatives/agriculture-human-sciences-and-natural-resources/healthy-food-systems-healthy-people/>
- 16 APLU. (2015). Addressing antibiotic resistance. Retrieved from <http://www.aplu.org/projects-and-initiatives/agriculture-human-sciences-and-natural-resources/antibiotics-and-agriculture/final-report-october-2015.pdf>
- 17 National Association of State Universities and Land-Grant Colleges (NASULGC). (2000). *Renewing the covenant: Learning, discovery, and engagement in a new age and different world*. Retrieved from <http://www.aplu.org/library/renewing-the-covenant-learning-discovery-and-engagement-in-a-new-age-and-different-world/file>
- 18 NASULGC. (1999). *Returning to our roots: The engaged institution*. Retrieved from <http://www.aplu.org/library/returning-to-our-roots-the-engaged-institution/file>
- 19 Mohrman, K., Ma, W., & Baker, D. (2008). The research university in transition: The emerging global model. *Higher Education Policy*, 21, 5; National Academies. (2014) *Convergence: Facilitating transdisciplinary integration of life sciences, physical sciences, engineering and beyond*. Washington, DC: National Academies Press.

- 20 National Academies. (2014) *Convergence: Facilitating transdisciplinary integration of life sciences, physical sciences, engineering and beyond*. Washington, DC: National Academies Press.
- 21 FAO. (2009). *High level expert forum – How to feed the world 2050*;  
Grafton, R.Q., Williams, J., & Jiang, Q. (2015). Food and water gaps to 2050: Preliminary results from the global and water systems (GFWS) platform. *Food Security*, 7(2), 209.
- 22 FAO. (2016). *The state of world fisheries and aquaculture 2016: Contributing to food security and nutrition for all*. Rome;  
Zeigler, M., & Steensland, A. (2016). *Global agricultural productivity report (GAP Report): Sustainability in an uncertain season*. Washington, DC: Global Harvest Initiative.
- 23 Tilman, D., Cassman, K. G., Matson, P.A., Naylor, R. & Polasky, S. (2002). Agricultural sustainability and intensive production practices, *Nature*, 418.
- 24 Ericksen, P. J. (2008). Conceptualizing food systems for global environmental change research. *Global Environmental Change*, 18 (1), p. 234–245.
- 25 Kremen, C. & Miles, A. (2012). Ecosystem services in biologically diversified versus conventional farming systems: Benefits, externalities, and trade-offs. *Ecology and Society*, 17(4), 40.
- 26 Sachs, J., et al. (2010). Monitoring the world's agriculture. *Nature*, 466, 558.
- 27 Meiyappan, P., Dalton, M. O'Neill, B.C., & Jain, A.K. (2014). Spatial modeling of agricultural land use change at global scale. *Ecological Modelling*, 152–174.
- 28 Environmental Protection Agency. (2015). Mississippi River/Gulf of Mexico Watershed Nutrient Task Force: Report to Congress. Retrieved from [https://www.epa.gov/sites/production/files/2015-10/documents/htf\\_report\\_to\\_congress\\_final\\_-\\_10.1.15.pdf](https://www.epa.gov/sites/production/files/2015-10/documents/htf_report_to_congress_final_-_10.1.15.pdf)
- 29 Baldos, U., & Hertel, T. (2015). The role of international trade in managing food security risks. *Food Security*, 7(2), 275–290.
- 30 Hertel, T., & U. Baldos. (2016). Attaining food and environmental security in an era of globalization. *Global Environmental Change*, 41, 195–205.
- 31 Soil Science Society of America. (2011). Soils sustain life. Retrieved from <https://www.soils.org/files/science-policy/ssa-grand-challenge-2011.pdf>
- 32 USDA, Economic Research Service. (2016). Irrigation and water use overview. Retrieved from <https://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use.aspx>
- 33 Zeigler, M., & Steensland, A. (2015). Global agricultural productivity report (GAP report): Building sustainable breadbaskets. Washington, DC: Global Harvest Initiative.
- 34 Bleed, A., & Babbitt, C.H. (2015). Nebraska's natural resources districts: An assessment of a large-scale locally controlled water governance framework. Lincoln, NE: Daughtery Water for Food Institute.
- 35 Hanak, E., & Stryjewski, E. (2012). California's water market, by the numbers, Update 2012. PPIC;  
California Environmental Protection Agency, Air Resources Board. (2016). Compliance offset program. Retrieved from <https://www.arb.ca.gov/cc/capandtrade/offsets/offsets.htm>
- 36 United Nations. (2002, August 29). World summit on sustainable development. Summit conducted in Johannesburg, South Africa. Retrieved from <https://sustainabledevelopment.un.org/milestones/wssd>
- 37 Ainsworth, E.A, & Ort, D. R. (2010). How do we Improve crop production in a warming world? *Plant Physiology*, 154, 526–530.
- 38 Araus, J. L., Slafer, G. A., Royo, C., & Sarret, M.D. (2008). Breeding for yield potential and stress adaptation in cereals. *Critical Reviews in Plant Science*, 27, 377–412;  
Ceccarelli, S. (2015). Efficiency of plant breeding. *Crop Science*, 55, 87–97;  
Flachowsky, G., & Mayer, U. (2015). Challenges for plant breeders from the view of animal nutrition. *Agriculture*, 5, 1252–1276.
- 39 Cardinale, B. J; Duffy, J. E; Gonzalez, D.U, Hopper, C, Perrings, P, Venail, et.al. (2012). Biodiversity loss and its impact on humanity. *Nature*, 486, 59–67;  
Ceccarelli, S. (2015). Efficiency of plant breeding. *Crop Science*, 55, 87–97;  
da Silva Dias, J.C. (2015). Biodiversity and plant breeding as tools for harmony between modern agriculture production and environment. *Agricultural and Biological Sciences Molecular Approaches to Genetic Diversity*, 6(1), pp. 87–116. Retrieved from <http://www.scirp.org/journal/PaperInformation.aspx?PaperID=53313&#abstract>
- 40 Araus, J. L., Slafer, G. A., Royo, C., & Sarret, M.D. (2008). Breeding for yield potential and stress adaptation in cereals. *Critical Reviews in Plant Science*, 27, 377–412.
- 41 Araus, J. L., Slafer, G. A., Royo, C., & Sarret, M.D. (2008). Breeding for yield potential and stress adaptation in cereals. *Critical Reviews in Plant Science*, 27, 377–412;  
Sangha, K. K. (2013). A holistic approach to assess the costs and benefits of modern agriculture. *Applied Ecology and Environmental*, 1(5), pp. 67–74. Retrieved from [https://www.researchgate.net/publication/260206858\\_A\\_Holistic\\_Approach\\_to\\_Assess\\_the\\_Costs\\_and\\_Benefits\\_of\\_Modern\\_Agriculture\\_System\\_in\\_Punjab\\_India\\_and\\_Some\\_Solutions](https://www.researchgate.net/publication/260206858_A_Holistic_Approach_to_Assess_the_Costs_and_Benefits_of_Modern_Agriculture_System_in_Punjab_India_and_Some_Solutions)
- 42 Araus, J. L., Slafer, G. A., Royo, C., & Sarret, M.D. (2008). Breeding for yield potential and stress adaptation in cereals. *Critical Reviews in Plant Science*, 27, 377–412.

- 43 Mwai, O., Hanotte, O., Kwon, Y. & Cho, S. (2015). African indigenous cattle: Unique genetic resources in a rapidly changing world. *Asian-Australasian Journal of Animal Sciences*, 28(7), 911–921.
- 44 Dobson, H., Smith, R., Royal, M., Knight, C. & Sheldon, I. (2007). The high producing dairy cow and its reproductive performance. *Reproduction in Domestic Animals*, 42, 17–23.
- 45 Rege, J. E. O. (1999). The state of African cattle genetic resources. I. Classification framework and identification of threatened and extinct breeds. In *Animal Genetic Resources Information Bulletin* (25), pp. 1–26. Retrieved from <https://cgispace.cgiar.org/handle/10568/10349>
- 46 WorldWatch. (2016). Global meat production and consumption continue to rise. Retrieved from <http://www.worldwatch.org/global-meat-production-and-consumption-continue-rise-1>
- 47 FAO. (2016). The state of world fisheries and aquaculture 2016: Contributing to food security and nutrition for all. Rome: Author.
- 48 Feed the Future, United States Agency for International Development. (2011). Feed the future research strategy. Retrieved from <https://www.feedthefuture.gov/resource/feed-future-research-strategy>
- 49 Renaudeau, D., et al. (2012). Adaptation to hot climate and strategies to alleviate heat stress in livestock production. *Animal*, 6 (5), 707–728.
- 50 Long, S. P., Marshall-Colon, A., & Zhu, X. (2015). Meeting the global food demand of the future by engineering crop photosynthesis and yield potential. *Cell*, 161, 56–66.
- 51 Gust, D. (1996). Why study photosynthesis? Retrieved from <http://swcta.net/goode/files/2015/11/Why-Study-Photosynthesis.pdf>
- 52 Zhu, X., Long, S. P., & Ort, D. R. (2008). What is the maximum efficiency in which photosynthesis can convert solar energy into biomass? *Plant Biotechnology*, 19, 153–159.
- 53 Office of Science, U.S. Department of Energy. (2005). Basic research needs for solar energy utilization. Retrieved from [https://science.energy.gov/-/media/bes/pdf/reports/files/Basic\\_Research\\_Needs\\_for\\_Solar\\_Energy\\_Utilization\\_rpt.pdf](https://science.energy.gov/-/media/bes/pdf/reports/files/Basic_Research_Needs_for_Solar_Energy_Utilization_rpt.pdf)
- 54 Yarris, L. (2015, April 16). Major advance in artificial photosynthesis poses win/win for the environment. *Berkeley Lab News Center*. Retrieved from <http://newscenter.lbl.gov/2015/04/16/major-advance-in-artificial-photosynthesis/>
- 55 Yates, D. (2016, November 17). Scientists tweak photosynthesis to boost crop yields. *Illinois News Bureau*. Retrieved from <https://news.illinois.edu/blog/view/6367/430749>
- 56 Liu, C., et al. (2015). Nanowire–bacteria hybrids for unassisted solar carbon dioxide fixation to value-added chemicals. *NanoLetters*, 15(5), 3634–3639.
- 57 Wise, T. (2013). Can We Feed the World in 2050? A scoping paper to assess the evidence. GDAE Working Paper No. 13-04. Retrieved from <http://www.ase.tufts.edu/gdae/Pubs/wp/13-04WiseFeedWorld2050.pdf>
- 58 Kumm, M., de Moel, H., Porkka, M., Siebert, S., Varis, O., & Ward, P.J. (2012). Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use. *Science of the Total Environment*, 438: 477–489.
- 59 Rethink Food Waste through Economics and Data (ReFED). (2016). *A roadmap to reduce U.S. food waste by 20 percent*. Retrieved from [http://refed.com/downloads/ReFED\\_Report\\_2016.pdf](http://refed.com/downloads/ReFED_Report_2016.pdf).
- 60 FAO. (2013). *Food wastage footprints: Impacts on natural resources*. Retrieved from <http://www.fao.org/docrep/018/i3347e/i3347e.pdf>
- 61 Zeigler, M., & Steensland, A. (2015). Global agricultural productivity report (GAP report): Building sustainable breadbaskets. Washington, DC: Global Harvest Initiative.
- 62 Rethink Food Waste through Economics and Data (ReFED). (2016). *A roadmap to reduce U.S. food waste by 20 percent*. Retrieved from [http://refed.com/downloads/ReFED\\_Report\\_2016.pdf](http://refed.com/downloads/ReFED_Report_2016.pdf).
- 63 Foundation on Future Farming. (n.d.). Agriculture at a crossroads: Food speculation. Retrieved from [http://www.globalagriculture.org/fileadmin/files/weltagrarbericht/EnglishBrochure/BrochureIAASTD\\_en\\_web\\_small.pdf](http://www.globalagriculture.org/fileadmin/files/weltagrarbericht/EnglishBrochure/BrochureIAASTD_en_web_small.pdf); Global Justice Now. (2016). Investment bank's revenue from food speculation 2010–2012. Retrieved from [http://www.globaljustice.org.uk/sites/default/files/files/resources/top\\_5\\_banks\\_food\\_speculation\\_estimates.pdf](http://www.globaljustice.org.uk/sites/default/files/files/resources/top_5_banks_food_speculation_estimates.pdf)
- 64 Buzby, J.C., Wells, H.F., & Hyman, J. (2014). Buzby, J.C., Wells, H.F., & Hyman, J. (2014). The estimated amount, value, and calories of postharvest food losses at the retail and consumer levels in the United States. Washington, DC: Economic Research Service, United States Department of Agriculture.
- 65 Gunders, D. (2012). Wasted: How America is losing up to 40 percent of its food from farm to fork to landfill. Washington, DC: Natural Resources Defense Council.
- 66 Jedermann, R., Nicomet, M., Uysal, I. & Lang, W. (2014). Reducing food losses by intelligent food logistics. *Philosophical Transactions. Series A, Mathematical, physical, and engineering sciences*, 372 (2017).
- 67 APLU. (2016). Healthy food systems, healthy people.
- 68 APLU. (2016). Healthy food systems, healthy people.



- 69 ReFED. (2016). A roadmap to reduce U.S. food waste by 20 percent.
- 70 APLU. (2016). Healthy food systems, healthy people.
- 71 United Nations. (2014). *World urbanization prospects*. Retrieved from <https://esa.un.org/unpd/wup/publications/files/wup2014-highlights.Pdf>
- 72 United Nations. (2014, July 10). *World's population increasingly urban with more than half living in urban areas*. Retrieved from <http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html>
- 73 DC Central Kitchen. (2015). *Turning the corner: The inside guide to fighting food deserts*. Retrieved from [https://dcentralkitchen.org/wp-content/uploads/2015/02/Healthy-Corners-Manual\\_Exec-Summary.pdf](https://dcentralkitchen.org/wp-content/uploads/2015/02/Healthy-Corners-Manual_Exec-Summary.pdf)
- 74 Central Intelligence Agency. (2016). World Factbook – Profiles for United States, Mexico, and Canada.
- 75 Neumann, B., Vafeidis, A.T., Zimmermann, J., & Nicholls, R.J. (2015). Future coastal population growth and exposure to sea-level rise and coastal flooding—A global assessment. *PLoS ONE* 10(3): e0118571. doi:10.1371/journal.pone.0118571
- 76 Roser, M. (2017). Agricultural employment. Our world in data. Retrieved from <https://ourworldindata.org/agricultural-employment/>  
USDA-ERS. (2016). Farm economy and farm labor background. Retrieved from <https://www.ers.usda.gov/topics/farm-economy/farm-labor/background.aspx>  
World Bank. (2017). World development indicators: Agricultural inputs. Retrieved from <http://wdi.worldbank.org/table/3.2>
- 77 Food and Agricultural Organization (FAO). (2015). The state of food insecurity in the world. Retrieved from <http://www.fao.org/3/a4ef2d16-70a7-460a-a9ac-2a65a533269a/i4646e.pdf>
- 78 Larsen, K. et al. (2014). Food access and children's BMI In Toronto, Ontario: Assessing how the food environment relates to overweight and obesity. *International Journal of Public Health*, 60 (1), 69.
- 79 FAO. (2017). Global report on food crises 2017.
- 80 FAO. (2003). Trade reforms and food security: Conceptualizing the linkages. Retrieved from <http://www.fao.org/3/a-y4671e.pdf>
- 81 Lowder, S.K., Skoet, J. & Singh, S. (2014). What do we really know about the number and distribution of farms and family farms worldwide? Background paper for The State of Food and Agriculture 2014. ESA Working Paper No. 14-02. Rome, FAO. Retrieved from <http://www.fao.org/docrep/019/i3729e/i3729e.pdf>
- 82 United Nations. (2014). World urbanization prospects.
- 83 Zeigler, M., & Steensland, A. (2016). Global Agricultural Productivity Report (GAP Report): Sustainability in an uncertain season. Washington, DC: Global Harvest Initiative.
- 84 Human Sciences Research Council. (2013). How do small farm households benefit from ICT access and use? Retrieved from <http://www.hsrc.ac.za/en/review/hsrc-review-march-2014/small-farm-ict>
- 85 Global Open Data for Agriculture and Nutrition (GODAN). (2016). A global data ecosystem for agriculture and food. Retrieved from <http://www.godan.info/documents/data-ecosystem-agriculture-and-food>
- 86 Ardichvili, A. (2008). Learning and knowledge sharing in online communities of practice: Motivators, barriers, and enablers. *Advances in Developing Human Resources*, 10 (4), 541–554.
- 87 Benin, S., Nkonya, E., Okecho, G., Pender, J.L., Nahdy, S., Mugarura, S., & Kayobyo, G. (2007). Assessing the impact of the national agricultural advisory services (NAADS) in the Uganda rural livelihoods. *IFPRI* discussion paper, Washington, DC. Retrieved from <http://www.ifpri.org/publication/assessing-impact-national-agricultural-advisory-services-naads-uganda-rural-livelihoods>
- 88 FAO. (2012). Smallholders and family farmers. Retrieved from [http://www.fao.org/fileadmin/templates/nr/sustainability\\_pathways/docs/Factsheet\\_SMALLHOLDERS.pdf](http://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/Factsheet_SMALLHOLDERS.pdf)
- 89 FAO. (2011). The state of food and agriculture 2010–2011: Women in agriculture, closing the gender gap for development. Retrieved from <http://www.fao.org/docrep/013/i2050e/i2050e.pdf>
- 90 Ricciardelli, A. (2015). The role of universities in the pursuit of local community empowerment, sustainable, smart and inclusive development in resilient communities—A comparison analysis of post-conflict Croatia and Kosovo. *Proceedings of the Euro Mediterranean Dialogue on Public Management, Rome, Italy*. Retrieved from [http://www.academia.edu/9815727/The\\_role\\_of\\_Universities\\_in\\_the\\_pursuit\\_of\\_local\\_community\\_empowerment\\_sustainable\\_smart\\_and\\_inclusive\\_development\\_in\\_resilient\\_communities.\\_A\\_comparison\\_analysis\\_of\\_post-conflict\\_Croatia\\_and\\_Kosovo](http://www.academia.edu/9815727/The_role_of_Universities_in_the_pursuit_of_local_community_empowerment_sustainable_smart_and_inclusive_development_in_resilient_communities._A_comparison_analysis_of_post-conflict_Croatia_and_Kosovo)
- 91 Zambrana, R. E., Ray, R., Espino, M. M., Castro, C., Cohen, B. D., & Eliason, J. (2015). “Don't leave us behind”: The importance of mentoring for underrepresented minority faculty. *American Educational Research Journal*, 52, 40–72.
- 92 Antonio, A. L. (2002). Faculty of color reconsidered: Reassessing contributions to scholarship. *Journal of Higher Education*, 73.5, pp. 528–602. Retrieved from <https://muse.jhu.edu/article/14873>
- 93 Kena, G., Hussar W., McFarland J., de Brey C., Musu-Gillette, L., Wang, X., Zhang, J., Rathbun, A., Wilkinson-Flicker, S., Diliberti M., Barner, A., Bullock Mann, F., &

- Dunlop Velez, E. (2016). The condition of education 2016 (NCES 2016-144). Washington, DC: U.S. Department of Education, National Center for Education Statistics.
- 94 Weinfeld, N. S., Mills, G., Borger, C., Gearing, M., Macaluso, T., Montaquila J., & Zedlewski, S. (2014). Hunger in America 2014: National report prepared for Feeding America. *Feeding America*, 160.
- 95 FAO. (2011). The state of food and agriculture 2010-2011: Women in agriculture, closing the gender gap for development.
- 96 Zselezky, L., Van Houweling, E., & Christie, M. E. (2013). Preliminary Study: Gender, higher education, and AET. Retrieved from <http://www.oired.vt.edu/innovate/wp-content/uploads/2015/09/Gender-Higher-Education-and-AET.pdf>
- 97 UNESCO. (2016). *Science report towards 2030*. Retrieved from [http://en.unesco.org/unesco\\_science\\_report](http://en.unesco.org/unesco_science_report)
- 98 Doss, C. R. (2001). Men's crops and women's crops: The importance of gender to the understanding of agricultural and development outcomes in Ghana's central region. *World Development*, 36(5), 900-915;
- Women and Youth Affairs Directorate of Ministry of Agriculture. (2015). Access of rural women to agricultural extension services, opportunities and challenges in Ethiopia. Retrieved from <https://agriknowledge.org/downloads/cn69m418x>
- 99 Manfre, C., Rubin, D., Allen, A., Summerfield, G., Colverson, K., & Akeredolu, M. (2013). Reducing the gender gap in agricultural extension and advisory services: How to find the best fit for men and women farmers. MEAS Discussion Paper 2. Retrieved from [https://agrilinks.org/sites/default/files/resource/files/MEAS%20Discussion%20Paper%202%20-%20Gender%20and%20Extension%20-%202013\\_04\\_01\\_0\\_0.pdf](https://agrilinks.org/sites/default/files/resource/files/MEAS%20Discussion%20Paper%202%20-%20Gender%20and%20Extension%20-%202013_04_01_0_0.pdf)
- 100 Ajilore, O. (2014). Rejuvenating sustainable agriculture discourses: Increasing youth engagement. *Global Landscapes Forum*. Retrieved from <http://www.landscapes.org/rejuvenating-sustainable-agriculture-discourses-increasing-youth-engagement/>
- 101 Lechtenberg, V., Ayeni, A., Christy, R., & Kramer-LeBlanc, C. (2014). BIFAD review of strategic human and institutional capacity development (HICD) issues and the role of USAID and Title XII under the Feed the Future programs. Retrieved from <http://www.aplu.org/projects-and-initiatives/international-programs/bifad>
- 102 FAO. (2008). An introduction to the basic concepts of food security. Retrieved from <http://www.fao.org/docrep/013/al936e/al936e00.pdf>
- 103 FAO. (2015). Trade reforms and food security: Conceptualizing the linkages.
- 104 Nettle, D., Andrews, C., & Bateson, M. (2016, July 28). Food insecurity as a driver of obesity in humans: The insurance hypothesis. *Behavioral and Brain Sciences*, 1-34.
- 105 European Food Information Council. (2005). The determinants of food choice. Retrieved from <http://www.eufic.org/en/healthy-living/article/the-determinants-of-food-choice>
- 106 Hoddinott, J., Maluccio, J.A., Behrman, J.R., Flores, R., & Martorell, R. (2008). Effect of a nutrition intervention during early childhood on economic productivity in Guatemalan adults. *Lancet*, 37 (9610), 411-6.
- 107 CDC. (2016). Vital statistics rapid release: Quarterly provisional estimates - Quarter 2, 2016. Retrieved from <https://www.cdc.gov/nchs/products/vsrr/mortality-dashboard.htm#trends>
- 108 Demment, M.W., Young, M.M., & Sensenig, R. L. (2003). Providing micronutrients through food-based solutions: A key to human and national development. *Journal of Nutrition*, 133, 3879S-3885S.
- 109 African Union Commission, NEPAD. (2014). *The cost of hunger in Africa: Social and economic impact of child undernutrition in Egypt, Ethiopia, Swaziland and Uganda*. Retrieved from <http://www.uneca.org/publications/cost-hunger-africa>
- 110 Waters, H. & DeVol, R. (2016). Weighing down America: The health and economic impact of obesity. Santa Monica, CA: Milken Institute.
- 111 Demment, M.M., Haas, J.D., & Olson, C.M. Changes in family Income status and the development of overweight and obesity from 2 to 15 years: A longitudinal study. *BMC Public Health*, 14(1). Retrieved from <https://www.ncbi.nlm.nih.gov/pubmed/24886200>
- 112 Godfray, H. C., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., & Toulmin, C. (2010). Food security: The challenge of feeding 9 billion people. *Science*, 327(5967), 812-818.
- 113 Strengthening Partnerships, Results, and Innovations in Nutrition Globally. (2013). Optifood. Retrieved from <https://www.spring-nutrition.org/publications/tool-summaries/optifood>
- 114 Brown, K.H., Engle-Stone, R., Kagin, J., Rettig, E., & Vosti, S.A. (2015). Use of optimization modeling for selecting national micronutrient intervention strategies. *Food and Nutrition Bulletin*, 36(3 Suppl), 141-148.
- 115 Arsenault, J.E., Hijmans, R.J., & Brown, K.H. (2015). Improving nutrition security through agriculture: An analytical framework based on national food balance sheets to estimate nutritional adequacy of food supplies. *Food Security*, 7(3), 693-707.

- 116 McClanahan, T., Allison, E.H., & Cinner, J.E. (2015). Managing fisheries for human and food security. *Fish and Fisheries*, 16(1), 78–103.
- 117 *Recommendation from Healthy Food Systems, Healthy People*
- 118 Ibid.
- 119 Ibid.
- 120 Lusk, J. & Perugini, M. (2016). Editorial for special issue on food consumption behavior: Economic and psychological perspectives. *Journal of Economic Psychology*, 55, 1–3.
- 121 Centers for Disease Control and Prevention. (2016). Estimates of foodborne illness in the United States. Retrieved from <https://www.cdc.gov/foodborneburden/estimates-overview.html>
- 122 Fukuda, K. (2015). Food safety in a globalized world. *Bull World Health Organization*, 93, 212.
- 123 Tirado, M., Clarke, R., Jaykus, L., McQuatters-Gollop, A., & Frank, J. (2010). Climate change and food safety: A review. *Food Research International*, 43, 1745.
- 124 Foran T., Butler J. Williams L., Wanjura W., Hall A., Carter L., & Carberry P. (2014). Taking complexity in food systems seriously: An interdisciplinary analysis. *World Development*, 61, 85–101,
- 125 Lammie, S. & Hughes, J. (2016). Antimicrobial resistant, food safety and one health: The need for convergence. *Annual Review of Food Science and Technology*, 7, 287.
- 126 Cleaveland, S. C., M. K. Laurenson, & Taylor, L. H. (2001). Diseases of Humans and Their Domestic Mammals: Pathogen Characteristics, Host Range and the Risk of Emergence. *Philosophical Transactions of the Royal Society of London B-Biological Sciences* 356:991–999. Retrieved from <https://www.ncbi.nlm.nih.gov/pubmed/11516377>
- 127 World Health Organization. (2012). Research priorities for zoonoses and marginalized infections. Geneva, Switzerland: World Health Organization, Report nr971.
- 128 Kuesch, G. T., et al. (2009). *Sustaining Global Surveillance and Response to Emerging Zoonotic Diseases*. National Academy of Sciences. Retrieved from [https://www.ncbi.nlm.nih.gov/books/NBK215317/pdf/Bookshelf\\_NBK215317.pdf](https://www.ncbi.nlm.nih.gov/books/NBK215317/pdf/Bookshelf_NBK215317.pdf)
- 129 Jansen, W., Grabowski, N., Gerulat, B., & Klein, G. (2015). Food safety hazards and microbiological zoonoses in European meat imports detected in border inspection in the period 2008–2013. *Zoonoses and Public Health*, 63, 53–61.
- 130 Lassen, S. G., et al. (2016). Lassen, S. G., et al. (2016). Two listeria outbreaks caused by smoked fish consumption—using whole-genome sequencing for outbreak investigations. *Clinical Microbiology and Infection*, 21(7), 620–624.
- 131 Warriner, K., Huber, A., Namvar, A., Fan, W., & Dunfield, K. (2009). Recent advances in the microbial safety of fresh fruits and vegetables. In S. L. Taylor (Ed.), *Advances in Food and Nutrition Research*, vol. 57 (155–208). San Diego, CA: Elsevier Academic Press Inc.
- 132 Ibid.
- 133 McCollum, J. T., et al. (2013). Multistate outbreak of listeriosis associated with cantaloupe. *New England Journal of Medicine*, 369(10), 944–953.
- 134 Datta, A. K. (2016). Toward computer-aided food engineering: Mechanistic frameworks for evolution of product, quality and safety during processing. *Journal of Food Engineering*, 176, 9–27;
- Huang, T., Lan, L., Fang, X. X., An, P., Min, J. X., & Wang, F. D. (2015). Promises and challenges of big data computing in health sciences. *Big Data Research*, 2(1), 2–11.;
- Ibekwe, A. M., Ma, J. C., Crowley, D. E., Yang, C. H., Johnson, A. M., Petrossian, T. C., & Lum, P. Y. (2014). Topological data analysis of *Escherichia coli* O157:H7 and non-O157 survival in soils. *Frontiers in Cellular and Infection Microbiology*, 4, 11.;
- Strawn, L. K., Brown, E. W., David, J. R. D., Den Bakker, H. C., Vangay, P., Yiannas, F., & Wiedmann, M. (2015). Big data in food safety and quality. *Food Technology*, 69(2), 42+;
- Velsko, S., & Bates, T. (2016). A conceptual architecture for national biosurveillance: Moving beyond situational awareness to enable digital detection of emerging threats. *Health Security*, 14(3), 189–201.
- 135 APLU and AAVMC. (2015). Addressing antibiotic resistance. Retrieved from <http://www.aplu.org/library/addressing-antibiotic-resistance/file>
- 136 World Health Organization. (2014). Antimicrobial resistance: Global report on surveillance. Retrieved from [http://apps.who.int/iris/bitstream/10665/112642/1/9789241564748\\_eng.pdf?ua=1](http://apps.who.int/iris/bitstream/10665/112642/1/9789241564748_eng.pdf?ua=1)
- 137 Tsalik, E. (2014). Antimicrobial drug resistance in all four corners of the earth. *Science Translational Medicine*, 6, 240.
- 138 APLU internal analysis of Delta Cost Project IPEDS Data (2013). Retrieved from <http://tcs-online.org/Home.aspx>;
- Mitchell, M., Leachman, M., & Masterson, K. (2016, August 15). Funding down, Tuition up: State cuts to higher education threaten quality and affordability at public colleges. *Center on Budget and Policy Priorities*. Retrieved from <http://www.cbpp.org/research/state-budget-and-tax/funding-down-tuition-up>
- 139 Falk-Krzesinski, H. J. (2012). Guidance for team science leaders: Tools you can use. *Team Science*, 2(2).
- 140 Manlove, K. R., et al. (2016). “One health” or three? Publication silos among the one health disciplines. *PLoS Biology* 14(4), e1002448.

- 141 Vogel, A. L., et al. (2013). The Team Science Toolkit. *American Journal of Preventive Medicine*, 45(6), 787–789.
- 142 Mauser, W., Klepper, G., Rice, M., Schmalzbauer, B. S., Hackmann, H., Leemans, R., Moore, H. (2013). Transdisciplinary global change research: the co-creation of knowledge for sustainability. *Current Opinion in Environmental Sustainability*, 5, 420–431.
- 143 Mauser, W., Klepper, G., Rice, M., Schmalzbauer, B. S., Hackmann, H., Leemans, R., Moore, H. (2013). Transdisciplinary global change research: the co-creation of knowledge for sustainability. *Current Opinion in Environmental Sustainability*, 5, 420–431.
- 144 Sunkel, C. (2015). Excellence and the new social contract for science. *EMBO*, 16, 553–556.
- 145 Clark, W.C. (2007). Sustainability science: A room of its own. *Proceedings of the National Academies of Science of the United States of America*, 4(6), 1737–1738.
- 146 National Science Foundation. (n.d.) Sustainability research networks competition. Retrieved from [https://www.nsf.gov/funding/pgm\\_summ.jsp?pims\\_id=503645](https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503645)
- 147 National Academy of Sciences- Board of Life Sciences. (2014). Convergence: Facilitating transdisciplinary integration of life sciences, physical sciences, engineering, and beyond. Retrieved from <https://www.nap.edu/catalog/18722/convergence-facilitating-transdisciplinary-integration-of-life-sciences-physical-sciences-engineering>;  
APLU, Coalition of Urban Serving Universities. (2016). *Collaborating for change: Revolutionizing the role of the university: Collaboration to advance innovation in higher education*. Retrieved from <http://www.aplu.org/library/revolutionizing-the-role-of-the-university/File>;  
American Academy of Arts and Sciences–Arise II Committee. (2013). *Advancing research in science and engineering: Unleashing America's research & innovation enterprise*. Retrieved from <http://www.amacad.org/content/Research/research.aspx?d=268>
- 148 National Academy of Sciences- Board of Life Sciences. (2014). *Convergence: Facilitating transdisciplinary integration of life sciences, physical sciences, engineering, and beyond.*;  
APLU, Coalition of Urban Serving Universities. (2016). *Collaborating for change: Revolutionizing the role of the university: Collaboration to advance innovation in higher education*. Retrieved from <http://www.aplu.org/library/revolutionizing-the-role-of-the-university/File>
- 149 Based on enrollment experience at University of California, Davis.
- 150 National Academy of Sciences- Board of Life Sciences. (2014). *Convergence: Facilitating transdisciplinary integration of life sciences, physical sciences, engineering, and beyond.*
- 151 Clancy, M., Fuglie, K., & Heisey, P. (2016). U.S. agricultural R&D in an era of falling public funding. Retrieved from <https://www.ers.usda.gov/amber-waves/2016/november/us-agricultural-rd-in-an-era-of-falling-public-funding/>
- 152 CGIAR. (2006). A Partnership for research and development: The United States of America and the CGIAR. Retrieved from [http://www.cgiar.org/www-archive/www.cgiar.org/pdf/CGIAR%20AND%20USA\\_DEC2006.pdf](http://www.cgiar.org/www-archive/www.cgiar.org/pdf/CGIAR%20AND%20USA_DEC2006.pdf)
- 153 For example, the National Institute of Environmental Health Sciences Centers, which rather than funding individual research projects, supports the administration and physical framework to being together scientists from multiple disciplines to pursue promising research opportunities. <https://www.niehs.nih.gov/research/supported/centers/core/>
- 154 United State Agency for International Development. (2011). *Feed the future: Research strategy document*.
- 155 Pardey, P., & Beddow J. (2017). Revitalizing agricultural research and development to sustain US competitiveness. Philadelphia: Farm Journal Foundation.
- 156 National Academy of Sciences- Board of Life Sciences. (2014). *Convergence: Facilitating transdisciplinary integration of life sciences, physical sciences, engineering, and beyond.*
- 157 Kragt, M. E., Pannell, D. J., McVittie, A., Stott, A. W., Vosough Ahmadi, B., & Wilson, P. (2016). Improving interdisciplinary collaboration in Bio-economic modeling for agricultural systems. *Agricultural Systems*, 143, 217–224.
- 158 National Academy of Sciences- Board of Life Sciences. (2014). *Convergence: Facilitating transdisciplinary integration of life sciences, physical sciences, engineering, and beyond.*
- 159 Ibid.
- 160 Kragt, M. E., Pannell, D. J., McVittie, A., Stott, A. W., Vosough Ahmadi, B., & Wilson, P. (2016). Improving interdisciplinary collaboration in Bio-economic modeling for agricultural systems. *Agricultural Systems*, 143, 217–224;  
Bishop, P. R., Huck, S. W., Ownley, B. H., Richards, J. K., & Skolits, G. J. (2014). Impacts of an interdisciplinary research center on participant publication and collaboration patterns: A case study of National Institute for Mathematical and Biological Synthesis. *Research Evaluation*, 23(4), 327–340.
- 161 Goring, S. J., Weathers K. C., Dodds, W. K., Soranno, P. A., Sweet, L. C., Cheruvelil, K. S., Kominoski, J. S., Rüegg, J., Thorn, A. M., & Utz, R. M. (2014). Improving the culture of interdisciplinary collaboration in ecology by expanding measures of success. *Frontiers in Ecology and the Environment*, 12, 39–47.



- 162 APLU, Coalition of Urban Serving Universities. (2016). *Collaborating for change: Revolutionizing the role of the university: Collaboration to advance innovation in higher education*. Retrieved from <http://www.aplu.org/library/revolutionizing-the-role-of-the-university/File>
- 163 National Research Council. (2013). Roadblocks and bridges to transdisciplinary research. In Waite, L. J. Plewes, T. J. (eds). *New Directions in the Sociology of Aging*. Washington, DC: National Academies Press;
- University of California, San Diego Senate Administrative Taskforce. (2007). Multidisciplinary research and education at UC San Diego best practices and guidelines for multidisciplinary appointments. Retrieved from [https://academicaffairs.ucsd.edu/\\_files/aps/reports/MJATFReport.pdf](https://academicaffairs.ucsd.edu/_files/aps/reports/MJATFReport.pdf)
- 164 NASULGC. (1999). Returning to our roots: The engaged institution. Retrieved from <http://www.aplu.org/library/returning-to-our-roots-the-engaged-institution/file>
- 165 USDA Economic Research Service. (2016). U.S. agricultural trade: Import share of consumption. Retrieved from <https://www.ers.usda.gov/topics/international-markets-trade/us-agricultural-trade/import-share-of-consumption.aspx>;
- USDA-Economic Research Service. (2016). Interactive chart: The evolution of U.S. agricultural exports over the last two decades. Retrieved from <https://www.ers.usda.gov/topics/international-markets-trade/us-agricultural-trade/interactive-chart-the-evolution-of-us-agricultural-exports-over-the-last-two-decades/>









**Association of Public and Land-grant Universities**

1307 New York Avenue, N.W., Suite 400

Washington, D.C. 20005-4722

**[www.aplu.org/ChallengeofChange](http://www.aplu.org/ChallengeofChange)**



ASSOCIATION OF  
PUBLIC &  
LAND-GRANT  
UNIVERSITIES