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Institute on Science for Global Policy (ISGP)

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Food Safety, Security, and Defense: *Focus on Food and the Environment*

Conference convened by the ISGP in partnership with
Cornell University, at the Statler Hotel,
Ithaca, New York, United States
October 5–8, 2014

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Sustainable Investment Produce

Effective Scientific Communities

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An ongoing series of dialogues and critical debates
examining the role of science and technology
in advancing effective domestic and international policy decisions

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Introduction

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Preface

The contents of this book were taken from material presented at an international conference convened by the Institute on Science for Global Policy (ISGP) on October 5–8, 2014, in partnership with Cornell University, in Ithaca, New York. This ISGP conference, the fourth in the ISGP program on Food Safety, Security, and Defense (FSSD), focused on Food and the Environment.

The process underlying the organization of all ISGP conferences begins with the recognition that there are significant advances and changes in several scientific fields (e.g., FSSD) that can be anticipated to have a major impact throughout societies worldwide. The significance of these advances internationally depends on how they affect the human condition as viewed through different cultural, ethical, and economic systems. Decisions within each society concerning how to appropriately incorporate such transformational science into public and private sector policies rely on candid debates that highlight the credible options developed by scientists. Since FSSD can potentially have such significant impact worldwide, it deserves attention from both domestic and international policy makers from a wide range of disciplines. ISGP conferences offer one of those rare environments where such critical debates can occur among credible scientists, influential policy makers, and a broad range of societal stakeholders.

Based on extensive interviews conducted by the ISGP staff with an international group of subject-matter experts, the ISGP invited eight highly distinguished individuals with expertise in FSSD to prepare the three-page policy position papers to be debated at the Ithaca conference. These eight policy position papers, together with the not-for-attribution summaries of the debates of each paper, are presented in this book. The areas of consensus and actionable next steps that were developed by all participants in the caucuses that followed the debates are also presented. The debate summaries and caucus results were written by the ISGP staff and are based on contributions from all conference participants.

Current realities

While the material presented here is comprehensive and stands by itself, its policy significance also can be viewed within the context of how domestic and international science policies have been, and often currently are being, formulated and implemented. While many of our most significant geopolitical policy and security issues are directly connected with the remarkably rapid and profound S&T accomplishments of our time, many societies struggle to effectively use S&T to address their specific challenges. Consequently, it is increasingly important that the S&T and policy communities (public and private) communicate effectively. Recent history suggests that most societies would benefit from improving the effectiveness of how scientifically credible information is used to formulate and implement governmental policies, both domestic and international.

Specifically, credible S&T information needs to be concisely presented to policy communities in an environment that promotes candid questions and debates led by those nonspecialists directly engaged in decisions. Such discussions, sequestered from publicity, can help to clarify the advantages and potential risks of realistic S&T options directly relevant to the societal challenges being faced. Eventually, this same degree of understanding, confidence, and acknowledgment of risk must be communicated to the public to obtain the broad societal support needed to effectively implement any decision.

The ISGP has pioneered the development a new type of international forum designed to provide articulate, distinguished scientists and technologists opportunities to concisely present their views of the credible S&T options available for addressing major geopolitical and security issues.

All ISGP programs rely on the validity of two overarching principles:

1. Scientifically credible understanding must be closely linked to the realistic policy decisions made by governmental, private sector, and societal leaders in addressing both the urgent and long-term challenges facing 21st century societies. Effective decisions rely on strong domestic and global public endorsements that motivate the active political support required to implement progressive policies.

2. Communication among scientific and policy communities requires significant improvement, especially concerning decisions on whether to embrace or reject the often transformational S&T opportunities continually emerging from the global research communities. Effective decisions are facilitated in venues where the advantages and risks of credible S&T options are candidly presented and critically debated among

internationally distinguished subject-matter experts, policy makers, and private sector and community stakeholders.

Historical perspective

The dramatic and rapid expansion of academic and private sector scientific research transformed many societies of the 20th century and is a major factor in the emergence of the more affluent countries that currently dominate the global economic and security landscape. The positive influence of these S&T achievements has been extremely impressive and in many ways the hallmark of the 20th century. However, there have also been numerous negative consequences, some immediately apparent and others appearing only recently. From both perspectives, it would be difficult to argue that S&T has not been the prime factor defining the societies we know today. Indeed, the 20th century can be viewed through the prism of how societies decided to use the available scientific understanding and technological expertise to structure themselves. Such decisions helped shape the respective economic models, cultural priorities, and security commitments in these societies.

It remains to be seen how the prosperity and security of 21st century societies will be shaped by the decisions made by our current leaders, especially with respect to how these decisions reflect sound S&T understanding.

Given the critical importance of properly incorporating scientifically credible information into major societal decisions, it is surprising that the process by which this is achieved by the public and its political leadership has been uneven and, occasionally, haphazard. In the worst cases, decisions have been based on unrecognized misunderstanding, overhyped optimism, and/or limited respect for potentially negative consequences. Retrospectively, while some of these outcomes may be attributed to politically motivated priorities, the inability of S&T experts to accurately communicate the advantages and potential risks of a given option must also be acknowledged as equally important.

The new format pioneered by the ISGP in its programs seeks to facilitate candid communication between scientific and policy communities in ways that complement and support the efforts of others.

It is important to recognize that policy makers routinely seek a degree of certainty in evaluating S&T-based options that is inconsistent with reality, while S&T experts often overvalue the potentially positive aspects of their proposals. Finite uncertainty is always part of advanced scientific thinking and all possible positive outcomes in S&T proposals are rarely realized. Both points need to be reflected in policy decisions. Eventually, the public needs to be given a frank, accurate assessment of the potential advantages and foreseeable disadvantages associated with these decisions. Such disclosures are essential to obtain the broad public support required to effectively implement any major decision.

ISGP conference structure

At each ISGP conference, internationally recognized, subject-matter experts are invited to prepare concise (three pages) policy position papers. For the October 5–8, 2014 ISGP conference in Ithaca, these papers described the authors' views on current realities, scientifically credible opportunities and associated risks, and policy issues concerning Food and the Environment. The eight authors were chosen to represent a broad cross section of viewpoints and international perspectives. Several weeks before the conference convened, these policy position papers were distributed to representatives from governments, societal organizations, and international organizations engaged with the ISGP at this conference (the United States, Canada, the United Kingdom, Costa Rica, Italy, Chile, and South Africa). Individuals from several private sector and philanthropic organizations also were invited to participate and therefore, received the papers. All participants have responsibilities and/or make major contributions to the formulation and implementation of domestic and international policies related to Food and the Environment.

The conference agenda was comprised of eight 90-minute sessions, each of which was devoted to a debate of a given policy position paper. To encourage frank discussions and critical debates, all ISGP conferences are conducted under the Chatham House Rule (i.e., all the information can be used freely, but there can be no attribution of any remark to any participant outside the conference setting). In each session, the author was given 5 minutes to summarize his or her views while the remaining 85 minutes were opened to all participants, including other authors, for questions, comments, and debate. The focus was on obtaining clarity of understanding among the nonspecialists and identifying areas of consensus and actionable policy decisions supported by scientifically credible information.

The not-for-attribution summaries of the debates, prepared by the ISGP staff from notes and recordings, are presented here immediately following each policy position paper. These summaries represent the ISGP's best effort to accurately capture the comments and questions made by the participants, including the other authors, as well as those responses made by the author of the paper. The summaries are, and should be read as, an overview of the areas of agreement and disagreement that emerged from all those participating in the debates.

Following the eight debates, small groups representing a cross section of the participants caucused to identify areas of consensus and actionable next steps to be considered within government, the private sector, and civil society. Subsequently, a plenary caucus was convened for all participants. While the debates focused on specific issues and recommendations raised in each policy position paper, the caucuses focused on overarching views and practical conclusions having policy relevance both domestically and internationally.

Concluding remarks

ISGP conferences are designed to provide new and unusual (perhaps unique) environments that facilitate and encourage candid debate of the credible S&T options vital to successfully address many of the most significant challenges facing 21st century societies. ISGP debates test the views of subject-matter experts through critical questions and comments from an international group of decision makers committed to finding effective, real-world solutions. Obviously, ISGP conferences build on the authoritative reports and expertise expressed by many domestic and international organizations already actively devoted to this task. As a not-for-profit organization, the ISGP has no opinions nor does it lobby for any issue except rational thinking. Members of the ISGP staff do not express any independent views on these topics. Rather, ISGP programs focus on fostering environments that can significantly improve the communication of ideas and recommendations and are designed to help ensure that S&T understanding is integrated into those real-world policy decisions needed to foster safer and more prosperous 21st century societies.

Conference conclusions

Area of Consensus 1

To provide the world's population with access to dependable, safe, and adequate sources of nutritious food, it is critical to adopt a more comprehensive systems approach to food security, both domestically and internationally. A comprehensive food system needs to link agricultural, natural, social, health, and nutrition sciences to ensure food security using sustainable and environmentally sound methods and policies.

Actionable Next Steps

- Expand the capacity of governmental, private, and intergovernmental financial institutions to collaborate from the earliest stages in the development of systems that give priority to food security based on considerations of economic and environmental factors, as well as land resources.
- Support investments in human capital that align public policies, programs, and agricultural, economic, health, and environmental systems under a single overarching scientific framework.
- Leverage existing and new technologies for enhanced detection and response to food safety risks along local, regional, and global food supply chains
- Incentivize science- and community-based strategies for diversification of farming systems to provide dependable access to nutritious food.
- Establish land and water use policies that ensure adequate supply resources for food production.

Area of Consensus 2

Developing and implementing a coherent nutritional and diversified food system to combat malnutrition (i.e., under and over consumption) is a critical global priority to ensure a healthy population, promote healthy ecosystems and physical environments, and promote safe and prosperous societies.

Actionable Next Steps

- Re-evaluate motivations for governmental subsidies by giving priority to fostering nutritionally rich crops.
- Refine research on micro and macronutrients with relation to their influence on health, based on scientifically informed dietary-intake recommendations.
- Promote the consumption of under-utilized crops and other food sources by adopting conventional and emerging technologies for diverse and high-nutrition food supplies.

Area of Consensus 3

To accurately understand and address the challenges and potential benefits associated with food security (e.g., food and water safety, soil health, water quality), it is essential to cooperatively engage, educate, train, and build collaboration among a broad range of communities, food producers, and scientists to accurately reflect their diverse perspectives and cultural values.

Actionable Next Steps

- Engage the public in transparent, evidence-based dialogues concerning the advantages and potential risks of technology to build the trust required to effectively enhance food security.
- Employ communication experts to engage and inform stakeholders regarding the consequences of consumption choices in an effort to enhance public understanding and promote behavioral changes related to healthy and sustainable food choices and the preparation of nutritious food.
- Incentivize integrated interdisciplinary research, extension, and teaching in the public and private sectors.
- Focus on the next generation of farmers, scientists, and entrepreneurs by publicizing the value and career-advancement opportunities of farming.

Area of Consensus 4

Advances in emerging science and technology, and scaling of existing S&T such as biotechnology, information technologies, and engineering, are essential to the establishment of safe and sustainable food and agricultural systems.

Actionable Next Steps

- Provide transparent and participatory dialogues among stakeholders to discuss potential solutions to societal concerns regarding the potential advantages and risks of genetically modified organisms (GMOs).
- Promulgate enforceable biosafety acts to facilitate the application of food and agricultural biotechnology.
- Focus on emerging research supporting sustainable food systems, including issues associated with the microbiomes, epigenetics, and ingestive behavior.

Area of Consensus 5

Establishing equitable and enforceable property rights regimes for land and natural resources focused on advancing food security, prosperity in farming communities, and environmental protection are essential steps for sustainable agriculture.

Actionable Next Steps

- Create transparent, enforceable land acquisition and ownership laws and regulations on national and local levels that foster effective management of agricultural/horticultural development while respecting the property rights of underrepresented people (e.g., women and minority groups).
- Enact and support transparent and accountable transnational codes of conduct for responsible investment in natural resources (e.g., the voluntary Principles for Responsible Investment in Agriculture and Food Systems).

Area of Consensus 6

Since risk management depends on the availability of validated metrics, the effectiveness and resiliency of the methods used to manage threats to the food system (e.g., severe weather, market instability, war, and communicable diseases) requires that better metrics be developed that capture the relationship between food safety and security and the political and natural environments (e.g., water availability, land tenure, energy usage, and carbon fluxes).

Actionable Next Steps

- Develop practical science-based metrics to evaluate the economic, social, and environmental externalities of food production (i.e., the "true cost of food") and assess the associated trade implications.

- Employ evidence-based criteria to formulate risk-mitigation strategies related to food safety, biotechnology implementation, and physical and market infrastructure.
- Invest in developing climate change adaptation strategies for all food system stakeholders (e.g., producers, distributors, and retailers).
- Create and support cost-effective financial systems (e.g., credit, insurance, and safety nets) to mitigate risk and facilitate investments, especially in rural and lower-income areas.
- Invest in early-warning systems and sentinel sites to promote timely and cost-effective disaster response.

ISGP conference program

<u>**Sunday, Oct. 5**</u>

15:00 – 17:00	**Registration: Statler Hotel**
16:00 – 16:30	**Conference Meeting: Science Presenters**
16:30 – 17:30	**Caucus Meeting: All presenters and participants**
17:30 – 18:30	*Reception* ***Welcoming Remarks*** **Dr. George Atkinson**, Founder and Executive Director, Institute on Science for Global Policy (ISGP) and **Dr. Kathryn Boor**, Dean of the College of Agriculture and Life Sciences, Cornell University,
18:30 – 20:00	*Dinner*
20:00 – 20:30	**Keynote speaker** **"Can We Build Food Systems That Are Climate-Smart Enough?"** **Dr. David Wolfe**, Professor of Plant and Soil Ecology, Department of Horticulture; Faculty Fellow at the Atkinson Center for a Sustainable Future, Cornell University, Ithaca, New York

<u>**Monday, Oct. 6**</u>

08:00 – 08:45	*Breakfast*

Presentations and Debates: Session 1

09:00 – 10:30	**Prof. Christopher Barrett, Charles H. Dyson School of Applied Economics and Management, Cornell University, United States** *Building Resilience for Global Food Security*
10:30 – 11:00	*Break*
11:00 – 12:30	**Dr. John Ingram, Environmental Change Institute, University of Oxford, United Kingdom** *Food Systems and Environmental Change: Navigating the Two-way Street*

12:30 – 13:45	*Lunch* **Speaker** **"Cornell University's College of Agriculture and Life Sciences: Delivering our Land-Grant Mission in an Ivy League Setting"** **Dr. Kathryn Boor**, Dean of the College of Agriculture and Life Sciences, Cornell University

Presentations and Debates: Session 2

14:00 – 15:30	**Prof. Wendy Wolford, Atkinson Center for a Sustainable Future, Cornell University, United States** *Competing for Land: Future Trajectories for Rural Development*
15:30 – 16:00	*Break*
16:00 – 17:30	**Prof. Jennifer Ann Thomson, University of Cape Town, South Africa** *Adopting Genetically Modified Crops Worldwide for Food Security*
17:50 – 18:45	*Reception at Johnson Museum of Art*
19:00 – 20:15	*Dinner*
20:15 – 20:45	**Keynote speaker** **"Elevating the Global Priority of Food and Nutrition Security through Feed the Future and the New Alliance"** **Dr. Julie Howard**, former Chief Scientist, Bureau for Food Security, USAID, and Senior Adviser to the Administration for Agricultural Research, Extension, and Education, Washington, D.C.

Tuesday, Oct. 7

08:00 – 08:45	*Breakfast*

Presentations and Debates: Session 3

09:00 – 10:30	**Dr. Don Stoeckel, Battelle Memorial Institute, United States** *Zero Tolerance is a Bad Strategy to Protect Food Safety*
10:30 – 11:00	*Break*

11:00 – 12:30	**Prof. Kalidas Shetty, Global Institute of Food Security & International Agriculture, North Dakota State University, United States** *Systems Solutions to Global Food Security Challenges to Advance Human Health and Global Environment Based on Diverse Food Ecology*
12:30 – 13:45	*Lunch*

Presentations and Debates: Session 4

14:00 – 15:30	**Dr. Jeffrey B. Blumberg, Friedman School of Nutrition Science and Policy and Jean Mayer USDA Human Nutrition Research Center on Aging, Tufts University, United States** *Ensuring Food and Nutrition Security through Changes in Food Development, Processing, and Culture*
15:30 – 16:00	*Break*
16:00 – 17:30	**Dr. Michael W. Hamm, Center for Regional Food Systems, Michigan State University, United States** *Regionalized Food Systems: Improving Resilience in the Face of Uncertainty*
18:00 – 22:00	**Focused group sessions**

Wednesday, Oct. 8

08:00 – 08:45	*Breakfast*
09:00 – 12:10	**Plenary Caucus Session** Dr. George Atkinson, ISGP Founder and Executive Director, and Dr. Sweta Chakraborty, ISGP Senior Fellow, *moderators*
12:10 – 12:30	**Closing Remarks** Dr. George Atkinson, ISGP Founder and Executive Director
12:30 – 13:30	*Lunch*
13:30	*Adjournment*

Building Resilience for Global Food Security**

Christopher B. Barrett, Ph.D.
Stephen B. & Janice G. Ashley Professor and David J. Nolan Director,
Charles H. Dyson School of Applied Economics and Management,
Cornell University, Ithaca, New York, U.S.

Summary

Many of the world's chronically poor and malnourished people live in increasingly volatile settings. Although most of the world has enjoyed unprecedented progress against poverty and food insecurity, the dangerous interface of climate change, demographic transition, conflict, and food-price spikes has already pushed several poor regions into permanent crisis. Festering crises in these regions are increasingly becoming crucibles in which broader societal insecurity erupts. This disturbing state of affairs, along with our expanded knowledge of the intimate interactions between short-term shocks and long-term development, has sparked widespread interest in "building resilience," meaning the capacity to resist and recover from both natural and man-made disasters. While resilience offers a very promising lens through which to strategically address global food security issues, the concept remains ill-defined and its implications for science and policy under-developed. How might the global policy and science communities effectively deploy an emerging resilience framework to overcome these challenges?

Current realities

The world has never enjoyed greater food security than it does today; but it has perhaps also never faced greater threat of regress. Over the coming decades, the prospective stressors on food security in developing countries are many (e.g., political instability, market volatility, demographic change, and climate and environmental change), with tremendous variation worldwide as to which has the greatest local relevance. Moreover, micronutrient deficiencies have replaced protein/energy malnutrition as the predominant source of global food insecurity. Many scientists and policymakers have been slow to transition from the Green Revolution era mindset of maximizing cereals yields to food systems-based approaches that focus on a more diverse range of agricultural products, as well as on post-harvest processing and distribution channels. Population and income growth, plus urbanization, imply that food security increasingly depends on post-harvest distribution and processing systems, not just on agricultural production. Meanwhile, heightened challenges of managing common resources, such as climate and ocean fisheries, make the task of productivity growth harder today than 40 years ago, when global leaders last collectively addressed food security issues. Growing competition for scarce natural resources, in particular fertile soils and fresh water, will constrain agricultural production growth and raise tensions. This competition places an ever-greater premium on technological change, some of which are highly controversial, such as transgenic crop and livestock varieties. Public policy responses related to intellectual property rights, migration, trade, and humanitarian relief, among other things, not only affect the food security of target populations, but also require coordination to avert adverse spillover effects on others' food security.

As the risks faced by the world's poor seem to have become more intense and less predictable, many international organizations' strategic responses have concentrated on "building resilience" so as to enhance resistance to and recovery from natural and man-made disasters while advancing environmentally and socioeconomically sustainable improvements in living standards. But what is resilience and how do we most effectively advance it for food security?

Scientific opportunities and challenges

Resilience has become a popular but imprecise buzzword in international development circles. Scientists can help by imposing greater precision in the use, measurement, and evaluation of the concept, as well as by prioritizing research based on resilience metrics that require further development. In the international development context, resilience is best understood as describing the well-being dynamics of individuals and populations, in particular, the capacity to avoid poverty and food insecurity in the face of stressors and shocks. Resilience offers the promise of a coherent, multidisciplinary approach to identifying how to most effectively help vulnerable populations gain control over their lives, as well as to identify which interventions most sustainably reduce the likelihood of people not having adequate access to sufficient, safe, nutritious food to maintain an active healthy life. But resilience also poses a scientific challenge because of the complexity of resilience measurement, which remains a work in progress.

Scientific advances throughout food systems will be essential to improve global food security. Advances in our knowledge of animal and plant genetics, as well as in soils and pest management, will be essential to build resistance to stresses such as drought, flood, salt, and evolving pests and pathogens as well as to increase availability and access to scarce vitamins and minerals. Engineering advances in water conservation and distribution grow more urgent in the face of climate change and rapidly expanding non-agricultural demand. Advances in post-harvest preservation and processing, as well as in our understanding of human nutrition, are needed to increase the bioavailability of essential minerals and vitamins as food consumption and production become more separated in space and time. Management and social sciences advances are likewise needed to overcome market and non-market institutional failures that impede the flow of healthy food among people and over time, as well as to improve eating behaviors. The potential financial, humanitarian, scientific, and social returns are huge.

But obstacles are legion as well. In particular, intellectual property regimes are increasingly burdensome to navigate, especially for smaller organizations. Short-term interests in decision-making, not only among elected leaders and publicly listed firms, but increasingly also among philanthropies, biases investments towards often-illusory "quick fixes" and away from necessary long-term financing of research and development, infrastructure, and education. Meanwhile, the generation-long decline of scientific capacity in the world's most vulnerable and ultra-poor region, sub-Saharan Africa, poses special challenges for the development of context-appropriate, science-based solutions to address the most vexing cases of food insecurity.

Policy issues

The Barrett and Constas (2014) framework for conceptualizing development resilience highlights three broad classes of enhanced food security interventions to build productive assets, reduce downside asset risk, and induce technological and institutional innovations designed to change behaviors that eliminate poverty traps. Building resilience for global food security will require both public and private-sector actions, with priorities necessarily varying according to context.

Government and international organization (e.g., United Nations World Food Programme [WFP] and Food and Agriculture Organization [FAO], World Bank) priorities include:

- Provide effective safety nets: Employment guarantee schemes, conditional cash transfer programs, and food assistance programs protect vulnerable peoples from catastrophic losses, while encouraging investment and productive risk-taking necessary for innovation and economic growth. These are the domain of national governments, but the most vulnerable places require coordinated international support. The UN, led by WFP, must build a multicountry system of long-term sentinel sites in the most vulnerable countries so as to improve early warning systems and evaluation platforms for safety.

- Re-invest in building agricultural scientific capacity in sub-Saharan Africa and south and central Asia: Roughly 90% of the food is consumed in the country in which it was grown because low value-to-weight and perishability make foods inherently local commodities. Agroecological variability requires extensive adaptation of technologies just as variation in sociopolitical institutions requires adaptation of policy prescriptions. Effective adaptation is impossible without building and maintaining adequate local scientific capacity.
- Reduce trade barriers: trade remains the most effective means of transferring food price and availability risk. Negotiators need to adapt the World Trade Organization's (WTO) latest round of trade negotiations (WTO Doha Round), launched in an era of historically low food prices, to the new high global food price regime. More effective agreements are also needed to manage global common pool resources (e.g., climate change mitigation and adaptation efforts, trans-boundary water and fisheries management). Australia's recent abandonment of carbon taxes is a warning sign of what is to come if China, the United States, and the European Union do not begin to cap emissions.
- Explore innovations in intellectual property rights. For example, convertible patent coverage to incentivize innovations of exceptional societal value for which there is scant commercial market (e.g., vaccines for tropical diseases, improved varieties of "orphan" crops).

While public policy is crucial, the private sector's role is large and especially needed to develop:

- Improved animal and crop genetic material for drought, flood, and pest resistance, and cost-effective means of enhancing and preserving micronutrients in food processing and distribution systems. Life sciences and food industries can profit from this, especially with reforms to intellectual property regimes and philanthropy-funded prizes to ensure a commercial market for discoveries targeted at poor populations' needs.
- Financial innovations for enterprise and employment growth. Financial innovations in impact investing, microequity, index insurance, catastrophe bonds, and other creative approaches are needed to induce debt and equity investment and to insure productivity-enhancing private investment in Africa and Asia. Index-based livestock insurance (http://livestockinsurance.wordpress.com/) demonstrates viability and impact.

- Cost-effective delivery of maternal and child health. Improved vaccine and micronutrient supplement delivery systems are needed to reduce disruptions to essential nutrient absorption during the crucial "first 1000 days" from conception through a child's second birthday.
- Cost-effective information delivery. Mobile information and communications technologies (ICT) can promote uptake of new technologies, labor mobility, and access to finance and markets. Invest in expanding ICT networks that, like Safaricom in Kenya, provide effective platforms for extension, education and financial services to reach poor, remote populations.

References

Barrett, C.B., ed. (2013). *Food Security and Sociopolitical Stability*. Oxford: Oxford University Press.

Barrett, C.B., & Constas, M. (2014). Toward A Theory of Resilience for International Development Applications. *Proceedings of the National Academy of Sciences,* in review.

Barrett, C.B., & Headey, D. (2014). Measuring Resilience in a Volatile World: A proposal for a multi-country system of sentinel sites. 2020 Conference Paper 1, International Food Policy Research Institute (IFPRI) Washington, D.C.

** ***A policy position paper prepared for presentation at the conference on Food Safety, Security and Defense: Focus on Food and the Environment, convened by the Institute on Science for Global Policy (ISGP), on October 5–8, 2014 at Cornell University, Ithaca, New York, U.S.***

Debate Summary

The following summary is based on notes recorded by the ISGP staff during the not-for-attribution debate of the policy position paper prepared by Dr. Christopher Barrett (see above). Dr. Barrett initiated the debate with a 5-minute statement of his views and then actively engaged the conference participants, including other authors, throughout the remainder of the 90-minute period. This Debate Summary represents the ISGP's best effort to accurately capture the comments offered and questions posed by all participants, as well as those responses made by Dr. Barrett. Given the not-for-attribution format of the debate, the views comprising this summary do not necessarily represent the views of Dr.

Barrett, as evidenced by his policy position paper. Rather, it is, and should be read as, an overview of the areas of agreement and disagreement that emerged from all those participating in the critical debate.

Debate conclusions

- Risk management is central to food security and although great progress has been made in enhancing global food security, it is now necessary to concentrate on nutritional security, especially for women and children. Women of child-bearing age must be properly nourished to bear healthy babies and children must have proper nourishment to become productive adults.
- Insurance in various forms must be greatly expanded to play a major role in food resilience. Uptake of new technologies that enhance food security and education of food producers regarding best practices are essential if insurance is to be a viable option.
- New varieties of crops must be developed that are resilient to disease and changing climate conditions (e.g., higher incidence of drought). Risk to food security from weather, disease, and other forms of loss must be managed if crops are to provide substance, especially to the rural population.
- To provide early warnings of food crises, multicountry sentinel systems are critically needed. To be effective, these systems require (i) the identification of feasible early-warning indicators, (ii) improved coordination and data-gathering capacity in under-developed areas, and (iii) the development of follow-up strategies that focus on human-welfare indicators such as nutrition and income.

Current realities

Global food security has seen significant progress over the past century. There has been a precipitous fall in the number of people worldwide who are chronically poor and food insecure during the past 40 years. Although the problem of food insecurity has not been solved, the rate of people who are undernourished has fallen by approximately 50% in the last 20 years.

There has been increasing recognition that the definition of food security based on caloric intake is insufficient because it ignores the necessity of vitamins and minerals, as well as micronutrients, as essential components of human health. Micronutrient deficiency affects a far larger population than does protein-energy malnutrition. For example, women who are iron-deficient suffer from anemia, children who lack vitamin A can go blind, and people who have an iodine and selenium deficiencies can suffer from irreversible stunted cognitive and physical growth. While these individuals may receive adequate calories, they are permanently cognitively and physically impaired by their vitamin or mineral deficiencies.

Height-age measurements are a good indicator of long-term nutrient deprivations, as well as a good measure of food security. Children who are not receiving enough energy protein and essential micronutrients are stunted in their growth, which can lead to future disadvantages (e.g., income losses, less likely to go to school, more likely to drop out of school before they complete secondary education). For women, body mass indices likewise are relatively good indicators of food security.

Access to insurance is a major component of food resilience. Households in Africa that held water-indexed insurance during the 2011 drought were two-thirds less likely to have had a distressed sale of livestock. Most agricultural insurance is heavily subsidized by governments and it was suggested that insurance subsidies benefit households more than cash handouts. Investments need to be made to achieve a better understanding of resilience and risk in humanitarian settings and in protracted crises, in which there is a luxury of time to understand all the variables affecting food security and risk strategies. The various resilience strategies currently being practiced by local populations also must be understood.

Resilience, particularly with respect to food security, has four components: (i) the technology of production, (ii) the farm-to-plate value-added component, (iii) international trade, and (iv) the political economy or the policy sphere. Because there is a trend toward urbanization as a result of economic development, there is a need to incentivize an agricultural industry to retain the most skilled and ambitious producers. Many leave the farm industry because it is difficult work and it is sufficiently less remunerative in developing countries than non-farm work. Individuals seldom choose to stay in farming unless they inherit an unusually productive operation. Those who remain in the industry need to be equipped with the best available technologies to help ensure growth in production and retention of well-trained, productive farmers. There is growing evidence that poverty is more effectively reduced through migration to rural towns than through migration to cities.

Scientific opportunities and challenges

While insurance involves transferring risk, overall risk reduction is complementary to, and as important as, insurance. It was suggested that transgenic crops, which are resistant to a variety of biotic and abiotic threats, and improved irrigation are necessary to reduce overall risk. Water management was suggested as the primary way to reduce risk due to weather fluctuations, especially for crop and livestock producers in Africa. While the use of new and/or modern technologies is absolutely essential if insurance is to be feasible, the uptake of technologies that may reduce risk remains very limited. Although insurance does not remove all risk associated with livestock mortality and crop loss, it increases producers' investment in the use of veterinary drugs because producers are more confident they can maintain a herd by reducing exposure to disease.

Risk must be managed if insurance is to be an effective tool to increase food security. To prevent crop losses, new technologies are needed and must be delivered to developing countries, especially small-holder women farmers, who are growing many of the crops in Africa. Because there is a lack of extension services in many developing countries, programs are needed to teach farmers how to prevent losses, which is the first step to making crop insurance feasible.

It was generally agreed that there is a need for multicountry systems to provide early warnings of crisis. Early-warning network systems in developing countries can be challenging to develop when governments lack funding, political structure, and effective data-gathering capacity. If such a system is to be constructed, it is necessary to determine feasible indicators. Following human-welfare indicators is effective, including evaluating the nutritional status of children, and income and the productive asset holdings of families that will enable them to achieve good livelihoods in the future.

There was consensus that one of the central tasks to combat current food insecurity is accelerating the development and distribution of food products that can be used to address serious deficiencies. While low caloric intake is an indicator of food insecurity, deficiencies in minerals and vitamins also are factors. Although biofortification of food products can effectively address deficiencies in minerals and vitamins, it is often impeded by intellectual property. An example was the creation of "golden rice" that contains beta-carotene, from which human bodies create vitamin A; deficiency of vitamin A can cause blindness. Although created 14 years ago, golden rice is not commercially distributed because of social opposition (e.g., field trials of golden rice in the Philippines have been destroyed by activists opposed to genetically modified [GM] foods). Rice is the most consumed product in the world and especially the most consumed staple by the world's poorest people in rural areas of Asia.

It was questioned whether it is possible to build a simulation model for resilience. There has been careful modeling of the relationship between various vegetative coverings, data that the National Oceanic and Atmospheric Agency (NOAA) generates regularly from satellite platforms and longitudinal herd history data. Currently, modeling is localized to one region and can predict crop yields with about a 92% accuracy rate. There currently is not enough data to indicate whether the dynamics of households' responses to index insurance can be accurately modeled. Scientists always want more information to improve certainty. To address this issue, the capacity for leveraging existing information, rather than collating new data, needs to be investigated.

Policy Issues

Collaboration among large corporations, NGOs, and national governments needs to be strengthened and incentives for corporations need to be expanded. Once there is enough private sector support for relaxing intellectual property, more progress can be made in developing countries. For example, in the 2011 Horn of Africa drought, there was collaboration between regional governments and the African Union. To ensure that private citizens, NGOs, and governments build institutional capacity, a group of national governments and/or international agencies must partner to coordinate information and logistics and develop simple educational tools.

A prerequisite, if not a foundation, for a rational model of resilience is political stability. An extensive distribution network also is necessary to mitigate risks, so if there is localized drought, the supply chain that includes numerous regions can compensate, improving regional food security. Without these two components — a sensible distribution network and political stability — insurance companies likely would be unwilling to underwrite insurance that would effectively limit food insecurity.

Investments to build agricultural scientific capacity in sub-Saharan Africa are needed. Governments must take the lead on this topic. While some African governments send students to different universities (many in South Africa) to earn doctorates, those governments often do not provide support when the students return to their home countries. Often students return to their home countries excited about their agricultural research but the local senior professors see the students as threats and as a result these bright students stagnate both professionally and scientifically. It is necessary to have Africa supporting African agriculture research.

Questions were raised about recovery after a drought and building an information system modeled after the famine early-warning system. The private sector must be encouraged to invest in monitoring systems for sentinel sites and in a suite of monitoring systems that are productive for a public/private partnership.

Work is ongoing with local cell phone providers in which publicly sourced, remotely sensed data on current conditions are received and processed for delivery to farmers. The cell phone is used by pastoralists to determine areas of unrest to be avoided or to ascertain current livestock prices. One question that needs to be answered is whether farmers and pastoralists will pay for information, or at least trade for information about current conditions. For example, herders provide simple reporting on vegetation species available and growth densities that could be collected from a variety of sources and returned to them as informational maps. Some of these sorts of innovations already have been happening because of individual initiatives encouraged by cell phone firms and supported by a variety of NGOs and government agencies.

Food Systems and Environmental Change: Navigating the Two-way Street**

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Summary

While advances in food production have largely kept pace with demand on a global basis, nearly 1 billion people are hungry, and about 2 billion more lack sufficient nutrients. Paradoxically, more than 2 billion are overweight or obese. Meanwhile, current methods of producing, processing, packaging, transporting, retailing, and consuming food are significantly contributing to degrading the natural resource base upon which our food security depends. Food system outcomes related to both food security and environment are currently significantly suboptimal. A host of research opportunities spanning the whole food system exists to address this situation, balancing the traditional "production" viewpoint with a stronger "consumption" viewpoint.

The ultimate goal is resource-efficient food systems. Intermediate goals are improving input use efficiency (from the production side), and reducing food waste (from the consumption side). Key research areas span technical, institutional and behavioral domains, and the full set of food system stakeholders (policy, business, civil society, and researchers) need to be engaged to ensure research outputs are appropriate and viable.

A food systems approach promotes innovative research and policy agendas by (i) systematically relating the full set of food system activities to their food security and environment outcomes; (ii) raising awareness of the potential unintended consequences of policy and/or practice interventions aimed at enhancing food system outcomes; and (iii) allowing for a systematic analysis of synergies and tradeoffs between potential winning and losing strategies. The foods system approach thereby helps to navigate the food security/environment "two-way street."

Current realities

Food production has historically outpaced food demand on a global basis, although the rate of increase is now slowing and there are marked regional differences. The problems of lack of calories and inadequate nutrition for billions of people are essentially due to lack of access to an adequate, balanced diet. For most, this inaccessibility is primarily caused by inequity and poverty; food affordability is central to food security. Paradoxically, because of a set of economic, cultural, and behavioral issues, more than 2 billion people are overweight or obese. Recent trends in incomes and food marketing, and hence diets, coupled with other lifestyle changes, indicate this number will grow substantially in coming decades.

Meanwhile, current activities related to producing food are already seriously undermining the natural resource base upon which our food security depends. For example, agriculture and fisheries account for more than 20% of greenhouse gas emissions; about 25% of global land area is degraded, largely due to food production, and about 75% of fresh water extraction is for irrigation; and about 70% of fish stocks are either fully or over exploited, or depleted.

The production of food is, however, just part of the food sector. Other food system activities (i.e. processing, packaging, transporting, retailing, and preparing food, collectively the food chain) also all have a significant environmental footprint. For example, about 40% of U.S. and 60% of U.K. food-related greenhouse gas emissions originate from post-farm activities; food processing accounts for 5% to 10% of industrial water use, and food processing effluent often pollutes water courses; and about 8% of aluminum is used in food and drink packaging.

There are growing concerns regarding increases in food demand, the threats of climate change undermining food production, and the impacts of land and marine management aimed at producing food on biodiversity and ecosystem functioning. This means that interactions between food security and environment are now center stage.

Scientific opportunities and challenges

The summary statistics above demonstrate that the food security/environmental issues are not only about food production, but relate to how the food system as a whole operates. Food systems include the full set of activities from "plough to plate": (i) producing food; (ii) processing food; (iii) packaging and distributing food; and (iv) retailing and consuming food. A full food system approach also includes the outcomes of these activities for (i) food and nutrition security, including access to, and utilization of food, in addition to food availability; (ii) other socioeconomic outcomes (e.g., employment and wealth); and (iii) the environment (Figure 1).

There is an urgent need to improve food systems to (i) enhance food security (and health) outcomes, (ii) improve their efficiency, and (iii) reduce their environmental impacts. Reducing food waste, which occurs in all food system activities, would help achieve all three. Adopting a food systems research approach helps to identify a host of scientific opportunities and challenges spanning all food system activities and outcomes, and helps to build a comprehensive understanding of system drivers and feedbacks (Figure 2). Research falls into three general categories: technical, institutional, and behavioral.

Technical research opportunities relate to (i) reducing the "yield gap" for many cropping systems by both reducing biotic and abiotic yield reducing factors and improving nutrient and water use efficiency to raise attainable yields; (ii) developing cultivars with enhanced nutrient profiles to help address hidden hunger; (iii) maintaining food safety and taste while reducing salt, fat, and sugar contents; and (iv) enhancing, and rapidly and accurately preventing, detecting, and controlling novel, emerging, and re-emerging pathogens to enhance food safety.

Institutional research opportunities relate to (i) reducing barriers to uptake of innovative technologies; (ii) understanding governance arrangements within and among the wide array of state and nonstate food system actors; (iii) reversing policies promoting the use for human-edible food being used for industrial and biofuels; (iv) enhancing intraregional trade; and (v) enhancing strategic food reserves.

Behavioral research opportunities relate to (i) overcoming resistance to innovative technologies (e.g., new cultivars, genomics, and genetic modification); (ii) reducing food waste by reducing both the "buy and bin" phenomenon and excess consumption in more affluent societies; (iii) increasing acceptability of novel foods (i.e., derived from algae and insects); (iv) awareness among consumers of balanced social, economic, and environmental sustainability issues; and (v) reducing "prophylactic" use of herbicides and pesticides in arable systems, and antibiotics in intensive animal systems, both of which lead to resistance build-up.

An overriding research challenge lies in developing frameworks and tools to assess the synergies and trade-offs among different societal goals of implementing the results of such research opportunities. Policy makers need to be able to gauge the impacts on both winners and losers of any technical, institutional, or behavioral change. As food is largely being produced, processed, distributed, and sold by private actors, ranging from smallholder farms to large food and retail companies, engaging private actors is crucial in the transition towards more sustainable food systems.

Policy issues

Food system activities are contributing significantly to environmental change. Environmental change is undermining the natural resource base upon which our food security depends, and will increasingly affect food supply, food quality, and food safety. Policies must be developed to help all food system stakeholders better navigate this two-way street so as to engender "resource-use efficient food systems."

Government policy makers need to build a more conducive "policy environment" to encourage technical, institutional, and behavioral changes aimed at enhancing food security while reducing negative environmental impacts. They also need to challenge the political lobby from vested interests for the status quo (e.g., biofuel quotas and trade tariffs).

Private sector actors need to increase their effort in assessing the resource-use efficiency of their activities. Many major food companies are already actively engaged in this as it makes good business sense: enhance the sustainability of the feedstock to ensure supply; enhance the sustainability of the customer base by promoting best practice.

Civil society needs to engage in the sustainability debate, including a more serious discussion about dietary change, through NGOs and social media. This will need encouragement from both industry and policy. Advertising, labelling, and peer pressure are key factors, and regulation (e.g. a fat tax) can also be an important driver of societal change.

Researchers need to develop better whole-system models of food systems that can be used to assess both the nutrition and environmental outcomes of given policy interventions. A wide range of stakeholders needs to be engaged to both determine information need and assess the usability of such a model(s).

In undertaking such work, all stakeholders need to recognize:

- the importance of nutrition, not just calorie, to reduce poor mental and physical development, especially in the population under the age of five;
- the increasing crisis of overconsumption, which has substantial negative economic, social, health, and environmental impacts;
- the increasing value addition in food chains, which is leading to more choice but at a higher price, and hence reducing affordability and thereby access to food for many;
- how urbanization is both lengthening food chains, and reducing the ratio of producers to consumers; and
- the value of urban horticulture (rather than agriculture) in enhancing nutrition, livelihoods, and waste recycling, and in reducing food losses of highly perishable produce in transport.

References

Ingram, JSI. 2011. A food systems approach to researching interactions between food security and global environmental change. *Food Security* 3, 417-431.

Ingram, JSI, H Wright, L. Foster, et al. 2013. Priority research questions for the UK food system. *Food Security* 5, 617-636.

Vermeulen SJ, BM Campbell and JSI Ingram. 2012. Climate change and food systems. *Annual Review of Environment and Resources* 37, 195-222.

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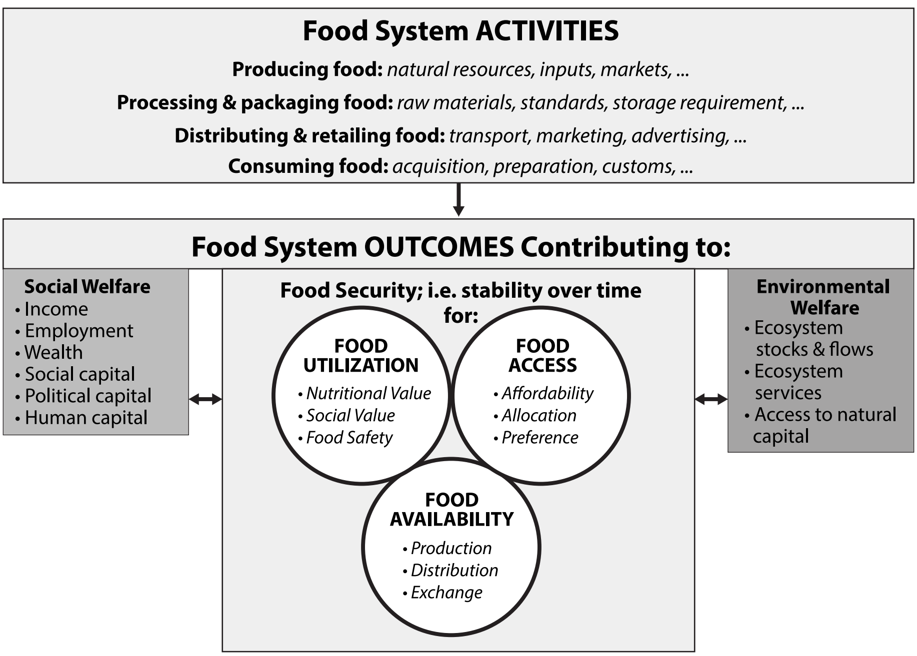

Figure 1 shows the range of food system *activities* (with example determinants); and their *outcomes* in relation to nine food security elements (conveyed in the bullet points in the circles), all of which underpin food security. All nine elements are derived from the FAO World Food Summit definition. Food system activities also have other socioeconomic and environmental outcomes (from Ingram, 2011).

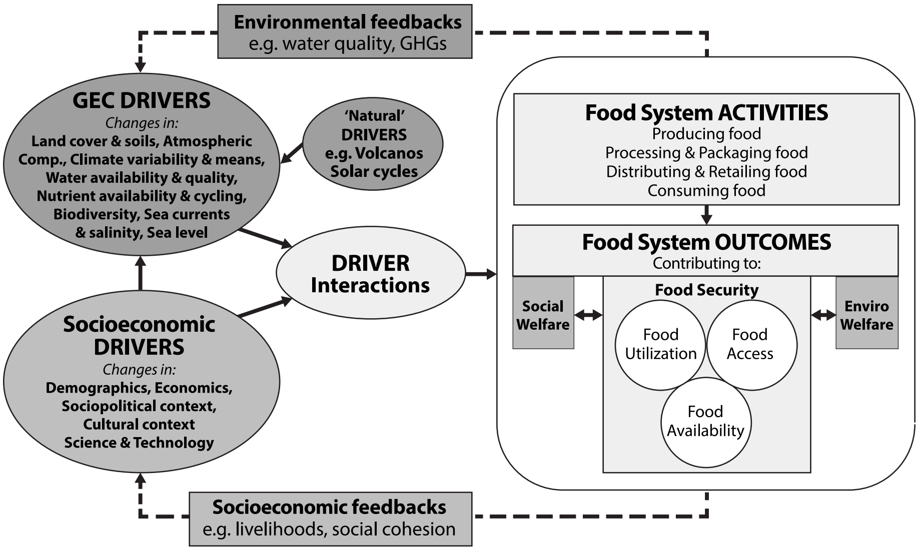

Figure 2 shows how socioeconomic and global environmental change (GEC) drivers interact to affect the food system activities and outcomes, and the feedbacks to these sets of drivers by current and adapted activities (from Ingram, 2011).

Debate Summary

The following summary is based on notes recorded by the ISGP staff during the not-for-attribution debate of the policy position paper prepared by Dr. John Ingram (see above). Dr. Ingram initiated the debate with a 5-minute statement of his views and then actively engaged the conference participants, including other authors, throughout the remainder of the 90-minute period. This Debate Summary represents the ISGP's best effort to accurately capture the comments offered and questions posed by all participants, as well as those responses made by Dr. Ingram. Given the not-for-attribution format of the debate, the views comprising this summary do not necessarily represent the views of Dr. Ingram, as evidenced by his policy position paper. Rather, it is, and should be read as, an overview of the areas of agreement and disagreement that emerged from all those participating in the critical debate.

Debate conclusions

- Although a food systems approach, which addresses the entirety of the food production system rather than discrete parts of it, holds promise for improving food security and environmental protection, this approach has not yet proven to be a practical guide for making decisions regarding priorities and allocation of resources.

- Sustainability of the global food system relies on independent and interrelated factors, such as environmental impact, energy use, the economic viability of business enterprises, affordability and access to nutritious food, and the ultimate health of the consumer.
- Addressing food system waste, environmental degradation, lack of nutritious foods, and over- and under-consumption will require consumer behavioral change and private and public investment, as well as societal willingness to be transparent about the effects of current consumer behavior on the environment and human health.
- The needs of the supply chain must be balanced against the needs of the customer base, even though there will be costs associated with doing so. Responsibility for a resource-efficient system lies with both businesses and consumers.
- A systems approach to food production can serve as a "map" showing linkages among the many interrelated parts of the system, enabling better technical, policy, and business interventions with fewer unintended consequences.

Current realities

It was generally agreed that a "systems" approach to food security and environmental protection is ideal for improving efficiency, sustainability, and access to the food production system. However, the systems approach has not yet proven that it can make a tangible difference in any of these factors.

A growing middle class is consuming an energy-dense diet that (i) is environmentally costly to produce in terms of waste and greenhouse gas emissions and (ii) can result in higher health care costs due to over-consumption of calories. Excess waste, environmental degradation, and lack of nutritious foods are significant problems within the system. In addition, environmental externalities (e.g., the costs associated with growing and producing food and subsequent effects on health) are not captured in the market price of "cheap" food.

Large corporations are increasingly motivated by the voice of the consumer to be more sustainable in their business practices, products, and services. Businesses and consumers are seeking guidelines and standards that will help them prioritize allocations of money and resources in which positive returns will be reflected. However, because of the complexity and interrelations of the food system, changes in one area are often found to cause unintended consequences in other areas.

There is substantial resistance to changes in the food system by producers, consumers, policymakers, and regulators. While creating value-added food involves extra expenditures and environmental costs, moving away from the existing model will require companies to forgo certain profit streams and consumers to abandon certain food preferences.

Most of the food safety risk in the supply chain emerges as a product moves through the value-added processes, which incorporate materials from a variety of countries into the final product. During these processes, material traceability can be difficult.

Innovative food production technologies (e.g., new farming techniques, genetically modified [GM] seeds) often are imposed on users instead of co-developed with them, leading to resistance to their use. The developers of new technologies naturally want to maintain control over their products, but farmers and others in the supply chain also want to maintain control over their livelihoods.

Finally, the food system is facing future challenges as well, such as an increasingly elderly population worldwide that will lead to fewer food producers, consumers with different dietary needs, and, most likely, higher food costs.

Scientific opportunities and challenges

A robust food system requires not only environmental sustainability, but economic, social (health), and energy sustainability. While sources of these factors are themselves independent, all become interconnected. Ultimately, improving the food system is going to require difficult decisions, such as appropriate pricing of water and carbon, and reducing waste and greenhouse gas emissions. These and other decisions will increase the price of food, change the types of foods available, and economically impact producers throughout the food supply chain. The overriding question: How can the efficiency of the food system be improved so that it produces better environmental and health outcomes while still providing employment, wealth, and equitable access to all participants?

Significant discussion centered on the need for recommended standards, priorities, and first steps for reforming the food system. While businesses may want to demonstrate greater environmental responsibility, guidance is needed regarding the best use of resources. There needs to be consensus as to a starting point and "the perfect should not be the enemy of the good." It was argued that such priorities and guidelines represent societal challenges that require conversations among all stakeholders. A food system approach can organize such conversations by serving as an analytical lens to look for synergies, and provide a checklist to ensure all relevant parties are involved in the discussion. In addition, it is important to identify the "control points," both physical and temporal, where decisions can be made that affect the entire food chain.

It was unclear whether a systems approach could help avoid unintended consequences when improvements are made to discrete areas (e.g., the dietary deviation from saturated fats in the middle of the last century led to greater use of margarine to improve heart health; when the health risks of trans fats in margarine became clear, a switch was made to palm oils; now palm oil production is leading to deforestation in some countries, as palm plantations replace tropical forests). However, it was generally agreed that scrutinizing the food system as a "map" could enable a better view of the linkages among parts of the system, indicating how technical, policy, and business interventions could address problems. At times, it could be beneficial to work around problems rather than addressing them directly, thereby accounting for the multiplicity of interrelated factors.

Behavioral change must be part of the solution and behavioral psychology must help improve message effectiveness. In addition, the media must be challenged to improve its reporting on the interrelated complexities of the food system and the need for dietary change. Creating behavioral change requires all stakeholders to cooperate, even while recognizing that there will be winners and losers as change occurs.

In the area of food safety, a food systems approach could address the problem of tracing ingredients by identifying accountability within the value-added chain, thereby enabling vigilance along the chain rather than only at the point of sale.

The application of innovative food-production technology also raises practical and moral societal questions: (i) who should control the usage of innovative technology? (ii) who should be in charge of and pay for research into new technologies or alternative crops, and (iii) what is the proper balance between public and private sector investment?

Although it was generally agreed demand exists for greater scientific capacity in specialty areas within the food system (e.g., more plant pathologists), it was argued that there also is a need for greater capacity in understanding the complexities of the food system, such as knowing where individual specialties fit into the system, and knowing how specialists can contribute their knowledge to the whole. The agricultural extension system could be one vehicle to accomplish such capacity building among all those involved in the food production chain.

Policy issues

The needs of the supply chain must be balanced against the demands of the customer base, even though there will be costs associated with doing so. Within this rebalancing, the overall economic viability of food system businesses must be maintained. Responsibility for a resource-efficient system lies with the private and public sectors, and with consumers.

Numerous strategies were suggested for improvement within the food system, including:

- preserving biodiversity (to prevent food insecurity),
- growing more nutritious foods,
- reducing water consumption,
- increasing transparency with regard to the carbon footprint of a food product,
- convincing consumers to reduce the over-consumption of calories,
- reducing waste at every step in the food chain, including through innovative,
- packaging (such as packages that show when a product is contaminated),
- certifying products as meeting an environmental standard,
- involving various affected communities (producers, manufacturers, consumers) in decision-making to resolve issues, rather than imposing new technologies.
- changing pricing practices to include environmental externalities that add to the cost of food production, and
- monitoring environmental impacts by introducing traceability into the food chain.

In addressing problems of access and affordability, policy must focus on enabling people to succeed on their own (e.g., increasing employment opportunities within the food system, providing education and nutrition programs). Existing within the food system are multiple possibilities for improving livelihood through employment and business opportunities.

Policies that encourage decentralized urban horticulture (i.e., small-space urban agriculture) can lead to more local consumption of fruits and vegetables, providing localities with both nutritional and economic benefits.

Competing for Land: Future Trajectories for Rural Development**

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Summary

The question of how to feed a growing global population without further compromising global resources has become perhaps the single most pressing issue of the 21st century. In recent years, concerns over high food prices and food insecurity have propelled investors of various kinds, including national governments, hedge/pension funds, individuals, and corporations to seek out new land for the purposes of producing flex crops (i.e., crops that can be used for multiple purposes, including food, fuel, and industry). Referred to by some as a "global land grab," investments in land have increased dramatically in the past decade, particularly in less-affluent countries, characterized by what the World Bank calls a "high yield gap" where land is under cultivation but maximum crop yields are not attained. While increased production on land with low productivity may be necessary to sustain a future global population of 10 billion, significant concerns have been raised regarding these new large-scale land acquisitions (LSLA). In particular, community advocates, development practitioners, and researchers have argued that LSLA have thus far tended to benefit investors (often foreign) over local communities, displace small farmers, threaten ecological integrity, and even reduce local food production. In response, opponents have proposed regulatory mechanisms to oversee land investments and championed pro-poor measures. Such measures support small-scale agroecological farming methods that mimic nature to sustain diversified productive landscapes over the long term. Whether LSLA and such pro-poor, small-scale measures are necessarily oppositional, it is clear that the global community needs a multidimensional response to the overlapping problems of low productivity, poverty, ecological fragility, and rural-urban maldevelopment.

Current realities

The first decade of the 21st century has served as a wake up call for those concerned with the future of food. High, volatile food prices and widespread food insecurity have become the new normal: in 2006–2007 and again in 2011, food prices increased rapidly, doubling or tripling the cost of key food items and leading to protests and antigovernment riots in more than 60 countries. In 2007, a historic 1 billion people were characterized as food insecure, and fears of continued population growth and changing diets generated concerns for geopolitical stability and global food supplies. As researchers, policy makers, and politicians sounded an urgent call to double world food production by 2050, the food crisis gave way to a rush for land. Soon dubbed a "Global Land Grab," by social movement activists, or the "new scramble for Africa," public and private investors have acquired large tracts of land for the purposes of increasing food and fuel production. These acquisitions made international news in 2009 when protestors took to the streets in Madagascar, mobilizing against the Ravalomanana government's decision to lease almost one-third of its arable land to a South Korean firm, Dae Woo Logistics. As more information was collected on LSLA (e.g., landmatrix.org), it became clear that something significant was happening. In one year, from 2008 to 2009, conservative estimates suggested the amount of land changing hands increased between 15- and 20-fold over the annual average for the preceding 40 years. All available research suggests that there is little reason to believe that such LSLA will diminish in number in the foreseeable future. For a wide range of investors (e.g., sovereign wealth fund managers in the Middle East, national governments such as China and India, and private investors), one of the most lucrative asset classes today is land.

As LSLA have increased and gained international attention, opposition has grown. While there are potential positive ramifications to increased investment in LSLA, such as increased investment in infrastructure, agricultural technology, and local development in the host country, as well as increased production of food and fuel, there are also real concerns. If left unchecked, LSLA could push up land prices, divert food from the poor and hungry (both because of dispossession and diversion of production to export markets), promote industrial agriculture at the expense of more sustainable local agricultural practices, degrade fragile environments, and exacerbate inequalities between rich and poor socioeconomic groups, regions, and countries. Instead of asking how we can increase production to feed the world, we might ask how we can feed those who go hungry. The majority of the world's poor reside in rural areas of less-affluent countries and many suffer ongoing or seasonal food insecurity even as they work on the land. The rural poor also tend to live in fragile environments where survival is a choice between migration to over-crowded slums or continued degradation of the local environment.

In this context, there has been increased interest in promoting sustainable, pro-poor rural development as a response to the combined effects of the global food crisis, climate change, and land degradation. Highly organized mobilizations by civil society groups and multilateral organizations worldwide have resulted in a focus on the "right to food" and food sovereignty and on the potential for increasing productivity and diversity on smallholder plots, such that the rural poor might eat better and grow crops in ways more consonant with the ecological and social systems in which they live. Advocates emphasize that increases in productivity and resource integrity can be made possible by adopting some combination of principles referred to as agroecology, sustainable intensification, or conservation agriculture, including no-till (or minimum disturbance), cover crops (dead and alive), intercropping, and diversification.

Scientific opportunities and challenges

Despite the somewhat sensational label of a global land grab, there is a great deal of uncertainty as to the motivations, dimensions and implications of LSLA. Perhaps most importantly, there is little consensus on how to define a "land grab" or how to differentiate a bad investment or investor from a good one. This difficulty stems from ideological differences, in part, as some argue that all LSLA are bad by virtue of being large-scale while others argue that the purpose of production is more important. But the difficulty also comes from the lack of empirical data; most of these LSLA are nontransparent, intentionally obscured, or simply transacted without sufficient oversight. Concerns about transparency are particularly evident in Africa, where roughly two-thirds of recent LSLA are located. In this region, more than 90% of the land is under customary tenure and investors have taken advantage of legal and institutional pluralism to engage in covert deal-making and corruption in the acquisition and leasing of land.

Notwithstanding the lack of definitional precision and data, there are some things upon which most researchers and policy-makers agree. There has been a significant increase in investments in land for the purposes of producing flex crops (e.g., sugar, oil palm, soy, corn) for food, fuel, feed, and industry. These LSLA tend to be very large — more than 50,000 and 100,000 hectares, and the dominant production model is monocrop, industrial agriculture targeting export markets. LSLA also look different in different places: in Latin America and Southeast Asia, acquisitions tend to be purchases and include promises of conservation; in sub-Saharan Africa, acquisitions are long-term leases often accompanied by promises of local development and employment. These promises are attractive but difficult to fulfill, in no small part because so many LSLA are not yet productive. It is estimated that three-quarters of all LSLA are not producing or not making money because of delays in building necessary infrastructure (e.g., roads, ports, storage facilities), the difficulty of manipulating local environments for the intended crops, resistance from local communities, and the likelihood that some of these investments were purely speculative.

While more information is needed about LSLA, more information is also needed about the potential for increasing productivity and reducing negative environmental impact on already-existing farmland (in both large and small farms) around the world. It seems clear that global food supplies could be increased simply by supporting the rural poor, promoting fairly straightforward changes in plant breeding, production practices, harvesting techniques, and building improved storage facilities and transportation networks. The information required arguably pertains more to the political challenges of increasing production among the rural poor than the technical challenges.

Policy Implications

- Support research on LSLA and alternative agricultural programs. There are organizations dedicated to data collection on this topic (such as the Land Matrix and the Land Deals Politics Initiative) and they need to be supported and linked to policy makers and practitioners.
- Provide and/or encourage regulatory oversight for LSLA; the Voluntary Guidelines on LSLA put forward by the Food and Agriculture Organization of the United Nations (FAO) need public support by national governments.
- Protect people's rights to land and to adequate representation and voice in the face of external interests in land and natural resources. Provide training and resources for promoting tenure security through strong norms, policies and rights.
- Fund research and extension in production methods (for small and large farms) that prioritize sustainability rather than short-term yield. Support the development of national extension agencies and agents such that they are equipped to promote sustainable production methods and able to reach a significant percentage of their target population.
- Promote policies and programs that conceptualize farming as part of a broader socioeconomic system that links rural and urban communities. Evidence from a wide range of programs suggests that the best answer to malnourishment and hunger is not simply increasing on-farm productivity but promoting multidimensional rural development that articulates health, production, markets, literacy, safety nets, and popular

consumption by bringing together civil society, government, and the private sector.

- Rebuild public plant breeding and agronomy capacity that works with the private sector but is not dominated by it. Target public plant breeding efforts towards sustainable production of local food and fiber crops (not simply commodity crops), including grains, tubers, and legumes. Research has become dominated by the private sector (e.g., Britain's public plant breeding institute being sold to Unilever) such that the main purpose is arguably profit rather than food security. Much objection to GMO crops stems not from the potential environmental risk but rather from the prospect of monopoly control and subjection to the dictates of market forces. If these political issues were addressed, international attitudes towards GMO crops might improve significantly.
- Impose or support pro-poor conditions on aid, including bilateral government aid and nongovernmental aid. Most of the world's poor live in rural areas in less-wealthy countries and many of those governments (e.g., Mozambique) are profiting from rapid resource extraction while receiving significant foreign aid. As countries grow economically, particularly from the profits of natural resources, the aid community should demand that governments match aid contributions with basic services.

References

Arezki, R., K. Deininger, and H. Selod. 2013. "What Drives the Global Land Rush?" *The World Bank Economic Review*. Oxford University Press.

Rulli, M.C. and P. D'Odorico. 2014. "Food appropriation through large scale land acquisitions," *Environ. Res. Lett.* 9 064030.

Wolford, W., J. Borras, R. Hall, I. Scoones and B. White, co-editors. *Governing Global Land Deals: The role of the state in the rush for Land*. London: Wiley-Blackwell.

*** A policy position paper prepared for presentation at the conference on Food Safety, Security and Defense: Focus on Food and the Environment, convened by the Institute on Science for Global Policy (ISGP), on October 5–8, 2014 at Cornell University, Ithaca, New York, U.S.*

Debate summary

The following summary is based on notes recorded by the ISGP staff during the not-for-attribution debate of the policy position paper prepared by Dr. Wendy Wolford (see above). Dr. Wolford initiated the debate with a 5-minute statement of his views and then actively engaged the conference participants, including other authors, throughout the remainder of the 90-minute period. This Debate Summary represents the ISGP's best effort to accurately capture the comments offered and questions posed by all participants, as well as those responses made by Dr. Wolford. Given the not-for-attribution format of the debate, the views comprising this summary do not necessarily represent the views of Dr. Wolford, as evidenced by his policy position paper. Rather, it is, and should be read as, an overview of the areas of agreement and disagreement that emerged from all those participating in the critical debate.

Debate Conclusions

- Because land tenure is a complex and increasingly important issue with regard to rural development, responsible oversight by governments dedicated to monitoring, publishing, and making transparent current land acquisition commitments is critical.
- Governments need to increase funding of research into effective plant breeding to aid the development of high-yield, disease-resistant food crops (e.g., pigeon pea, sorghum and millets) utilized by rural communities. Private companies see little or no economic incentive for research into such food crops, preferring to focus on commodity crops such as soy and palm oil.
- To aid in policy development and enforcement, universally accepted definitions must be developed for such terms as LSLA and "land tenure."
- To make it feasible and attractive for small-holder farmers and their children to continue to farm, high quality schools using advanced technology must be readily available in rural areas to expand educational opportunities for both adults and children. In addition, governmental investment in small-holder farms and in a small-holder extension services are required to help small holders effectively and profitably farm their land.

Current realities

Land tenure is at the heart of both agricultural transformation and structural transformation of an economy, making it part of a complex set of issues underlying rural development. Currently there is serious interest by outside investors in acquiring rural land, especially in Sub-Saharan Africa. These investors promise to respect "voluntary guidelines" concerning land use and land tenure, but a system that outlines guidelines within the context of specific countries and locales does not exist. In addition, the binding legal right of investors to the acquired land is not always clear. In most cases, the governments of these countries are not yet equipped to facilitate and oversee those transactions.

Because investors are reluctant to disclose how much land they have acquired and what terms were used in the acquisition, it is difficult to define LSLA and therefore the amount of land that has been acquired by outside investors is currently unknown in many developing countries.

There is debate as to whether lands acquired by foreigners should be returned to native residents. Many land deals have been negotiated covertly and often to the detriment of local small-land holders. Currently, there is little oversight by governments dedicated to monitoring land acquisitions and ensuring that the agreements are transparent. Data are seldom made public as to who has been awarded land and where and under what conditions the transactions were made.

Typically, land is being acquired by large companies, investment groups, and other countries. Countries such as China, India, and Qatar are acquiring land for future production of food. Private companies are acquiring land for commodity crops such as soy and palm oil. Investment groups are using land as a hedge against inflation. By contrast, in South Africa and Zimbabwe, the governments have made the "land grab" and redistributed land to native residents for small-scale farming — although those same governments did not provide training for rural famers, thereby increasing the odds for failure.

Two-thirds of all documented land acquisitions are speculative, rather than actively intended for agricultural production. These speculative large-scale land acquisitions do not produce regionally edible foods required for food security. Instead production is most often in large-scale commodities such as soy, palm oil, or biofuels that are exported.

In most of the less-affluent world, water is more scarce than land, and becoming scarcer at an increased rate. A significant portion of Sub-Saharan Africa is landlocked and heavily reliant on groundwater, which can pose a problem for communities unable to identify sustainable sources of water for agricultural production. There is concern about the issue of water rights, especially where land investments make it essential to acquire water for the purposes of agriculture. Although investors may be funding the discovery of ground water, that discovery also can benefit communities.

It is critical to recognize that small-holder agriculture is not always the goal of native rural communities. Younger generations and their parents see education as a pathway to higher-paying jobs that offer more choices than farming. In many parts of the world, rural people are moving to urban areas not because they want to quit farming, but because agricultural careers generally are less remunerative. A conversation about small-holder agriculture that is facilitated by outside interests must take these local realities into account and not prejudge the most appropriate development path for any country.

Scientific opportunities and challenges

Plant breeding, which also has a connection to land tenure, is primarily controlled by the private sector. Fewer doctoral students pursue academic careers in the field of plant breeding. While private investment in agricultural research is growing, public investment in agricultural research has declined in the past 20 to 25 years. Most private research funding in plant breeding is invested in four or five large commodity crops. Private companies do not have the incentives to conduct research on the less widely planted crops (i.e., pigeon pea, sorghum, and millets), any of which are grown by small-holder farmers. There remains a need to continue bioengineering these non-commodity food crops to improve disease-resistant and yield production, and thus improve regional food security. Under these conditions, there is a need for governments to invest in site-specific plant-breeding research focused on developing plants that would improve agricultural success for small holders.

Presently, there is a global deficit of emerging plant-breeding technologies. There also are very few women in the field of plant breeding. Although the research in agricultural technology being conducted in public land grant universities needs to be continued since it produces some of the best science in agricultural technologies, there needs to be a balance between public and private research recruiting of plant breeders.

Since land tenure (i.e., who or what owns the rights to the land) is a complex issue, understanding land tenure requires that the value of the land area itself needs to be separated from the value of the functionality of the land. Land tenure has been narrowly understood as land governance or land administration, but a more discerning definition also requires a thorough understanding of the norms of land access and use in a particular locale.

It was questioned how binding and legal land acquisitions are in different parts of the world, but no conclusions were reached. For example, in parts of Africa, the government cannot assure investors of a legally binding document providing ownership of the land.

There was significant discussion surrounding how education can be provided for farm families with little or no access to schools. Advances in information technology in rural parts of the world could lead to improvements in education. Since rural areas worldwide are increasingly served by cell phone towers, a serious effort has emerged to provide information to farmers by cell phone. An opportunity exists to adapt this technology to provide education for children as well as adults.

Policy issues

Because the information regarding the identity of those entities that are making large-scale investments in rural lands is limited and often unreliable, there is a need for responsible oversight by governments that is focused on monitoring, publishing, and making transparent land acquisition arrangements. To accomplish this, data need to be available regarding who has been awarded land as well as where and under what conditions the transactions were made. There also is a question about the rights of widows to land the family historically farmed. While the United States Department of State (DOS) and United States Agency for International Development (USAID) are both investing resources to provide these data, ultimately the less-affluent countries must participate in these efforts.

Since different countries have different traditions of land ownership, it is challenging to identify a universally accepted definition of land tenure. Nonetheless, one is needed. In places such as Africa, where land rights traditionally were held by tribes, the question of ownership becomes increasingly complex because many countries were formed without consideration of the tribal territories.

If small holders are to have any part in a process that promotes rural development in conjunction with urban development, there must be credible investment in small-holder farms and in the small holder extension services. A major policy question concerns where funds will be obtained for this investment.

Increased governmental funding for research into the development of improved food crops is a necessity. Large companies see little or no economic incentive for research into non-commodity food crops. Currently, there are few data regarding the funding required to produce more successful varieties of food crops that are acceptable in less-affluent countries.

Educational opportunity must be provided for farmers if they are to stay on their land. Because many who leave rural areas and migrate to urban areas go in search of more education, schooling needs to be provided in rural areas, perhaps using educational opportunities based on the expanded use of information technology.

A question arose as to whether American-owned companies should be allowed to make LSLAs in developing countries. If LSLAs are bad for native populations, then should the U.S. government step in to police such purchases? This question was not fully addressed in the debate.

Adopting Genetically Modified Crops Worldwide for Food Security**

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Summary

One of the ways to increase food security with concomitant improvement of the agricultural environment is to adopt genetically modified (GM) crops. This method is used when crops cannot be improved by conventional breeding. Apart from the currently available suite of crops, mainly maize, soybean, cotton and canola resistant to insects and/or tolerant of herbicides, there are many more in the pipeline specifically adapted for use in less-affluent countries. These include nutritionally enhanced rice and sorghum, virus-resistant maize and canola, bacterial- and fungal-resistant bananas, insect-resistant cowpeas and eggplant, and drought-tolerant maize. Though these technologies have great promise, their deployment will require political will. Government, the private sector, academics and farmers' groups will have to be involved in order to allow countries to profit from these crops. Concrete steps that can be taken to further this technology include the development of bioeconomy policies, promulgation of biosafety acts, fast-tracking proven crops (such as herbicide resistant soybean), establishing public understanding of biotechnology platforms, encouraging the development of farmer-assistance organizations including extension officers, and using economists to determine losses due to the nonacceptance of GM crops.

Current realities

More than 840 million people suffered from chronic hunger in 2011-2013 (FAO 2013). While the vast majority of these live in rural areas in less-affluent countries, malnutrition is also prevalent in urban areas. While the demand for food is set to increase, many agricultural sectors will produce more non-food products for energy and feed. Natural resources needed for agriculture will be threatened by factors such as climate change and urbanization. While GM crops offer just one of many solutions to these problems, their adoption is being hampered by a number of factors including lack of political will, the spread of misinformation by anti-GMO lobbyists, and the exorbitant costs required to commercialize new GM crops (largely as a result of unreasonable regulatory requirements). In particular the antipathy to GM crops shown by many European Union countries has had a detrimental effect on their development and introduction in Africa. One example is the now completely discredited paper published by Séralini *et al* in 2012 in *Food and Chemical Toxicology* in which they claimed that rats fed on GM maize developed cancer. This caused the Kenyan government to halt all imports of GM crops and continues to be cited by other governments as a reason for nonadoption of such crops. In addition, there is a fear that the less-affluent countries will lose their export markets if GM crops are introduced on a larger scale (e.g., GM soybean export by Brazil and Argentina).

Although obstacles to the implementation of GM crops remain, the positive environmental impacts of these crops are impressive. In a recent study of the key impacts globally from 1996 to 2011 it was found that insect resistance leads to a significant decrease in the use of insecticides. Furthermore, herbicide tolerance leads to important changes in the profile of herbicides in favor of more environmentally benign products and also facilitates changes in farming systems, enabling farmers to engage in conservation tillage. In turn, conservation tillage results in lower levels of greenhouse gas emissions from reduced tractor fuel use and additional soil carbon sequestration due to reductions in soil erosion. In the instances in which herbicide tolerance has led to overuse of glyphosate-based weed killers, leading to weed resistance in some regions, farmers are increasingly adopting a mix of reactive and proactive weed management strategies incorporating a combination of herbicides. The authors conclude that "the overall environmental gains arising from the use of GM crops have been and continue to be substantial."

In addition to positive environmental impacts, GM crops can also help with food safety and security. No food in the history of humankind has ever been subjected to such rigorous safety tests as foods derived from GM crops. As long ago as 2004 the Food and Agricultural Organization (FAO) of the United Nations declared that there were no deleterious effects from the consumption of foods derived from GM crops discovered anywhere in the world, and it has had no cause since then to change this opinion. More recently the EU Commission Directorate for Research stated in 2010 that there are no new risks to human health or the environment from any GM crops commercialized thus far.

Regarding food security, the fact that farmers continue to increase plantings of GM crops worldwide speaks for itself. In its annual Global Status of Commercialized Biotech/GM Crops: 2013, the International Service for the Acquisition of Agri-Biotech Applications (ISAAA) reported that in the 18th year of commercialization, the hectarage of GM crops has steadily increased, with 12 years of double-digit growth rates, reflecting the confidence and trust of millions of risk-averse farmers.

For the second consecutive year, in 2013, farmers in less-affluent countries planted more hectares than industrialized countries. Currently, the area planted with these crops is 50% more than the total landmass of China or the United States.

Scientific opportunities and challenges

There are important new GM crops in the pipeline, which, if adopted, could significantly improve food security. These include Vitamin A-enriched rice, called Golden Rice due to the yellow color of beta-carotene it contains, which is converted to vitamin A when ingested. Vitamin A deficiencies are common in less-affluent countries and some 1.9 million to 2.8 million people, mainly women and children, died from this deficiency in 2010.

Sorghum is the only viable food grain for many of the world's food-insecure populations and is uniquely adapted to Africa's climate, being both drought-resistant and able to withstand periods of water logging. However, it is lacking in vitamins and micronutrients. To solve this, a consortium under Africa Harvest is developing an improved GM variety.

Maize streak virus (MSV) is endemic in Africa and can cause huge losses to both commercial and small-holder farmers. Although traditionally bred resistant lines are available, these are not adaptable to all maize varieties. Laboratories at the University of Cape Town have developed MSV-resistant GM maize lines that can be readily crossed into many varieties. However, because of the enormous costs of bringing these to the market they have not even undergone field trials despite having been available for many years. A similar situation exists for Cassava mosaic virus, resistant lines having been developed by scientists in Uganda and the U.S.

In countries such as Uganda, Burundi, and Rwanda, plantains are an important food source. The two major diseases are caused by a bacterium resulting in wilt, and a fungus that causes black sigatoka. Scientists in Uganda and Kenya have not only pioneered methods to genetically modify bananas and plantains, they have also developed varieties resistant to both diseases. They have subjected them to confined field trials and the results are extremely impressive.

Insect-resistant crops such as maize and cotton have been grown commercially for many years with great success. The same type of gene has been introduced into cowpea, one of the most important food legume crops in the semiarid tropics. It is being subjected to confined field trials in Nigeria, Burkina Faso and Ghana and preliminary results show good protection.

In Bangladesh, insect-resistant brinjals (eggplants) have been introduced with notable farmer acceptance. Unfortunately, their introduction into India and other

Asian countries has been blocked. Farmers sometimes must spray with insecticides every second day.

The Water Efficient Maize for Africa (WEMA) project is giving excellent results in confined field trials for drought-tolerant maize in South Africa, Kenya, and Uganda. Its commercialization will be a boon for farmers throughout the continent.

Policy issues

In almost every country where GM crops are flourishing (e.g., South Africa and Burkina Faso), the lead has been taken by the government. Without political will, very little can be achieved. However, more public awareness about the realities of GM crops, undertaken by academics, the private sector and by farmers themselves is necessary to ensure the successful and timely adoption of this technology. Awareness by politicians of how successful GM promotion strategies could lead to positive influences on elections could aid in increasing political will. To facilitate the adoption of GM crops the following steps are recommended:

- Develop a bioeconomy policy including GM crops, preferably under the Department of Science, with buy-in from other relevant departments such as Agriculture, Health, Trade, Environment and Education. The term "bioeconomy" encompasses biotechnological activities and processes that translate into economic outputs, particularly those with industrial applications. These could include, in agriculture, the development of crops that address the challenges of climate change, including diminishing water and grazing; in health, the manufacture of drugs, vaccines and other biologicals locally; and in industry and the environment, biobased chemicals, biomaterials and bio-energy.
- Promulgate biosafety acts (e.g., the GMO Act of 1997 of South Africa) with reasonable and enforceable regulations, though not inhibitory, preferably under the Department of Science. Once established, have "fast track" capabilities for GM crop approval, as is being done in Brazil and Canada.
- Establish a Public Understanding of Biotechnology entity in the responsible government department to educate and debate with the public, especially at schools and tertiary education establishments, using professional communicators. Stress the importance of food security, food safety and environmental safety.
- Encourage the private sector, including farmers' groups, to establish information dissemination platforms (e.g., South Africa's AfricaBio and Open Forum on Agricultural Biotechnology in Africa [OFAB]) to share

experiences and foster responsible stewardship, including the running of Open Farmers' Days. Relevant politicians should be invited to these events to see the advantages of GM crops and to hear the views of farmers, their constituents.

- The Department of Agriculture should employ and empower Extension Officers to assist farmers in the use and stewardship of GM crops.
- Economists from both the public and private sectors should determine what has been lost to individual countries, in terms of income and human health, by not introducing specific GM crops. One such study estimated that the delay in implementing Golden Rice has cost at least USD$1.7 billion since 2002, with USD$199 million lost to India alone. The latter translates into the prevention of 600,000 to 1.2 million cases of blindness and about 180,000 deaths of children in that country.

In conclusion, now is the time to act to prevent further suffering and loss of life due to food insecurity, especially in less-affluent countries. Finding ways to build political will for this technology and to counter misinformation about GM crops are two ways to help encourage the adoption of valuable food products.

References

Brookes, G., and *Barfoot,* P., *(2013)* Key environmental impacts of global genetically modified (GM) crop use 1996–2011. *Agriculture and the Food Chain.* 4-2: 109-119

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represent the views of Dr. Thomson, as evidenced by her policy position paper. Rather, it is, and should be read as, an overview of the areas of agreement and disagreement that emerged from all those participating in this critical debate.

Debate Conclusions

- Although negatively viewed by many in more-affluent nations, bioengineered or GM crops are an integral part of an overall approach to supply micronutrients that are otherwise unavailable in less-affluent countries, thus improving food security.
- To effectively address the public's distrust of GM biotechnologies, it is critical to increase transparency and improve accountability through (i) open and informed discourse, (ii) long-term studies of the effects of GM crops on human health, and (iii) standardized regulations for product labeling of GM ingredients.
- Because the public is poorly informed about agriculture, food systems, biotechnologies, crop breeding, and food security, better public education needs be undertaken in collaboration with scientists and science communicators to ensure that the public can participate in discourse and decisions, based on scientifically credible information, regarding the use of GM crops.
- Governmental organizations must evaluate the food security challenges relevant to their jurisdictions and financially support science-based solutions. Implementing these solutions will likely require developing the political will needed to effectively address public distrust of GM foods.

Current realities

Many people in less-affluent nations rely on GM crops to supply micronutrients because of weaknesses in their respective food production systems, particularly when it comes to inefficient transportation systems for food items. These deficiencies constitute a significant issue in terms of food security. The difficulties in transporting consumables from areas of the world with high yields to areas in need are often exacerbated by regional challenges found in many resource-poor areas (e.g., limited access to electricity, political unrest, government corruption).

There was general agreement that GM crops are indeed necessary to establish food security worldwide. Research by economists strongly suggests that many areas of the world will greatly benefit if GM crops were employed, increasing crop yields and improving nutritional value in regionally based staple foods. GM crops also can provide alternatives to crops requiring intensive pesticide treatment and help develop immunities to deadly pathogens (e.g., bananas, papayas).

It is evident that widespread negative public opinion and objections to GM crops exists. Objections include the association of GM technology with multinational corporations and the assessment that GM crops are unnatural. Because there have been few longitudinal studies on the effects of ingesting GM crops, many people are unconvinced of their safety. The public is undereducated about how modern agriculture and food systems have developed, including technologies already widely used.

Lack of political will is another significant obstacle to public acceptance of GM technology. Many politicians are afraid to support GM crops because they fear disapproval and backlash from an often anti-GM public. Lack of effective communication regarding GM crops to the general public from the scientific community also contributes to such distrust.

Although Europeans do not consider GM organisms (GMOs) to be a viable option for ensuring food security, Europe still relies heavily on imported GM crops. To prevent outbreaks of mad cow disease, Europeans no longer feed livestock with animal products, but instead feed livestock with imported GM soybean and maize, mainly because of the difficulty of sourcing non-GM feed crops in large enough quantities.

The absence of transparent communication early in the development of GM crops concerning the risks versus the benefits of the technology contributed to wide spread distrust, and strong emotional avoidance. Furthermore, misinformation is currently being spread by media sources around the world. Due to efforts to correct misinformation and release scientifically accurate reports, public opinion in some countries are becoming more positive regarding GMOs.

The scientific community's primary strategic mistake was focusing on the concerns of farmers and the food production industry rather than the concerns of consumers. For example, in terms of toxicology and health risks, saturating crops with pesticides pose a known danger, as opposed to the unknown long-term effects of genetic modification. However, GM production is rarely presented as an alternative to treating crops with pesticides. Additionally, there are many examples of genetic engineering used by the pharmaceutical industry that are uncontested by the public.

Lack of regulation in labeling products as to their GM content has allowed product labels established in one country to be concealed or manipulated when the product is exported. Additionally, in countries where large portions of the population are illiterate or where many products are sold outside of established storefronts, labeling is highly ineffective. While some companies have attempted to address public outcry against GM crops by releasing GM-free labeled versions of popular products, they have not experiences an increase in sales as a result of those changes.

GM crops are not a panacea to improving food security. While some GM crops have been successful against borer-type insects, pesticide sprays are still required to resist other types of destructive insects (e.g., aphids). As with any type of insect-resistant technology, insects eventually adapt to the genetic modifications of a crop.

The portion of the world that controls economic decision-making is not currently faced with widespread food insecurity and is consequently less inclined to support GM crops as part of a solution to food insecurity and more inclined to attribute food insecurity in less-affluent countries to inefficient distribution.

Scientific opportunities and challenges

A common objection to GM crops is that it is an unnatural manipulation. It was noted, however, that most agriculture is unnatural, as it involved cross breeding plant varieties that would not naturally breed. The lack of public understanding of genetic modification, hybridization, and traditional breeding practices is an opportunity for scientists to reach out and educate communities. Additionally, scientists can inform the public by producing research that addresses their primary concerns (e.g., that GM crops are safe for human consumption, that inserted genes will not be released into the environment).

One significant challenge related to GM crop research is the high cost of undergoing multiple trials (e.g., field, food safety, and environmental). Smaller companies cannot afford these expenses, so they either rely on governmental support or partner with multinational corporations that are frequently viewed as a threat to small farmers. Disagreement arose as to whether, from the perspective of resource allocation, it would be more effective to invest in lower-tech solutions to food security rather than GM practices.

Some considered that GM technologies be utilized only when crops cannot be improved by conventional breeding while others stated that genetic modification has the ability to improve crops irrespective of whether it is used in combination with traditional breeding strategies.

Another challenge of GM crops is that, just as with chemical insecticides, insects can eventually adapt to insect-resistant products. Essentially, GM crops have a limited lifespan of efficacy.

While pest-management solutions have been introduced (e.g., agroecological solutions) that present fewer potential risks than GM technologies, these approaches have not actively been supported by the public. It was generally agreed that the messaging regarding pest management solutions has been improperly presented to the public.

The historic lack of communication and transparency about GMOs among the agricultural industries, research institutions, and consumers has created distrust for agricultural biotechnologies as a whole. To address this distrust, it is essential to increase transparency and improve accountability through open communication among all stakeholders. There are several strategies to improve communication (e.g., testing messages prior to widely dispersing, avoiding saturating messages with research, and tapping into value systems that are of importance to the general public). Messages must be directed at consumers, not farmers. For example, messages to consumers should not focus on removing chemicals from the production environment or improving yields, as these are not factors that directly affect consumers. If consumers no longer trust science, politics, or industry, a trustworthy source of information about GM technologies must be identified and used to engage the public. Developing consumer trust will require consistent, responsible actions, transparent communication, and time.

Additional research is needed into the long-term effects on humans of consuming GM products and such trials could address public concerns. There are many examples during the past 20 years of animals consuming GM crops without negative health consequences, which could be viewed as professional feeding trials. By not conducting superfluous human feeding trials, funding could be provided to support other food security measures.

Policy issues

Although genetic modification of crops is not the only solution available to improve food security, it is a viable option for most countries. Localized evaluation of the problem is required and governments need to support evidence-based solutions (e.g., the African Union might consider investing in experimental crops that are resistant to maize streak virus, a pathogen specific to Africa). Multinational corporations also need to support the development of GM crops that address significant international climate-related challenges.

Farmers' days, extension offices, and group cooperatives are vital for the economic protection and education of farmers. Farmer education, particularly with regard to emerging biotechnologies, can be accomplished through nonprofit technology-development groups, such as Africa Bio in South Africa and Open Forum on Agricultural Biotechnology in East Africa. These organizations need to unite various stakeholders (e.g., farmers, breeders, researchers, seed companies) in discussions of the safe and effective use of biotechnologies over time.

Public education about agriculture, food systems, biotechnologies, crop breeding, and food security needs to be improved (e.g., via informative commercials and social media forums) to ensure the public can intelligently participate in discussions surrounding GM crops. Steps must be taken to prevent the public from rejecting, without scientific basis, the emerging biotechnologies (e.g., genome editing, RNA interference) in the same way that it is rejecting current GM technologies.

Labeling can be an effective method to inform consumers regarding GM ingredients. Products labeled "GM-free" must produce evidence supporting this claim. The public also needs to have access to information on the type and amount of pesticide and insecticide sprays that are used in the production of their produce. At a minimum, labeling systems must (i) be consistent on a national level, and preferably standardized internationally and (ii) regulate terminology such as "non-GM" and "GM-free." Organizations that could regulate the international standard of food labeling included the World Health Organization (WHO) or the United Nations.

To ensure credibility and impartiality, it is critical that biosafety regulations are overseen by separate regulatory departments, such as the departments of agriculture or the environment (although faults in both of those suggestions were noted). A trusted bureaucracy that makes decisions by weighing the full risks and benefits of these agricultural technologies is required.

Message testing regarding GM technologies prior to broad release from the scientific community will improve the efficacy of such messaging. Messaging must be regionally specific and primarily highlight the emotionally valuable aspects of GM technology (e.g., how GM crops are helping to solve the food shortage problem and are combating the effects of climate change) and secondarily address the science behind these technologies. Risks must be presented alongside benefits.

Scientists must continue to address specific public concerns through laboratory research, monitoring, and evaluation. Longitudinal studies conducted by organizations not associated with GM development may help quell public skepticism. Breeders, biotechnologists, ecologists, and evolutionary biologists must collaborate to produce GM crops that are responsive to a variety of ecological challenges. The interdisciplinary aspects of this field also are relevant to producing effective science communication, risk assessment, political influence, and economic evaluation.

The private sector, subject-matter experts, and advocacy groups need to encourage national and international conversations about the risks and benefits of all pest-management solutions, not just GM technologies (e.g., chemical pesticides, agroecological options). Studies of the ecological impacts of pest-management methods might be considered.

GM technologies provide an opportunity to boost the nutritional value and resiliency of crops grown globally and the governments of more-affluent nations need work with those of less-affluent nations to help solve food security and agricultural production problems.

Zero Tolerance is a Bad Strategy to Protect Food Safety**

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Summary

When promulgating regulations, government agencies tend to be unwilling to directly accept negative outcomes, including illness, as an acceptable possibility for the citizenry. This aversion reflects political reality. However, avoidance of risk thresholds can be counterproductive to public health. Of paramount importance is the development of acceptable risk levels against which to establish and scientifically evaluate quantitative food safety criteria and, thereby, to appropriately protect public health. Quantitative targets allow application of the best available technologies for modeling and monitoring hazards to effectively enhance food safety. The proposed Produce Safety Rule (PSR) under the U.S. Food and Drug Administration (FDA) Food Safety Modernization Act (FSMA) is intended to assure food safety through science-based minimum standards, or regulatory criteria. The fact that the PSR borrowed the science-based criteria for recreational water quality and applied them to irrigation water is a case example of the need for quantitative risk criteria. Without quantitative risk criteria, it is impossible to evaluate whether PSR water quality criteria are overly protective or not protective enough. Furthermore, it is impossible to test alternatives to the proposed criteria for equivalent levels of public health protection. In the broader sense of food safety, beyond irrigation water quality, risk models and other tools can be effectively used to guide policy. A short list of application examples includes the establishment of irrigation water quality targets, detection probability targets for pathogens or toxins on imported foods, and efficacy evaluation for new technologies, such as utilization of gene sequence information in the detection pipeline. Once established, the risk modeling structure allows effective communication of the scientific basis for policy decisions designed to enhance food safety, and the protective value of food safety criteria and regulations.

Current realities

Consumption of fresh produce, like any other activity, is not risk free. Recognizing this reality, food safety objectives often are stated in relative terms, as in the PSR "to minimize the risk of serious adverse health consequences or death from consumption of contaminated produce." Despite the nuanced wording of food safety objectives, public perception of food tends to be binary (e.g., fresh vegetables are safe but raw meat and eggs are not necessarily safe). Food safety programs should help producers meet the desire and obligation to deliver safe products while enabling effective communication of risk level (which is never zero). In this way the producer or retailer might assure the consumer that consumption of a fresh produce product is safe, from the perspective that the product does not carry elevated risk of illness, and that the producer, packer, and distributor have considered food safety and have implemented practices focused on preventing contamination.

In many instances, communication of risk and risk mitigation is hampered by a food safety regulatory structure that does not include numeric risk targets. Inclusion of such numeric risk targets would greatly facilitate applying science to guide regulatory, management, and policy decisions. As a case example in the U.S., the proposed PSR is intended to assure food safety through "science-based minimum standards," or regulatory criteria. Although the term science-based provides a degree of confidence in these standards, linkage of the science with the desired level of food safety is lacking in the PSR. In contrast to the criteria in the PSR, other water quality criteria, including the 2000 Beaches Environmental Assessment and Coastal Health (BEACH) Act and the Safe Drinking Water Act (SDWA), are benchmarked to numeric targets (i.e., maximum acceptable increased risk of illness). To establish these benchmarks, scientific evaluations of epidemiology and quantitative microbial risk assessment were applied to establish the relationship between risk targets and actionable enforcement criteria. Instead, the PSR simply applied to irrigation water the science-based criteria for recreational water quality. While the logic is compelling (if it's safe enough for swimming, it should be safe enough for irrigation), the scientific basis is anecdotal rather than data driven. Lack of a target acceptable risk level greatly hinders development of science-based criteria for monitoring, such as are required by the FSMA.

The risk level that defines safe often is termed acceptable risk. In other regulatory arenas, science-based criteria are required to meet an acceptable risk criterion. Specifically, as described above, the U.S. Environmental Protection Agency (EPA) recreational water criteria in support of the BEACH Act are based on an acceptable risk level of 8 cases of gastrointestinal illness per 1,000 fresh-water swimmers or 19 in 1,000 marine-water swimmers. These values trace back to research conducted in the 1950s and historical detection limits for increased gastrointestinal illness above background gastroenteritis levels. Similarly, the acceptable risk criterion for drinking water used to support the SDWA is 1 illness in 10,000 consumers. A similar acceptable risk criterion is required to evaluate the effectiveness of criteria, such as those contained in the PSR, and to evaluate the acceptability of alternate practices, alternative standards, and variances as described in the PSR.

The language of the FSMA implies that a similar risk-backed criterion is meant to be applied to regulated activities such as irrigation of the edible portion of the crop. To evaluate alternate practices or measurements on the basis of equivalent risk to anticipated produce safety rule requirements, it is necessary that the limit must be based on a quantified acceptable risk criterion. In other words, the management or regulatory criterion (i.e., a measurable water-quality attribute, such as the density of a fecal-indicator microorganism) must be indexed to an acceptable risk level if future demonstration of equivalency is desired, as in the case of a variance request or alternate monitoring target proposal as described in the PSR. If we accept that zero risk cannot be attained, a non-zero acceptable risk level must be defined to validate or justify the irrigation water criterion. Only in this way can research be designed with measurable outcomes to show equivalency to FDA-approved management practices (the PSR).

Scientific opportunities and challenges

Food safety can be greatly enhanced by taking advantage of sophisticated risk analysis tools used in other fields, such as mitigation of terrorism risk. The Department of Homeland Security (DHS) Chemical, Biological, Radiological, and Nuclear Terrorism Risk Assessment (CBRN TRA) program illustrates some opportunities and challenges. The CBRN TRA models follow the path of contaminants from the point of introduction to the point of contact. This framework effectively represents a confluence of quantitative microbial risk assessment (i.e., the calculation of the dose of microbial contaminant delivered and probability of illness as an outcome) with probabilistic risk assessment (i.e., the inclusion of probability of initiation, represented by frequency of contamination events). This framework could be a powerful tool for both calculation and communication of risk given different inputs. In particular, these calculations can be used to estimate level of input (e.g., monitoring criteria such as for irrigation water quality or sampling effort for produce coming from the field) that feed into a particular target outcome (e.g., an acceptable risk level).

Stakeholder acceptance of the CBRN TRA models has, in some cases, been challenging. In addition to realistic calculations, models can be limited by the data upon which they are based. In particular, the Food Consequence model of the Bioterrorism Risk Assessment (BTRA) carries out calculations that are directly relevant to other food safety management programs. One major challenge for development of the BTRA Food Consequence model was obtaining credible data to describe for all relevant organisms (i) the amount of contaminant introduced in the scenario, (ii) growth and/or decay characteristics, (iii) dose-response relationships in consumers, and (iv) conditions experienced by the organisms from point of application to point of consumption. In addition, validation of risk models for a relevant scope of pathogens, product distribution systems, and regional effects are critically important to stakeholder acceptance. Failure to normalize risk across all potential "pathways" through a model can be seen as bias, or preference for one consumer group over others. Throughout the process, stakeholder education is critical to acceptance and successful implementation.

Policy issues

A well-informed, risk-focused framework for food safety is essential to establish consistent, informative regulations and criteria. The following policies and actions would result in an improved framework for food protection.

- Establish risk targets in food safety regulations. In the case of the PSR in the U.S., the FDA should establish a quantitative risk target.
- Require quantitative risk calculations as part of criteria development and formulation of rules designed to manage risk:
    - Require information gap analysis as part of the FSMA implementation in the U.S. and comparable regulations worldwide to ensure that investments are effectively directed to fulfill model data input requirements to address model information gaps. These input requirements include interactions of various environmental conditions in carrier matrices, such as food surfaces or irrigation water, and impact of background microbial communities.
    - Implement education programs to communicate results to the public in ways that are realistic. For example, by conducting mock contamination events and tracking foods, with results compared against modeled processes. This approach is similar to efforts undertaken by USDA for control of foreign animal disease spread (e.g., highly pathogenic avian influenza and foot-and-mouth disease).
- Leverage existing capabilities, similar to those developed by the DHS for CBRNE TRA, to effectively and consistently manage safety for production of fresh produce and regulation of vulnerabilities such as irrigation water quality. In this way, take advantage of existing risk management analysis tools to accurately estimate the dose delivered to consumers based on key

factors including initial dose, decay processes, distribution characteristics, and consumption behavior.

- Utilize risk model results to revise the regulatory structure through what-if analysis using a range of conditions modeled in the risk model; explicitly require use of the risk model to allow variances from regulatory criteria based upon equivalent achievement of threshold risk levels.
- Implement programs to develop better detection methodologies for international trade, raw product monitoring, and monitoring at different steps of the process with criteria/sampling frequency dictated by modeled conditions.
- Formulate policies and regulations with attention to rapid development and acceptance of new measurement technologies that help to address risk-based criteria. Sampling and analysis of bulk samples by massively parallel next-generation DNA sequencing can be used to screen large pools of product for threats that are both known and unexpected (e.g., intentional contamination with biological agents that are not part of the normal public health risk suite).

*** A policy position paper prepared for presentation at the conference on Food Safety, Security and Defense: Focus on Food and the Environment, convened by the Institute on Science for Global Policy (ISGP), on October 5-8, 2014 at Cornell University, Ithaca, New York, U.S.*

Debate Summary

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Debate conclusions

- A risk-based, food safety framework designed to facilitate policy prioritization and decision-making and quantifies both health benefits/risks and economic impact is urgently needed. Risk-assessment metrics can serve to evaluate the effectiveness of food safety regulations, thereby ensuring that credible scientific understanding appropriately informs the political decisions that define acceptable risk for the public. These policy decisions can effectively delineate the viability of technologies and methodologies when used to implement policies.
- To facilitate implementation of a risk-based framework, technological advances that enable the detection of food contaminants (microbial and chemical) are critically needed. Such advances need to provide results within a single day, be easily portable, and require minimal economic investment for food producers and distributors.
- Effective public communication of the real risks of food-borne illness must be developed to garner consumer and political support for a risk-based regulatory framework.
- Effective utilization of a risk-based framework and distribution of advanced surveillance technologies in the global food system will improve the cost effectiveness of regulations and inspections, promote more equity between small- and large-scale food producers, and support more fairness in international trade negotiations.

Current realities

There was widespread agreement that zero-tolerance frameworks for food-borne contamination, and safety regulations in general, were not normally scientifically based nor practically achievable. A risk-based framework was viewed as an appropriate and powerful approach to inform regulatory and policy deliberations. Risk itself was proposed as a common currency or common denominator that can unify analysis and guide actions with regard to the food system. Policy decisions often remain disconnected from rigorous scientific understanding and strive for safety ideals that are not justified by risk analysis and statistics. Such efforts are usually driven by emotional and social considerations.

Current regulations under the United States FSMA of 2011 are a "one-size-fits-all" approach. Some stakeholders, such as large-scale growers, are able to bear the cost and support efforts to meet regulations, while small-scale growers are potentially forced out of the market. This issue demonstrates the trade-offs between demanding high safety and allowing vibrant local food systems. Current regulatory approaches promote a centralized food system that impedes regionalization and give large corporations a competitive advantage through market distortions. In particular, small-scale farmers are unable to afford professional safety experts to assure compliance with complex regulations. Implementing specific numeric targets for risk (e.g., number of microbes in food) would improve market competition by allowing for various approaches to achieve a desired result.

Scale-appropriate regulations are a related critical issue with FSMA. Despite efforts to create science-based food safety regulations, FSMA is generally scale-insensitive, demanding the same level of risk regardless of the production and distribution levels. Statistical calculations or modeling approaches may not exist that determine appropriate risk levels for various scaled distributions (e.g., roadside vegetable stands, farmer's markets, or national distribution centers). Instead, exceptions such as the Tester-Hagan Amendment to FSMA have been enacted to exempt growers based on production size, rather than risk level. Such size-based exemptions have been applied to Community Supported Agriculture (CSA) organizations.

In broader terms, a risk-based framework for food safety was discussed as the current approach for the World Health Organization (WHO) International Health Regulations (IHR). These risk-assessment frameworks provide "an algorithm and decision-making matrix" to inform and guide global governments on the basis of public health surveillance. Recent evaluation of the WHO/IHR process also identified issues with zero-tolerance as a critical knowledge gap. While WHO utilized specific numeric targets in the past, it has eliminated specific numeric targets for water safety standards in recent years. Efforts of organizations like the Cochrane Collaboration to systematically analyze health data were highlighted as a way to build consensus and cross-pollinate ideas between scientists and policy makers.

A moderate challenge was raised to the risk-framework proposal, in that it does not include an accounting of the health benefits of consuming foods such as fresh fruits and vegetables; such benefits would need to be incorporated into a full picture of risk analysis. The efforts of the European Union and the International Life Sciences Institute (ILSI) with the Benefit-Risk Analysis of Foods (BRAFO) program is a good example of creating a common scale for a risk-assessment framework. This is an important approach to understand both health benefits and risks simultaneously. Today's consumers may take traditional food safety for granted in terms of microbial contamination and heavy metals. Safety from these issues is the minimum expectation. Consumer demands now are defining food safety to also include risks of chronic diseases, diabetes, and cancer.

Significant discussion centered on the difficulty of communicating concepts such as "perceived risk" and "real risk" to the public. It also is difficult to effectively communicate with vastly different stakeholders, such as scientists, industry representatives, policy makers, and consumers. The food system is not only complex, but food consumption is a very personal and emotional experience, which makes imposing numeric risk assessments (e.g., one in 10,000 consumers getting sick) a difficult task. Numeric risk assessments would be difficult for scientists to support, and perhaps impossible for lobbyists to accept given their commercial interests. This is confounded by the concept that 100% food safety is theoretically possible — a concept that requires a dollar value placed on human life to implement a food-safety system that is practical and not cost-prohibitive. Furthermore, any suggested improvements to the food-safety system will raise costs and require some, if not many, stakeholders to pay, more at the farm or market level.

Scientific opportunities and challenges

A major scientific opportunity is the development of low-cost technologies that can be applied in the field and quickly measure a variety of microbial contaminations with high accuracy and sensitivity. Technologies for microbial contamination ideally would need to rapidly and reliably detect up to 10 different organisms at concentration levels spanning three log scales. "In-field" testing rather than shipping samples to testing labs an approach that could be readily used in developing countries was identified as a priority despite the strong scientific and economic challenges. One specific illustration was the need for a hand-held device that for \$10 to \$15 could test DNA and generate results within one day. A low cost for such testing is paramount, because the food industry is highly sensitive to cost increases. Although difficult, progress is being made and some technologies are purportedly not that far away. There are some international efforts with a focus on deployment in less-affluent countries.

New technologies and methodologies also are being created to facilitate more frequent surveillance for contaminations and improve statistical extrapolations for exposure levels. In terms of sampling frequency, these aforementioned technological improvements are needed to facilitate more frequent testing of multiple relevant samples.

A suggestion was made to pursue new technologies that allow consumers to directly test or assess products. A highlighted example is food packaging that turns color in response to salmonella contamination.

A critical challenge will be the utilization of these improved approaches to create a more flexible and scalable food-safety regulation framework, as opposed to the current "one-size-fits-all" framework, with politically based exemptions. These approaches may be particularly important for small-scale local growers and distributors who, with current methodologies and small population distribution of their products, may be selling produce contaminated above a maximum threshold (e.g., an amount that would make more than one in 10,000 people sick) that goes undetected because their product is not consumed by enough people to detect an outbreak.

Challenges abound in effectively communicating and promoting risk-based frameworks. Consumer acceptance of such an approach will be difficult because the topic rests in both the scientific and policy communities. The challenge of helping the media understand risk is a compounding factor. There is a gap that must be bridged between the acceptance of risk in activities such as driving a car and the lack of acceptance of risk in the food supply.

A numerical value for acceptable risk is not an inherently compassionate position. However, for the framework to be supported, all stakeholders (the producers, consumers, and policy makers) must believe in the validity of an acceptable risk level. Scientists are responsible for defining two things: a protocol by which to achieve a goal, and the calculation of that goal's cost to society. Communicating in a "cold-hearted" and emotionless fashion may lead to a loss of credibility, especially when the public's desired risk exposure is achievable only through unreasonable economic burden. However, the fact that a minimal-tolerance system is currently cost-prohibitive highlights the need for better consensus building around acceptable risk levels.

Additional factors could be included in the metrics that inform a risk-based framework. Specifically, along with the risks of food-borne illnesses, it is important to include the known health benefits of eating certain foods such as fruits and vegetables. It also is necessary to develop a consensus in which various scientific disciplines generate different interpretations of risk, or develop a new type of framework that can synthesize diverse data to yield an overall risk assessment. An example of this concern is the low-level presence of the toxin acrylamide in potatoes. Potatoes are one of the better dietary sources of potassium, but they have a higher (but still epidemiologically noncompelling) acrylamide content when cooked. Decreased potassium levels cause issues with raised sodium levels. This simple example demonstrates the scientific complexity to be found in a risk-benefit analysis of food consumption. Analyses must enlist the efforts of toxicologists, nutrition scientists, public health scientists, and food scientists. The clear challenge is developing analytics to arrive at a unified position that can inform food system policy.

Policy issues

A risk framework provides a common currency not only for implementing regulations, but for performing cost-benefit analysis. For example, a risk framework can help determine if nations should invest more in produce safety or in the safety of baby food. It also has the potential to inform regulatory prioritization, such as whether it is more beneficial to public health to be aggressively regulating vegetable farmers or hog farmers. This type of high-risk area prioritization also could inform decisions on financial responsibilities concerning violations or grievances. Furthermore, this approach can guide broader decisions, such as the prioritization of food safety and nutritional deficiencies.

A risk framework also provides a clear methodology for constructing food-safety policy. The communication and determination of acceptable risk is a political process. But once that value is determined (e.g., one illness in 100,000 consumers), then analysis of contaminant levels and epidemiological studies can directly link exposure to public health outcomes. Scientific research and statistical modeling can then prescribe the necessary methodological templates and regulatory mandates needed to achieve acceptable risk levels. This approach has been utilized extensively for bioterrorism risk assessments, and similar models can be adapted to ensure food safety at small- and large-scale levels. Additionally, a risk-framework approach is amenable to determining the costs of societal goals and acceptable risks.

Outreach and farming-education efforts, like the Agricultural Extension programs at U.S. land-grant universities, are essential programs for disseminating methodologies that could be used to achieve specific numeric targets for food-borne illness risk. Support of these programs must continue.

Commissioned "blue ribbon panels" of experts, convened to interpret the whole of scientific literature on a particular topic and draft strategic plans and policy recommendations, were considered a valuable approach to build consensus across divergent scientific views. However this approach alone is not sufficient to effectively advance either the scientific or public understanding of risk.

Regarding the role of government mandates versus methodological templates, current U.S. policies are a combination of both regulatory mandates and templates (or voluntary compliance). Improvements in both approaches will be required in the future. For example, the U.S.D.A. Good Agricultural Practices Program needs to continue to provide methods and educational tools to assist farmers, but it also needs to create stronger numerical targets of risks to public health.

While a risk framework that requires numerical targets for exposure or illness is incompatible with the enactment of regulatory exemptions for small-scale producers and distributors, it was generally agreed that exemptions remained appropriate and in some cases, were even a required compromise.

Expanding the use of a risk-based framework in monitoring the global food supply chain would be difficult. Because of current funding levels and practical concerns, only extremely small percentages of food in the supply chain can be effectively monitored and tested, and it is not likely that those limiting factors will be reduced in any significant way. The further development of domestic or even international standards of risk-acceptance levels for imported foods could inform more efficient inspection efforts and dramatically reduce the cost of bringing food into other countries. The goal should not be zero risk tolerance for adverse incidents like mad cow disease or E. coli, but rather a global food system that is made more secure as new threats emerge.

There is also an opportunity to strengthen the global food trade. Many international producers cater to the mandated safety regulations of the U.S. and the E.U. Targeting an accepted level of risk allows for variances in methodology to achieve that risk, unlike mandating a singular approach. This framework also instills a sense of ownership in the process for producers because they are contributing their knowledge and expertise to the system. Therefore, the development and application of global sanitation standards based on risk could help to create fairness and equality between large and small markets, and promote more productive international trade negotiations.

Systems Solutions to Global Food Security Challenges to Advance Human Health and Global Environment Based on Diverse Food Ecology**

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Summary

On a global level, there is rapid emergence of diet-linked chronic diseases that represent a new reality of food security. This recent global increase in diet-linked noncommunicable chronic diseases (NCDs) places a heavy burden on long-term health care management and overall costs, thus consuming higher levels of national health care budgets. All NCDs involve a metabolic malfunction that manifests itself in enhancing oxidative stress (i.e., oxygen function breakdown) at many cellular and organ levels. Food crop-based diets designed for management of oxidative stress will be an important part of the overall solution to combat NCDs. The most cost effective of these metabolic innovations for NCDs is improved design of food crops based on agroecological diversity and enhanced redox-linked bioactive components (i.e., oxygen stress protecting compounds) that can prevent oxidative stress and thus mitigate NCDs. Such food design must contain both macronutritional and micronutritional ingredients, including bioactive compounds that can counter oxidation-linked malfunctions of NCDs. Such enriched foods are also essential in advancing community-wide nutrition and health, while concurrently increasing the agroecological diversity (i.e., plant biodiversity) of local food crops. All these efforts greatly benefit the global ecology.

Current realities

The current global food and nutritional security model must be improved to generate adequate global food production from a wide diversity of crops that will meet macro/micronutrient needs along with phytonutrients (e.g., phenolic antioxidants) to counter obesity-linked NCDs. NCDs represent a large financial burden on health care systems worldwide, a burden that has been increasing in recent years. Given that NCDs at their core have a metabolic malfunction that includes increased oxidative stress, solutions that enhance natural antioxidants to combat this stress would have a substantial impact on NCD prevention. Although recent strategies by such agencies as the United Nations and the U.S. Agency for International Development (USAID) have included a focus on nutrition, their focus has been limited to the traditional macro/micronutrient model that excludes the bioactive components of food responsible for limiting NCDs.

The current economic and production practices favor highly processed carbohydrate-enriched foods and are dependent on a narrow selection of major cereal crops. These cereal crops are less resilient and robust in responding to and dealing with climate change extremes because they are bred for yields rather inducible responses to abiotic stress (e.g., salinity and temperature). In addition, global food security currently is dependent on petroleum fossil fuel-based nitrogen that contributes to the unsustainable addition of nitrogen wastes, which affect ecology and human health. Globally, nitrogen in the soil has doubled in the last 100 years. Excess nitrogen is a third ecological dimension of the food cycle — in addition to increasing carbon emissions and poor water quality — that worsen human health in terms of vascular hemoglobin function and global ecology (e.g., worsening algal blooms and associated toxins).

At the sociopolitical level, subsidies favoring a restricted choice of cereal crops over balanced co-production of pulses (i.e., legumes) impair nutritional security with a breakdown of the agroecology, especially with regard to biodiversity of healthy crops and soil biology. Overall, the lack of food diversity, from an unsustainable ecology focused on restricted crop choices and excess fertilizer application, coupled with high consumption of hyper-processed carbohydrates and lipids, without micronutrients and oxygen stress protecting phytonutrients, is increasing obesity-linked NCDs globally. Answers to the above challenges affecting global food security require integrated, systems-based solutions that use nutrition-based food security for the betterment of human and animal health and for an improved agroecology that is based on crop and food diversity.

Scientific opportunities and challenges

Integrated systems-based platforms are needed for advances in life sciences. Such integration will extend into global food security challenges, where systems strategies will be used to assist in the development of biological-based solutions in a post-genome era. The calorie model of limited agricultural commodities is incomplete, as increased calorie density from highly processed foods does not account for the variability in oxygen function responsible for cellular energy generation from foods. Food components must not only provide basic macro/micronutrients, but also counter oxygen malfunction through compounds such as phenolic phytochemicals (i.e., oxygen stress protectors), which are removed during food processing.

The above point must be addressed by encouraging soil health by (i) improving soil rhizosphere microflora (i.e., the beneficial microflora in the root zone), (ii) enhancing phenolic antioxidant responses in seed germination, and (iii) growing crop varieties, such as legumes and cereals, with beneficial phenolic antioxidant bioactivities for countering oxygen malfunction. The development of redox-balancing foods, which protect against oxidative stress-linked breakdown, through less-processed crops that contain enhanced phenolic antioxidants can serve as a systems-based critical control point to balance metabolic dysfunction (i.e., fewer NCDs). Such an integrated system improves soil health and microflora that affects human health-relevant oxygen stress by using phenolic antioxidants. These enriched whole grain foods can be the foundation for enhanced agroecology, food production, food security, energy crops, and human health. Integrated sustainability of these systems and challenges across the global agroecology and rural and urban communities is essential. Such a foundation in systems logic is key to addressing food security challenges, while also simultaneously addressing ecological breakdown and human health.

From this systems-based foundation of redox-balancing foods, crop metabolic innovations must emerge. This overall approach has the potential benefit of addressing both crop-production challenges and improving their resilience to climate change. These integrated systems must be part of overall solutions to more-resilient and multi-purpose agricultural systems that better address global food security, through crop and food diversity models, both for ecological sustainability as well as an improved approach to addressing the challenges of human health.

Policy issues

Bioactive-enriched and microbial-based bioprocessed food crops can be integrated as a part of comprehensive solution where bioactive ingredients provide multiple functions such as countering critical steps of NCD emergence:

- Food diversity must advance components of local food production, including technologies for non-seasonal indoor production of bioactive fresh foods using energy from waste recycling.
- Fruits, vegetables, greens, pulses, and herbs must be developed with respect to nutritional-linked health outcomes and NCDs and suitably developed as "crops for health."
- National, state and local administrations must continue to shift food

security-linked health policies towards integrated nutritional security-based health outcomes, focused both on traditional malnutrition challenges and emerging NCDs.

- International agencies such as Food and Agriculture Organization (FAO) and the World Health Organization (WHO) must coordinate efforts to work with national bodies to inform political and sociopolitical discourse on evidence-based scientific rationale regarding moving food subsidies away from refined carbohydrates and traditional calorie-focused food security models.
- International bodies linked to the United Nations must integrate "crops for health" and "foods for health" as a diversified value-added agricultural development platform for economic advancement of local communities.
- Post-harvest technologies must be advanced globally and integrated well into crops/foods for health and reduce waste of quality foods that are major antidotes for malnutrition and NCDs.
- Crops for health varietal development and related food-processing technologies must develop agricultural systems for climate change resilience and robustness, using a dual function bioactive crops model based on redox biology (i.e., oxygen stress balance in cells), in which oxygen stress-protecting bioactives for health can also provide crop production resilience in response to climate change.

References

Paliyath, G., and Shetty, K. (2011) Functional Foods, Nutraceuticals, and Disease Prevention: A Window to the Future of Health Promotion. *Functional Foods, Nutraceuticals and Degenerative Disease Prevention* (Paliyath, G., Bakovic, M., and Shetty, K. (Eds). John Wiley & Sons, NY. Pages 3-10.

Sarkar, D., Ankolekar, C., and Shetty, K. (2012) Functional Food Components for Preventing and Combating Type 2 Diabetes. *Emerging Trends in Dietary Components for Preventing and Combating Disease.* Edited by Patil, B. et al., ACS Symposium Series. Volume 1093. March 6, 2012 (Web). Chapter 20, pages 345-374.

Sarkar, D., and Shetty, K. (2014) Metabolic Stimulation of Plant Phenolics for Food Preservation and Health. *Annual Review of Food Science and Technology*, 5: 395-413.

*** A policy position paper prepared for presentation at the conference on Food Safety, Security and Defense: Focus on Food and the Environment, convened by the Institute on Science for Global Policy (ISGP), on October 5-8, 2014 at Cornell University, Ithaca, New York, U.S.**

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Debate Conclusions

- An integrated nutrition-based systems approach to food security can mitigate adverse effects of current global food production practices on human health, climate, and the environment.
- An effective systems approach relies on fine-tuning key local control points, based on geographic variations, to effectively drive optimized outcomes. A local focus also provides greater opportunities for community stakeholder interactions and informed decision-making.
- Collaborative research into human and environmental microbiomes is critical to understanding key ecological interactions and will provide an opportunity to make full use of a systems-based approach to food.

Current realities

While our current food system is capable of feeding the world's 7 billion inhabitants, the food supply is poorly distributed and improperly constituted to combat the rising issue of malnourishment. More than 1 billion people lack a reliable supply of food, especially in less-affluent areas of the world, while other areas are experiencing epidemic levels of obesity and overconsumption. To address the current nutritional and environmental failures of our food systems, a new metabolic food systems approach must be implemented that is based on identifying key control points.

At present, there is an emphasis on calorie-based nutritional standards that has resulted in an increase in the rate of noncommunicable diseases such as diabetes and heart disease. Calorie-based nutritional standards do not account for the ways in which individuals process key food-based components (e.g., glucose). The basis for this type of nutritional approach was the Green Revolution, which emphasized a high-carbohydrate balance and deviation from a balanced mix of bioactive food components. An example of the pervasiveness of this approach is the preponderance of calorie-rich, nutrient-deprived foods provided by municipal governments in public school lunch programs.

It was generally agreed that current political and economic initiatives have exacerbated current food systems challenges. Economic systems do not properly account for all negative externalities in the cost of food, such as the true costs to society associated with noncommunicable, chronic diseases. Moreover, commodity price supports and subsidies often have been misappropriated to crops and food products that contribute to the multiple failings of our food systems.

The role of the public in determining which food systems become favored in the United States was unclear. The public's failure to embrace food options that promote health (e.g., legumes, fruits, vegetables, less-common grains) may be attributed to the high cost of these options and the inefficiency associated with bringing them to market. Alternatively, members of the public may not act in their own best interest and there tends to be resistance when individual choices and behavior are controlled legislatively.

Issues involving pollution and climate change, particularly as related to the use of nitrogen, were linked to the failures of the food system. Agriculture is highly dependent upon nitrogen as a nutrient fertilizer to sustain yields. Nitrogen production has increased dramatically, resulting in excess greenhouse gas emissions, nitrous oxide air pollution, and depletion of oxygen in water supplies (eutrophication). Moreover, nitrogen may be used inefficiently. Certain crops (e.g., corn) do not utilize nitrogen efficiently in their root systems, leading to excess waste.

Scientific opportunities and challenges

A systems-based approach to developing a new food system has both benefits and limitations. A broad systems-based approach likely will include a multitude of variables. Although perfect optimization of these variables is not feasible, emphasis needs to be placed on identifying and manipulating key control points in the system to reach desired outcomes.

A systems-based approach must identify components that can provide multiple beneficial system outcomes. For example, legumes can reduce the rate and impact of noncommunicable chronic diseases while also benefitting the ecosystem.

To what extent might changes in microbiome constitution, within the context of a systems-based approach, address the failures of our present food systems to provide adequate nutrition and reduce waste? A distinction was made between the microbiome of humans and that of root and soil systems. Further research is needed into how dietary changes (e.g., a move toward narrow carbohydrate consumption and increased micronutrient consumption) affect the human microbiome and subsequently the health of an individual. In root and soil systems, a "zero-tolerance" philosophy that seeks to eliminate all risk of foodborne illness is an impediment to implementing an effective systems-based approach based on an optimized soil and crop microbiome. Such an approach removes not only harmful bacterial colonies from crops, but beneficial bacteria that should be cultivated as part of a healthy microbiome. Distinguishing between harmful and beneficial bacteria is a significant scientific challenge.

The availability of land is an important factor in implementing an integrated, systems-based approach to food security. There was disagreement concerning the manner in which land will need to be utilized in a new approach. Land may be considered a limited resource and yields of certain common crops (e.g., cereal grains) would need to be reduced to accommodate the growth of more micronutrient-rich legumes, fruits, and vegetables. However, there may be significant opportunities to increase the productivity of land, notably based on research into the effects of root morphology and soil microbiome. This would allow the food system to accommodate increased production of micronutrient-rich food without significantly reducing grain yields.

While nongrain food crops (i.e., legumes, fruits, and vegetables) were lauded for their beneficial health impacts, it was noted that there are significant post-harvest issues associated with these products. Nongrain foods are highly perishable and contribute to excess waste if not promptly consumed. While a local food production approach can help alleviate post-harvest pressures placed on nongrains, significant improvements in other technologies (e.g., vertical growing, electrical engineering, LED systems) are necessary to overcome post-harvest issues.

Certain nonperishable food items can provide valuable micronutrients in the face of the post-harvest issues associated with fruits, vegetables, and legumes. Products such as tea, wine, coffee, and cocoa provide key micronutrients, particularly phenolic compounds that promote oxidation reduction.

There was broad agreement concerning the potential agricultural value of intercropping on a larger scale. Intercropping allows crops to enjoy a variety of ecosystem services provided by neighboring crops. However, this approach is feasible only for small-holder farms at present. To scale intercropping of legumes and maize grains to an industrial level, significant and persistent investments need to be made in researching the root morphology optimization of intercropped landscapes. It was noted that past research in this area did not yield significant results.

Policy issues

To appropriately set food-system agendas, food policy makers must utilize an integrated model that includes economic, human health, climate change, and ecological factors. Determining and including the full external costs of food, including health and environmental impacts, is a critical policy challenge.

No single approach can provide a universal solution to our food-system issues. However, local initiatives are essential in identifying control points to be optimized in the system. The vast majority of the world's food suppliers are small enterprises — 500 million small farmers provide food for 70% of the world. Given the complexity of the food system, policies that engage all stakeholders at the local level are considered the most effective approach to achieving desired food-system outcomes. National and international policies should remain flexible and provide a broad framework through which local policies can be crafted.

Collaboration with community organizations is essential to improving food-system outcomes. In Massachusetts, for example, a local church group and a group of university scientists partnered with the mayor to encourage the development of home vegetable gardens and other healthy food initiatives.

Technology for ensuring minimal food waste and optimal nutritional content are integral to implementing a systems-based approach. A key challenge for policy makers is determining how to integrate these technologies on the local scale. Rather than attempting to identify a single approach, policy should be driven by the context of each local situation.

Land issues are a key area in need of policy implementation. Land allocation should be examined in the context of more optimally serving food systems. For example, land allocation for grains grown for the sole purpose of providing feed for livestock was identified as a possible area for policy intervention. While policy mechanisms that reallocate this land for production of legumes, fruits, and vegetables may be a proper action, an initial first step will require shifting public preferences away from high meat consumption.

To achieve a functional systems-based approach to food, policymakers must change public attitudes about food. Because of a multitude of factors, people often do not act in the best interests of their own health and well-being. An increased emphasis on public education is a possible way to affect food choices, such as re-examining food labeling to allow for the dissemination of information about the health effects of ingredients. Another possible way to change behavior is to engage locally with community stakeholders, such as parents concerned about school lunches and indigenous communities determined to alleviate chronic diseases.

There were conflicting views on the role of grains that currently constitute the bulk of the calorie-based nutritional system. It was suggested that grain production should not be reduced and that grain should remain an integral part of the food system. However, given the view that land availability is fixed, policymakers will need to consider tools to promote more efficient land use for crops. Ending commodity price supports for grain was seen as a possible mechanism to drive land use towards a more systems-based mix of crops.

To make full use of the benefits of microbiome optimization, policy makers will need to determine acceptable levels of risk. To minimize the potential for foodborne illness, harmful bacteria are eliminated during processing. However, these processes indiscriminately eliminate potentially beneficial bacteria as well. Policy makers must work in consultation with the scientific community to accurately assess risk levels associated with attempting to cultivate healthy bacterial constitution.

Ensuring Food and Nutrition Security through Changes in Food Development, Processing, and Culture**

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Summary

During the next 50 years, the impacts of a worldwide population approaching 10 billion people and inexorable changes in global climate present a critical challenge to food security (i.e., ensuring that sufficient food is available) and nutrition security (i.e., ensuring that food quality meets human nutrient needs). New policies that identify and support solutions to feeding the world are essential; resources such as fertile land and fresh water are diminishing and changes in temperature and atmospheric carbon dioxide can reduce both crop yields and the nutrient quality of important plant foods. Because these problems are complex, solutions must be multi-pronged. These solutions must directly achieve greater production of nutritious foods with fewer resource inputs, improved food stability for storage and distribution, reduced food loss and waste, broader use of natural foodstuffs, and the development of novel foods using new technologies. Some of these solutions are apparent today and include: (i) using genetically engineered plants (commonly referred to as "genetically modified organisms" [GMOs]) to improve sustainability, yield, and nutrition, (ii) developing processing methods to safely enhance the preservation, storage, nutrient content, and transportation of food, (iii) creating approaches to reduce loss and waste throughout the food supply chain, and (iv) recognizing the value of uncommon and novel foods, e.g., from insects and bioprinting, respectively.

Current realities

Population growth in the next 50 years could require increases in food production by as much as 60% to meet the global demands of food and nutrition security. However, the Food and Agriculture Organization of the United Nations (FAO) reports that today we have 925 million people who are hungry and many more who are malnourished and food insecure, mostly in less-wealthy countries in Asia and sub-Saharan Africa. In these regions, 100 million children are underweight, and poor nutrition is associated with nearly half of the deaths (3.1 million) in children under the age of 5. Without distracting from the critical problem of childhood malnutrition, it is important to note that modern nutrition science is directed not only to the prevention of protein-energy malnutrition and micronutrient deficiencies, but also to the promotion of optimal physiological function and the reduced risk for common chronic conditions, such as cancer and cardiovascular and neurodegenerative diseases. The resulting demand for greater production and distribution of safe and nutritious food coincides with the impact of climate change, natural resource constraints, and competing resource demands (especially for the production of biofuels), and presents a considerable challenge for agriculture and food systems worldwide.

More than 50 years ago, Norman Borlaug and other instigators of the Green Revolution bred new high-yield crop varieties and spread modern agricultural production techniques across the world, saving a billion people from starvation and helping to promote world peace by increasing the food supply. Among smallholder farmers in Asia, the adoption of these new innovations increased productivity and produced enough food to lower the real prices of staple foods for consumers. In addition, the demand for labor in rural areas increased, generating new jobs and increasing wages for poor and unskilled workers, and food security improved. However, increasing occurrences of droughts and flooding, and changing climatic patterns, are now requiring a shift in crops and farming practices that cannot be easily accomplished. The application of new-generation technology, including genetic engineering, can build upon the original successes documented in the Green Revolution.

While food production must increase to meet future demands, it is essential to recognize that one-third of all food (about 1.3 billion tons per year) is currently lost or wasted between agricultural production and household consumption. Food losses in industrialized countries are as high as in less-affluent countries, but in less-affluent countries more than 40% of the food losses occur at the post-harvest and processing levels, while in industrialized countries, more than 40% of the food losses occur at the retail and consumer levels. Annual food waste at the consumer level in more-affluent countries (222 million tons) is almost as high as the total net food production in sub-Saharan Africa (230 million tons). Though the approaches vary between less- and more-affluent countries, food supply chains need to be strengthened through practices such as the promotion of food processing to enhance their preservation, storage, nutrient content, and transportation.

In addition to strengthening the food supply chain, introducing uncommon and novel foods can also contribute to food and nutrition security. Uncommon foods are those that are traditionally used in specific regions or cultures but are not widely established elsewhere (e.g., insects [entomophagy] and marine algae) and those that present themselves as particularly sustainable. Novel foods are often defined as those that have never been used as food or that result from a process that has not previously been used for food (e.g., bioprinting, the construction of a biological structure by computer-aided 3-D printing, and cell culture technology), and can be designed to meet specific nutrient needs. Regulations regarding the notification, authorization, specification, and labeling of novel foods vary markedly by country. GMOs are generally regulated differently than novel foods.

Scientific opportunities and challenges

While unforeseen advances in agricultural, food, and nutrition science cannot be predicted, opportunities are available for further development and application of existing technologies that can promote food security and nutrition security. Genetic engineering, while certainly not a panacea, can increase plant defenses against untoward environmental conditions and/or improve nutrient composition, but its application is hampered by public misunderstanding, fear, and mistrust of the technology. Regulation of GMOs varies enormously between countries with marked impact, as illustrated by the fact that 170 million hectares of genetically modified crops are grown around the world, but cultivation within the European Union is restricted to 0.1 million hectares. Further, current regulation of GMO food is based on how it is produced ("process based") rather than on its novelty or potential for harm ("phenotype based"). The process-based approach also confusingly permits organisms with the same phenotype but generated via different technologies to be dealt with differently (e.g., transgenesis versus chemical or radiation mutagenesis). Current policies are unclear on genetic engineering created by methods that were not available when GMO regulations were created 20 years ago. The process-based approach inhibits innovation and misdirects and impairs effective risk management.

Emerging technologies in food processing can serve to enhance food safety, increase food supplies, and promote human health. Processes such as ultrahigh temperature pasteurization, ionizing radiation, pulsed electric fields, and high-pressure processing demonstrate these advantages. However, many consumers fail to understand the value of these technologies and often perceive processed foods as inherently less nutritious and unhealthy compared to those marketed as "natural."

Ensuring future food security also requires consideration be given to less common food sources, such as insects and marine algae, and novel foods produced by technologies such as bioprinting and cell cultures (in vitro) to produce "meat" and other foodstuffs. Meeting this goal requires acquisition of new knowledge regarding the attributes and limitations associated with the production and consumption of uncommon and novel foods.

Policy issues

Applying Genetic Engineering to Plant Foods

- Increase public and private investment in GMOs in order to increase yields and nutrient content, particularly targeted to countering the impact of climate change and to decreasing the use of expensive and potentially harmful inputs (e.g., fertilizers and pesticides) via changes in regulations and taxation by the United States Department of Agriculture (USDA), French National Institute for Agricultural Research (INRA), and FAO.
- Expand germplasm repositories (gene banks) and characterize individual plants to identify useful genotypes and phenotypes for the creation of novel cultivars suitable to specific geolocations and environmental conditions, via USDA and FAO.
- Make more transparent to the public the benefits and risks of GMOs through educational programs via USDA, FAO, and agencies concerned with public health.
- Investigate and promulgate the rational use of GMOs in the context and implementation of good agricultural practices (e.g., integrated pest management, crop rotation, maintenance of soil structure) via USDA and FAO.
- Harmonize regulations across countries for GMOs and food ingredients derived from GMOs, including review, approval, and labeling via the FAO, Organisation for Economic Co-operation and Development (OECD), U.S. Food and Drug Administration (FDA), European Food Safety Authority (EFSA), and Codex Alimentarius.
- Revise current regulations of GMOs from "process-based" to an approach that focuses instead on their novelty or potential for harm (e.g., their phenotype) via the FDA, USDA, FAO, and EFSA.

Applying Food Processing

- Use biotechnology and fortification, particularly through the valorization of waste by-products (e.g., via extraction of fiber and polyphenols), to increase nutrient content and density.

- Promote safe, stable fresh produce with innovative processing technologies (e.g., non-thermal methods) as well as established but underutilized methods (e.g., irradiation).
- Develop educational programs to reverse the adverse perception of food processing among consumers via the Centers for Disease Control and Prevention (CDC) and USDA.

Reducing Food Loss and Waste

- In less-affluent countries, invest in infrastructure for food processing, storage, transportation, refrigeration, and markets to reduce post-harvest losses of fruits, vegetables, meat, and fish.
- In more-affluent countries, market heterogeneous produce to counter "appearance quality standards" that lead to rejection by supermarkets and by consumers.
- Modify food processing lines for trimming and related steps for appearance standardization to collect by-products treated as waste that can be valorized for human use.

Tapping the Potential of Uncommon and Novel Foods

- Explore and characterize the traditional consumption of uncommon foods for large-scale and sustainable applications in a broad range of foods acceptable in other cultures.
- Invest in the development of new food technologies, such as bioprinting, molecular gastronomy, nanotechnology, and cultured (in vitro) meat.

** ***A policy position paper prepared for presentation at the conference on Food Safety, Security and Defense: Focus on Food and the Environment, convened by the Institute on Science for Global Policy (ISGP), on October 5-8, 2014 at Cornell University, Ithaca, New York, U.S.***

Debate Summary

The following summary is based on notes recorded by the ISGP staff during the not-for-attribution debate of the policy position paper prepared by Dr. Jeffrey Blumberg (see above). Dr. Blumberg initiated the debate with a 5-minute statement of his views and then actively engaged the conference participants, including other authors, throughout the remainder of the 90-minute period. This Debate Summary represents the ISGP's best effort to accurately capture

the comments offered and questions posed by all participants, as well as those responses made by Dr. Blumberg. Given the not-for-attribution format of the debate, the views comprising this summary do not necessarily represent the views of Dr. Blumberg, as evidenced by his policy position paper. Rather, it is, and should be read as, an overview of the areas of agreement and disagreement that emerged from all those participating in the critical debate.

Debate conclusions

- To address the food demands of a growing world population as well as the rising obesity rates associated with overconsumption, the global food system must develop new food products from under-utilized or novel resources and improve the nutritional content of food in general.
- A combination of many approaches is needed to ensure food security for the world's growing population: (i) a consensus-derived standardization of regulations for new food technologies is critically needed to support innovation; (ii) the latest nutritional knowledge of the health benefits of bioactive compounds must be used to update recommended dietary intakes and to create new food products with high nutrient density and value; and (iii) food loss must be mitigated through improved infrastructure and expanded re-capture of essential nutrients (i.e., "valorization") from processing byproducts.

Current realities

The world's population is predicted to approach 10 billion by 2060, with likely expansion of urban populations. Feeding this increased population will require a broad variety of practical approaches. Debate centered on the need to (i) promote food-product innovation, and (ii) reduce food and nutrient waste to meet growing demand. Unique challenges also exist in addressing overconsumption and rising obesity rates.

Although several areas of the global food system are ready for innovation, barriers exist that impede progress. For example, a limited number of agreed-upon definitions and regulations address the processes of creating and distributing GMOs, instead of focusing on the ultimate food crop phenotype and developing uniform product labeling. This is a significant impediment to expanding acceptance and usage of GMOs, which may be required to adequately feed a growing global population. For example, the Cartagena Protocol on Biosafety outlines methods of GMO transit, handling, and use to account for potential risks to human health, but does not provide clear guidance to breeders or companies when creating new seed products. In a related issue, the lack of FDA regulations on GMO product labeling has resulted in private sector and consumer confusion.

The implementation of innovative technologies and the development of novel products (e.g., food derived via synthetic technology) face unique hurdles in the food industry. Food consumption is a very emotional and social act, and consumers generally do not react positively to changes in products. At best, consumers simply do not purchase new food products, and at worst, respond with a strong negative outcry. Current consumer demand in food products was described as "organic, traditional, and healthy." This viewpoint discourages companies from innovating when creating healthier foods or introducing foods from novel sources (e.g., food derived from insects). Because of similar consumer pushback, some effective food safety and preservation methods (e.g., irradiation) also are underutilized.

Food loss is a major concern. Food waste is not just loss of food itself, but also loss of (i) the energy inputs necessary to produce the food, (ii) environmental resources such as nitrogen and water, and (iii) human labor resources. Over the last 30 years, approximately 95% of global food system investment has been in increasing production, with only 5% directed toward reducing waste. This disparity must be changed to meet the needs of the growing population. Distinctions were drawn between pre/post-harvest food loss and consumer waste, each with different causes depending on the socioeconomic status of their locations. In general, most food loss in lower-income countries is due to inefficient processing, limited infrastructure and distribution channels, or inadequate preservation. In most affluent countries, food loss occurs at the consumer level, where a combination of low prices and high incomes drive excessive food consumption and waste. While there are benefits to reducing food waste in high-income nations, consumers may not necessarily reward private company's efforts or accept government regulations. It was generally agreed that greater opportunity could be found in efforts to improve the food supply chains in lower-income nations (e.g., improving refrigeration capacity for Pakistani dairy farmers has substantially reduced waste). Although government action likely will be important in improving infrastructure issues, the private sector in less-affluent countries often is more involved in the food supply chain than the government.

The loss of essential nutrients may be considered as more significant than the loss of calories. Food loss traditionally is viewed in terms of lost tonnage or lost monetary value. But in light of current nutritional research, there is a need to change the metrics and refocus loss-mitigation efforts on the retention of essential nutrients and bioactive compounds. The USDA has recently completed an exercise in redefining metrics on nutrient loss, calculating that each American discards the equivalent of a balanced diet in 44 days.

Currently a large amount of bioactives such as polyphenols and fiber, and other nutrients are "left behind" during crop harvesting and processing. These byproducts are often utilized for cattle feed, but modern food processing has the potential to capture the nutrients and reincorporate them into new food products, preserving the vitamins, minerals, and bioactive compounds. Known as "valorization," this process exists for byproducts such as onion skins, orange peels, and almond skins. Companies like Bioflavia in Canada are producing fiber polyphenol dietary supplements from repurposed grape skin powder. While some nutritional value will undoubtedly be lacking in valorized products compared with whole foods, this approach has promise for maximizing yields for nutrients such as essential vitamins.

The global food system has developed in the past several decades such that of .approximately 50,000 edible plants, 60% to 70% of calories come from only five crops: soybeans, corn, rice, wheat, and potatoes. This is not sustainable in terms of resources and environment, and does not provide sufficient micronutrients and bioactive compounds to maintain optimal health. In some initial steps to address this issue, the U.S. Executive branch has developed a nutritional strategy for Feed the Future and directed relevant agencies to invest more in horticulture to better understand the health role of bioactives and micronutrients.

The U.S. State Department and U.S. Agency for International Development (USAID) have prioritized nutrition efforts during the first 1,000 days of life. The Scaling Up Nutrition (SUN) Movement is an example of international efforts to ensure all people have access to food and good nutrition. The National Academies Institute of Medicine Food and Nutrition Board has recently convened a panel to determine if recommended daily allowances for omega-3 fatty acids should be examined, which may establish approaches for incorporating bioactives into the existing framework of nutrition policy.

Concerning rising rates of obesity, sustained efforts to promote healthy choices (in particular through the USDA and U.S. Department of Health and Human Services) have had little impact on consumers' eating habits. Food companies have been responsive to some recommendations from nutrition scientists and dieticians (e.g., offering low-fat products, reducing sodium content, adding fiber to cereals). Although these efforts are encouraging, it is still too early to know if they will appreciably modulate obesity rates.

Overconsumption imposes a cost on the environment as well as on individuals' health. Food companies are beginning to recognize consumers' expectation that those companies will promote public health and act as part of the solution to obesity.

The food industry is expected to promote moderation in food intake and to provide healthier food products that are less energy dense (less fat and sugars) and more nutrient dense. However, the extent of food companies' ability to effectively solve obesity is limited. In some sense, the food chain has to be "pulled" by consumer demand, not just "pushed" by nutritional or environmental concerns. Increasing fiber content in cereals is an example of how sales decreased in response to the introduction of a healthier food product.

Scientific opportunities and challenges

Feeding a growing global population is achievable through immediate actions to develop innovative new food products and reduce post-harvest loss. These approaches are expected to be costly in research and development and also require improvements or expansions in infrastructure. Therefore, large private corporations, national governments, and international agencies are the primary participants in addressing global nutrient needs. It was argued, however, that local and organic agriculture will be a vital component in achieving sustainable nutrition for the world.

One of the most significant opportunities and challenges is in creating new food products that "deconstruct foods and reconstruct them" to deliver optimized benefits and promote health. The emerging field of epigenetics may be a new frontier for utilizing nutrition to optimize health. Epigenetics research is discovering how the environment and nutritional intake can modulate gene expression and influence chronic disease or infection risks. Nutritionists and food scientists are expanding the understanding of dietary micro and macronutrients, fatty acids, and bioactives like phytochemicals. Nutrition scientists are investigating specific nutritional interventions to promote (i) optimal growth and development in children and (ii) health maintenance in adults. Nutrition science is not yet a prescriptive approach, however. Significant additional investigations are needed and the Institute of Medicine's nutrient Recommended Daily Allowances need to be updated. But some policies (e.g., folic acid fortification to promote neuronal development) already have been implemented.

To deliver optimized ingredients for health, new food products must incorporate new nutritional knowledge and demonstrate acceptable efficacy, safety, and allergenicity characteristics. Because consumers are driven by taste, convenience, and cost, and traditionally have been resistant to new technologies, food companies may need to utilize food scientists and persuasive marketing to effectively deliver any newly developed foods.

Lack of consumer acceptance of new food technologies also presents a significant financial hurdle. Given expected negative reactions by consumers, it will be difficult to obtain investment funding for emerging biotechnologies (e.g., cultured *in vitro* meat, bioprinted food), even though these technologies may prove necessary to ensure food security in light of climate change.

Reducing food waste is not likely to have a single solution. In some affluent nations, waste may be reduced at the retail and consumer levels, perhaps through multidisciplinary efforts to promote moderation in serving sizes and alter consumer behaviors (e.g., the rejection of minimally blemished fruit). But high average incomes and low food costs encourage wasteful behaviors, and effective consumer waste reduction is likely to come at a high cost. By contrast, less-affluent countries' waste-reduction solutions require improvements in infrastructure, with a balance between low-cost, easy-to-implement, low-tech solutions and high-cost, high-tech approaches. Although some high-technology solutions developed at food companies may prove profitable, they likely will require more time to demonstrate effectiveness. Proving efficacy and maintaining maximal safety of new food technologies is critical in all approaches taken.

Recapturing nutrients through valorization requires a process that is inexpensive enough to be feasible. The goal of valorization is not to replace whole foods with extracts or supplements, but to utilize current food-processing byproducts as ingredients in new food products. Scientists must demonstrate that the valorized nutrients are still bioavailable and active. In some cases, valorization may prove to be quite expensive, and a tax on sugar or fat may be a way to pay for these efforts. However, such a tax has proven ineffective in changing consumer behavior, as evidenced by New York City's soda tax. The real value of valorization is in the profitable use of "waste" so that governmental subsides or incentives are not needed.

Encouraging people to choose healthier diets and increase their energy expenditure is a major challenge. New educational and interactive tools such as social media and personal monitoring devices (e.g., "smart watches") may prove to be persuasive.

The lack of diversity in dietary plant foods is a concern because of expanding knowledge of the health benefits of bioactive phytochemicals. The five global staple crops are nutritionally inferior to crops like sorghum, millet, and quinoa. These under-utilized crops are more resilient to environmental changes and require less energy to grow, but they are not as palatable in themselves. Efforts are needed to create new food products that incorporate these less energy-consumptive ingredients and appeal to consumers.

Policy Issues

International agreement on definitions and standards for new food technologies (e.g., GMOs) should be harmonized through organizations like the Codex Alimentarius Commission. Harmonization and enforcement of regulations likely will require new levels of collaboration between the FDA, the United Kingdom Food Standards Agency (FSA), the World Health Organization (WHO), and the Food and FAO. Standardized nutritional definitions and regulations are needed to optimize the nutrient content of foods.

While the current lack of clear, consistent regulations globally on novel food technologies (e.g., nanotechnology applications in food processing and packaging) allows for some innovation, ambiguities also create inconsistencies. Food companies cannot pursue a uniform processing procedure that is acceptable around the globe, and they fear that nanotechnology application may yield negative consumer feedback in the absence of a regulatory framework that demonstrates efficacy and safety. A consensus-derived standardization of regulations for new food technologies is critically needed to utilize the latest food innovations in the fight against global hunger.

For GMOs in particular, standardized regulations need to shift away from "process based" concerns and toward "risk based" assessments. That is, GMO crop regulations need to be based solely on their phenotypic nutrition and safety characteristics, and not on the scientific processes used to create the crop.

International governing bodies and leadership must respect a certain level of national autonomy, and food policies must allow nations to express their unique cultural practices and beliefs.

Agricultural policy makers should promote a market for underutilized crops like sorghum, millet, and quinoa. A subsidy incentive framework may be necessary.

New and updated USDA and Institute of Medicine, Food and Nutrition Board Daily Reference Intakes are needed for phytochemicals, especially polyphenolic compounds shown to have beneficial health effects. "Nutrient density" (defined as the number of essential vitamins, minerals, amino acids, and fatty acids delivered per 100 calories of a food product) has potential as a standardizing metric for international food regulations and policies. Effective food policies require updated dietary reference intakes and Recommended Daily Allowances that take into account nutrient density.

Reducing post-harvest, pre-consumer food waste in less-affluent countries requires a significant investment in infrastructure. While generally believed to be the responsibility of governments and the public sector, initial infrastructure investment may need to come from the private sector. Any public policy or private company effort to reduce waste and expand distribution must hold safety absolutely paramount.

Private-sector stakeholders need to continue to play a significant role in providing healthier, more responsible food products to consumers. Nutrition education alone has not significantly reduced rates of obesity, diabetes, or cardiovascular disease. Private-sector food scientists need to complement educational and exercise programs by creating new healthy foods and improving the nutritional value of existing food products. This includes creating more nutrient-dense foods, reducing calories, and decreasing portion sizes.

To fully address the issue of obesity, collaborative forums are required that synthesize the combined efforts of nutritionists, private -sector stakeholders, microbiologists, social scientists, political scientists, communication specialists, and politicians. These combined efforts need to pursue the development of healthier foods and also create new ways to impart a sense of responsibility in making healthy choices. These interdisciplinary forums also need to be tasked with establishing and enforcing deadlines for implementation, to ensure that food security issues do not grow beyond control.

Taxation of less-healthy food products has proven to be minimally effective in altering consumer behavior and, consequently, is not an effective approach. Taxation also is not an effective method for funding waste reduction or improving infrastructure. Consumers must acknowledge the societal cost of overconsumption and poor dietary habits before any taxation approaches will be accepted.

While education and outreach efforts to encourage nutrient-rich diets need to address all ages, priority should be placed on infancy and childhood. Nutrition communications and behavior programs now being established in higher education need to be supported and expanded to promote best-practice multidisciplinary efforts that improve current eating behaviors and decrease obesity rates.

Regionalized Food Systems: Improving Resilience in the Face of Uncertainty**

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Summary

Regionalized food systems provide an opportunity for improving resilience in the global food supply in a period of increasing uncertainty due to climate change, population growth, fresh water stress, and energy cost, among other threats. In affluent countries, this is primarily about rebuilding parts of the food system that were systematically lost in the 20th century. Within less-affluent countries, many local food systems are already regional in nature so it is important to seed development to enhance, not diminish, these regional food systems through appropriate modernization and intensification. In both cases, science and technology, coupled to community-based development techniques, have critical roles to play in improving productivity and efficiency at small and mid-size scales, reducing in-field and post-harvest losses of food, improving diet choice among consumers, and enhancing chances for livelihood expansion across a large percentage of the population.

Current Realities

The sustainability and resilience of our food system is, in part, dependent on the development, maintenance, and/or enhancement of regional food systems around the world. This does not imply a deconstruction of current global trade. Rather, we need to develop regional food systems that optimize the production, consumption, and supply chain infrastructure of food within a defined region, while integrating with larger regions as well as the national and global supply of food in a manner that provides a healthy, sustainably produced diet to a region's inhabitants.

During the last century, a number of factors have combined to both increase the availability of a wide range of foods and increase the vulnerability of those foods to disruption. In the United States, we increasingly rely on concentrated production centers for a wide variety of foods — especially fruits and vegetables but also an array of animal products. For example, the Central Valley of California supplies a large percentage of the U.S. domestic fruits and vegetables and is experiencing severe drought conditions. It is estimated that 40% of the region will not be planted and/or harvested this year. The concentration of production in this relatively small area could leave us vulnerable to disruption. Often the expertise for production of these crops is unavailable elsewhere. Hence, the capacity of our food system to absorb disturbance and reorganize so as to retain essentially the same function and structure (i.e., resiliency) is in doubt. Regionalized food systems would improve resiliency by distributing the various food system functions, starting with production, more broadly.

There are several reasons why food system resiliency is important. The literature on climate change is clear: humans have significantly impacted global climate and will continue to do so with deleterious consequences on the environment and resource ability for the foreseeable future. Simultaneously, the global population will increase by some 2 billion people between now and 2050, requiring an estimated additional 2.4 trillion pounds of food annually. The U.S. population will increase by more than 100 million during the same period, and U.S. agriculture is threatened by changes in climate. In the latest U.S. Census of Agriculture, the number of farms in all size categories decreased as well as a continuing decrease in the amount of total farmland.

Our dietary patterns also impact land use and greenhouse gas emissions. All studies to date investigating the impact of dietary patterns on environmental sustainability indicate significant variation on atmospheric carbon and/or land needs depending on dietary choices — typically the greater the amount of plant products in the diet the lower the greenhouse gas emissions.

Scientific opportunities and challenges

The need to improve global capacity for regional food production diversity, while also insuring a reduction in both energy use and land-intensive consumer demand patterns, is clearly indicated. Since the spatial urban "eating footprint" typically exceeds the boundaries of the city by many times, urban food practices and behaviors affect food systems and natural resources. In affluent countries, dietary patterns tend to exacerbate dietary impact on climate change and land use primarily because of high levels of meat consumption. The challenge in the developing world is to improve the food security for a wide swath of the population in a manner that reduces the potential of climate change impacts. Research indicates as countries develop, dietary patterns tend to move toward more resource-intensive practices that promote climate change. There is very little public or private policy focused on creating a playing field that prioritizes development (in affluent countries) or maintaining/enhancing (in less-affluent countries) of regional systems. Such priorities include new farmer development and support, supply-chain infrastructure creation, and consumer-preference targeting. Increasing urban/rural population ratio (especially in less-affluent countries) also will mean fewer farmers per capita, generating even more challenges.

How people access food has a number of implications for strategies to enhance food security as we move through the 21st century. It is estimated that in East Africa, the bulk of the population (and certainly the lower half of the economic strata) will continue to rely on traditional market systems as people urbanize with less self-provided food for the bulk of their daily sustenance. This implies three things: (i) the need for much greater productivity by farmers in these parts of the world, (ii) the need for much greater attention to post-harvest losses of food and (iii) the need for a better understanding and community-based development of the supply chain infrastructure in traditional markets throughout less-affluent countries.

Recent research highlights the impending growth of the "modern market sector" and the continued majority importance of the traditional sector in supplying and distributing food to urban residents during the next 25 years. Those in the lower half of the economic spectrum will continue to experience the traditional sector as the main source for urban food provisioning. This food system depends on regional/local production and a dynamic supply chain. In these areas, promoting improved food security and equitable economic growth in the traditional sector requires a community-driven approach. However, there is very little support to this sector in terms of policy promoting community-driven infrastructure development, or "appropriate technology" development — arenas where science and the private sector could play a role. It is clear that a focus on "appropriate community-based modernization" of the traditional sector will provide a dynamic action and outcome regarding market development for rural farmers, livelihood generation along the supply chain, and enhanced capacity for food security. Since cities in Sub-Saharan Africa generally will rely on local and regional food production, it is imperative that urban demand and rural supply are better linked, conceptually and in practice, to regional and local food systems and also to overall capacity of local, regional, and global agrifood systems.

Affluent countries have been moving along a path of regional food system redevelopment, while in less-affluent countries, the challenge is to not squander the existing regional food systems under the aegis of "modernization." Globalization has proceeded at a rapid pace with increases in food imports, food exports, and the worldwide distribution of foods. World trade agreements have consistently expanded the reach and regulation of global food suppliers, while often inhibiting efforts at local food system preferencing. Simultaneously, in affluent countries there has been growth in interest and activity around regional food systems in which relationships among people and with natural resources are important. In the U.S., this interest in local/regional purchasing, either directly from farmers or indirectly from a number of outlets, has expanded beyond fresh produce to include locally processed and value-added products. In the last 10 years this development has expanded well beyond farmers' markets to all facets of the wholesale, retail, and institutional markets.

Policy Issues

We have an opportunity to develop, redevelop, and maintain regionalized food systems across the globe in a manner that supports trade but simultaneously prioritizes a diversity of regionalized production, processing, and distribution. The outcome is a more resilient, food-secure, and sustainable food system for ourselves and future generations. There are a range of groups and institutions that can provide funding and leadership for the policy issues enumerated, including national governments with coordination through international bodies, the philanthropic sector, various private sectors and academic sectors for research and development, and academic sectors for training of engineers and other scientists in community-based technology development.

- Identify and implement scale- and community-appropriate technology to improve the efficiency of production and post-harvest management of food products (e.g., the smaller-scale farming sector). Technology that is accessible, affordable, and appropriate for conditions around the globe needs to be developed in this context. This must be made readily available along traditional supply chains in less-affluent countries and developing regional supply chains in affluent countries. Large and small companies in cooperation with engineering schools could develop scale-appropriate equipment.
- Foster land, soil, fresh water, and nutrient preservation/restoration practices in affluent and less affluent countries. This recognizes that preservation and restoration of our natural resources is a prerequisite for a sustainable food supply that enhances food security for future generations. Food and Agriculture Organization (FAO) and *International Federation of Organic Agriculture Movements (I*FOAM) internationally; U.S. Department of Agriculture (USDA) and *National Oceanic and Atmospheric Administration* (*NOAA*) nationally; NGOs such as World

Wildlife Fund and American Farmland Trust and foundations such as C.S. Mott and Surdna are examples for engagement in this arena.

- Promote incentives for young people to consider farming as a career worldwide. This necessitates investment in training, infrastructure development, land access, capital access, and fair-market access within both the academic (e.g., land grant universities in U.S.) and private sectors. USDA, U.S. Treasury, and the Environmental Protection Agency (EPA) as well as their state counterparts and foundations such as W.K. Kellogg and Jesse Smith Noyes are examples for engagement in this arena.
- Develop public policy incentive programs for residents of all countries focused on healthier eating and the reduction of the obesity epidemic. USDA's Supplemental Nutrition Assistance Program (SNAP); Wholesome Wave Foundation, and Fair Food Network; Community Support Agriculture purchases via insurance companies are examples for engagement.
- Give priority to a national security agenda that emphasizes food security and a food system designed for sustainability in a manner similar to that done relating climate change to national security and challenges for the national defense apparatus. Center for Regional Food Systems at Michigan State University exemplifies a location for this type of analysis.

References:

Hamm, M.W. 2009. Principles for Framing a Healthy Food System. *Journal of Hunger and Environmental Nutrition* 4(3-4): 241-250.

Hamm, M.W. 2008. Linking Sustainable Agriculture and Public Health: Opportunities for Realizing Multiple Goals. *Journal of Hunger and Environmental Nutrition*, 3(2/3):169-185.

Tschirley, D., S. Haggblade, and T. Reardon. 2013. Africa's Emerging Food System Transformation. http://gcfsi.isp.msu.edu/downloads/2013_MT2_White_Paper.pdf

***** A policy position paper prepared for presentation at the conference on Food Safety, Security and Defense: Focus on Food and the Environment, convened by the Institute on Science for Global Policy (ISGP), on October 5–8, 2014 at Cornell University, Ithaca, New York, U.S.***

Debate Summary

The following summary is based on notes recorded by the ISGP staff during the not-for-attribution debate of the policy position paper prepared by Prof. Michael Hamm (see above). Prof. Hamm initiated the debate with a 5-minute statement of his views and then actively engaged the conference participants, including other authors, throughout the remainder of the 90-minute period. This Debate Summary represents the ISGP's best effort to accurately capture the comments offered and questions posed by all participants, as well as those responses made by Prof. Hamm. Given the not-for-attribution format of the debate, the views comprising this summary do not necessarily represent the views of Prof. Hamm, as evidenced by his policy position paper. Rather, it is, and should be read as, an overview of the areas of agreement and disagreement that emerged from all those participating in the critical debate.

Debate conclusions

- To ensure that existing farmland is used in a sustainable manner and preserved for the next generation of farmers, policy frameworks (e.g., crop insurance) and incentive programs (e.g., Purchase of Development Rights [PDR] programs) must be explored.
- To increase farmer profits and provide incentives for the younger generation to consider careers in agriculture, the private sector needs to develop appropriately scaled and priced equipment for smaller scale production. Public-private partnerships may be necessary to support the availability and implementation of these new and existing technologies globally through increased investment in research and development.
- While current popular demands for niche markets, local food sourcing, and sustainable energy have attracted younger people to careers in farming, access to degree programs and training and mentoring opportunities is critically needed to improve the rates of success for these inexperienced farmers.

Current realities

In the United States, future farmers will originate from three different backgrounds: (i) those who learned about farming firsthand (e.g., reared or worked on a farm), (ii) young people with no generational connection to farming, and (iii) immigrants who may or may not have a farming background.

University student-run organic farms (e.g. Rutgers University, Michigan State University) allow students to acquire farming experience and appreciate the effort required in farming. High schools also have begun developing student-run gardens, which have led to successful entrepreneurial spin-off projects. These initiatives address the need to encourage younger people to value the practice of farming, as well as provide experience for potential future farmers.

Farmer decision-making and behavior are influenced by a variety of direct and indirect measures: i) policy frameworks such as crop insurance that incentivize farmers to produce the insured crop rather than diversifying, ii) the ability to rent farm land allowing options for crop rotation, and iii) incentives for farmers to remove land from row crop production to reduce pollution (e.g., excess nutrients from agricultural fertilizer used in the Mississippi basin have resulted in eutrophication and a "dead zone" in the Mississippi delta). Parallel issues are emerging in more- and less-affluent countries (e.g., East Africa) with regard to urban food systems. Farming increasingly is being viewed as destructive to the environment, while food products are undervalued, resulting in low profits. Appropriately scaled and priced equipment for small-scale production is lacking in both the U.S. and other countries.

The state of Michigan has seen the growth of a variety of food-related development networks in the last 12-15 years, such as farmers markets, food hubs, and incubator kitchens to start new food businesses. State government agencies also have been created (e.g., Michigan Food Policy Council) and economic development funds have supported several food development initiatives (e.g., hoop house and farmers market development, state agricultural products served in K-12 schools). Current research is being undertaken to conduct a network analysis of this growth and development. A shared measurement system for stakeholders (e.g., small-scale NGOs, state-level NGOs) is being developed by the Michigan State University Center for Regional Food Systems to track progress towards six goals set out by the Michigan Good Food Charter to be reached by 2020.

Scientific opportunities and challenges

The number of children from farming families who plan to continue farming is rapidly decreasing. Most existing ownership transition plans for family farms do not include passing farms to the next generation. While this creates opportunities for new farmers, these young people possess neither land as collateral nor the skillsets of those from traditional farming backgrounds (e.g., understanding the implications of changing seasons for production, or strategies for market development). Despite this lack of hands-on experience, many larger farms value the expertise and skillsets provided by schooling (i.e., high school and higher education), which teaches younger people how to run farm operations on a mass scale and size.

Research surveying farmers across the U.S. has found that farmers primarily want their land to be used for farming. However, farmers also value their land as a financial asset for their retirement. The challenge is to determine how best to incentivize farmers to share their land with the next generation of farmers.

In the U.S., there is a high demand for agricultural land (e.g., western New York, Midwestern U.S.) and land affordability is a challenge, particularly for younger generations of farmers. Low-interest loans or grant programs (e.g., Farm Credit East) aid new farm enterprises, and are helpful for younger people who want to engage in farming. There are opportunities to expand upon such programs.

In some areas (e.g., Michigan) farmers and land grants have utilized research to diversify agricultural products and build expertise as a response to market challenges such as organic farming and competition from China. This has created entrepreneurial opportunities for both the public and private sector (e.g., Michigan Market Maker, which connects farmers to new markets).

Advances in farming (e.g., transgenic crops that ensure high production yields) and modern technology (e.g., robotic dairy milking machines) is attracting the younger generation back to farming. However, the costs associated with buying or renting land and with modern farming technologies serve as considerable barriers for the next generation of farmers. There is opportunity for the private sector to develop appropriately scaled and priced equipment for smaller scale production that utilizes sustainable energy (e.g., solar power).

There also are opportunities to harness the younger generation's passion and curiosity regarding issues of environmental sustainability and agriculture. Various sociocultural factors have raised the popularity of agriculture for the younger generation, including the showcasing of food in pop culture (e.g., Food Network) and the appeal of certainty of origin (e.g., growing vegetables oneself) in a society where comfort is found in certainty. Because the pool of young aspiring farmers is relatively small, the ability of the next generation to replace older retiring farmers may be overstated. Failure rates for small businesses like vegetable farms also are disheartening and serve as a deterrent to potential farmers. There is opportunity here to develop incentives and policies for both small-scale and large-scale agriculture that help offset risk and cost.

Effort is required to encourage interest in agriculture by younger people around the world. Opportunity exists to bring modern farming technologies to other parts of the world (e.g., high tunnel technology in Nepal) as a way to ultimately increase farmer profits.

Development of urban horticulture is a scientific opportunity, particularly in larger depopulated U.S. cities such as Detroit. The challenges are to reduce the energy needed for cultivation (e.g., indoor lighting) and to ensure the spaces used for agriculture are safe from city contaminants (e.g., lead). Urban horticulture is by no means a panacea, but could provide a useful repackaging of available city landscapes.

Regional food systems have been giving way to demand for local food sourcing. The challenge of local sourcing of food is that existing infrastructures typically are designed for the large-scale flow of materials, and there will be difficulty in redesigning systems to handle smaller and more local production and distribution. This challenge creates niche opportunities for new businesses and private sector endeavors.

Policy issues

It is imperative to provide degree programs and training opportunities for young people interested in farming, and to encourage them to pursue these services. Training and mentoring opportunities must be developed for nongenerational future farmers to access land and capital, learn strategies for market development, and gain the experience and skillsets needed for farming. Additional training opportunities and programs for immigrants also are required to offset the decreasing number of U.S. farmers from traditional farming backgrounds.

PDR programs have been issued in the U.S. (e.g., New Jersey) where local municipality bonds are matched by the state. While smaller amounts of money for land (e.g., $100,000 per acre) may not incentivize farmers, larger PDR programs resulting in larger matched sums can encourage farmers to sell their land development rights to their local governments (e.g., county) while still retaining ownership of the land at its agricultural value and continuing use. The farmers could bestow their land to their progeny or sell it at the agricultural value, allowing for the preservation of the land for farming purposes.

The Farm Bill is changing and can function as an instrument to attract the younger generation to agriculture, but to leverage the Farm Bill, the public sector needs to work much more closely with the private sector, as opposed to traditional farming groups who do not consider sustainability issues in the same way. The Farm Bill also could promote fruit and vegetable production in addition to grain and cotton, which it currently is not doing.

New subsidy programs provide cost-free loans for farming technologies (e.g., high tunnels) and in return require products from those farms to be provided to low-income populations through various means (e.g., farmers markets, Headstart program, food stamps). Similar cost-free loans for technology programs must be implemented throughout other parts of the world to i) get new technologies onto the farms, and ii) provide healthy foods to low-income populations.

Food production can be defined by region (e.g., local, national) and regions can strive for food sovereignty (i.e., the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems), wherein indigenous resources provide a healthy diet for everyone within the region. Regional constraints can be subjective (e.g., differing geopolitical boundaries), but there is some opportunity to work with policymakers to designate areas to achieve food sovereignty. However, while regional food sovereignty may be a worthy academic exercise, it may not be the most practical use of policymakers' time. Rather, constructing policy at different levels (e.g., local, national, international) to encourage a diverse and mixed food system is preferable.

Organic food products are one of the fastest growing sectors in retail and many large processing companies (e.g., General Mills, Kellogg's) have acquired small organic brands, resulting in better distribution for organic products. Organic foods initially were a niche market, but are now ubiquitous in large food markets and popular among average consumers. Local products (e.g., New York cheese products) have the potential to follow the same trajectory and be distributed nationally or even internationally. Such prospects can play a role in invigorating the younger generation and must be supported through incentives for the private sector.

Immigrants face many similar challenges to nongenerational future farmers (e.g., access to land and capital) and additionally may not have in-depth knowledge of U.S. markets. Successful state programs exist (e.g., California, Texas) that provide migrant farm workers with opportunities to become independent farmers. These programs, which also can help address the need for farm labor, must be expanded.

Acknowledgment

Numerous individuals and organizations have made important contributions to the Institute on Science for Global Policy (ISGP) program on Food Safety, Security, and Defense (FSSD). Some of these contributions directly supported the efforts needed to organize the invitation-only ISGP conference, *Focus on Food and the Environment,* convened in partnership with the Cornell University at the Statler Hotel, October 5–8, 2014. Other contributions aided the ISGP in preparing the material presented in this book, including the eight invited policy position papers and the summary record, without attribution, of the views presented in the discussions, critical debates, and caucuses that ensued.

The ISGP greatly appreciates the willingness of those in the scientific and policy communities who agreed to be interviewed by the ISGP staff in their efforts to organize the content of this ISGP conference. Of special significance were the efforts of those invited by the ISGP to present their views of how environmental changes can be anticipated to impact food security throughout society. Their willingness to engage policy makers and other scientists in the vigorous debates and caucuses that comprise all ISGP conferences was especially appreciated. The biographies of these eight authors are provided in this ISGP book.

The success of every ISGP conference critically depends on the active engagement of all invited participants in the often-intense debates and caucuses. The exchange of strongly held views, innovative proposals, and critiques generated from questions and debates fosters an unusual, and even unique, environment focused on clarifying understanding for the nonspecialist. These debates and caucuses address specific questions related to formulating and implementing effective public and private sector policies. The ISGP is greatly indebted to all those who participated in these not-for-attribution debates and caucuses.

The members of the ISGP Board of Directors also deserve recognition for their time and efforts in helping to create a vital, increasingly relevant not-for-profit organization focused on addressing many of the most important societal questions of our time. Their brief biographical backgrounds are presented at the end of this book.

The energetic, highly professional work of the ISGP staff merits special acknowledgment. The staff's outstanding interviewing, organizing, and writing skills remain essential to not only organizing the conference itself, but also to recording the often-diverse views and perspectives expressed in the critical debates, accurately

capturing the areas of consensus and actionable next steps from the caucuses, and persevering through the extensive editing process needed to assure the accuracy of the material published here. All of the staff members' work is gratefully acknowledged. Their biographies are provided in this book.

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Dr. George H. Atkinson
Founder and Executive Director
Institute on Science for Global Policy
December 29, 2014

ISGP books from ISGP conferences listed below are available to the public and can be downloaded from the ISGP Web site: www.scienceforglobalpolicy.org. Hardcopies of these books are available by contacting Jennifer Boice at jboice@ scienceforglobalpolicy.org.

ISGP conferences on, or related to, Emerging and Persistent Infectious Diseases (EPID):

- *EPID: Focus on Antimicrobial Resistance,* convened March 19-22, 2013, in Houston, Texas, U.S., in partnership with the Baylor College of Medicine
- *21st Century Borders/Synthetic Biology: Focus on Responsibility and Governance*, convened December 4–7, 2012, in Tucson, Arizona, U.S., in partnership with the University of Arizona.
- *EPID: Focus on Societal and Economic Context*, convened July 8-11, 2012, in Fairfax, Virginia, U.S., in partnership with George Mason University
- *EPID: Focus on Mitigation*, convened October 23–26, 2011, in Edinburgh, Scotland, U.K., in partnership with the University of Edinburgh.
- *EPID: Focus on Prevention*, convened June 5–8, 2011, in San Diego, California, U.S.

- *EPID: Focus on Surveillance*, convened October 17–20, 2010, in Warrenton, Virginia, U.S.
- *EPID: Global Perspectives*, convened December 6–9, 2009, in Tucson, Arizona, U.S., in partnership with the University of Arizona.

ISGP conferences on Food Safety, Security, and Defense (FSSD):

- *FSSD: Focus on Food and the Environment,* convened October 5–8, 2014 in Ithaca, New York, U.S., in partnership with Cornell University.
- *FSSD: Focus on Food and Water,* convened October 14–18, 2013 in Lincoln, Nebraska, U.S., in partnership with the University of Nebraska–Lincoln.
- *FSSD: Focus on Innovations and Technologies,* convened April 14–17, 2013 in Verona, Italy.
- *FSSD: Global Perspectives,* convened October 24, 2012, in Arlington, Virginia, U.S., in partnership with George Mason University.

ISGP conference on Science and Governance (SG):

- *The Genomic Revolution*, convened September 6, 2014, in cooperation with the Parliamentary Office on Science and Technology of the British Parliament within the House of Lords. London, United Kingdom.

ISGP Academic Partnerships (IAP) conference

- *EPID: Focus on Pandemic Preparedness*, convened April 11–12, 2014 in Collegeville, Pennsylvania, U.S., in partnership with Ursinus College.

Biographical information of Scientific Presenters and Keynote Speakers

Scientific Presenters

Chris Barrett, Ph.D.

Prof. Christopher Barrett is the David J. Nolan Director and the Stephen B. & Janice G. Ashley Professor of Applied Economics and Management and an International Professor of Agriculture in the Charles H. Dyson School of Applied Economics and Management, a Professor of Economics in the Department of Economics, and a Fellow in the David R. Atkinson Center for a Sustainable Future (ACSF) at Cornell University. He teaches and conducts research in the areas of international development, environmental and resource economics, international trade, markets and price analysis, agricultural production and distribution, and applied econometrics. Dr. Barrett has authored 14 books and more than 260 journal articles or book chapters. In addition, he edits the Palgrave Macmillan book series *Agricultural Economics and Food Policy* and is presently an associate editor or editorial board member of various publications including the *African Journal of Agricultural and Resource Economics*, *European Review of Agricultural Economics*, and *Journal of African Economies*. Dr. Barrett is Co-Director of the Cornell African Food Security and Natural Resources Management Program, and is a recipient of the Cornell College of Agriculture and Life Sciences' Award for Outstanding Career Accomplishments in Science and Public Policy. He is also an elected Fellow of both the Agricultural and Applied Economics Association and the African Association of Agricultural Economists.

Jeffrey Blumberg, Ph.D.

Dr. Jeffrey Blumberg is a Professor in the Friedman School of Nutrition Science and Policy at Tufts University and also serves as the Director of the Antioxidants Research Laboratory at the Jean Mayer USDA Human Nutrition Research Center on Aging at Tufts. His research includes the food content, bioavailability, and pharmacokinetics of polyphenols and their impact on biomarkers of chronic disease risk. Dr. Blumberg has published more than 300 scientific articles and serves on the editorial boards of several scientific journals, including the *Tufts University Health and Nutrition Letter*, *Journal of Environmental Pathology, Toxicology and Oncology*, and *Journal of Medicinal Food*. He is a Fellow of both the American College of Nutrition and the

American Society of Nutrition. Dr. Blumberg is committed to the incorporation of sound nutrition science into public health policy and has served as a member of the Surgeon General's Workshop on Health Promotion and Aging, the Sports Medicine Committee of the U.S. Olympic Committee, the WHO/FAO Consultation on Preparation and Use of Food-Based Dietary Guidelines, and the Food Advisory Committee of the FDA.

Michael Hamm, Ph.D.

Dr. Michael Hamm is the C.S. Mott Chair of Sustainable Agriculture at Michigan State University (MSU) and the Director of the MSU Center for Regional Food Systems. He is affiliated with the Departments of Community, Agriculture, Recreation and Resource Studies; Crop and Soil Sciences; and Food Science and Human Nutrition at the university. Dr. Hamm serves on the Michigan Food Policy Council was the cofounder and is a member of Eastern Market Corp. Board of Directors, and chairs the National Advisory Committee of the W. K. Kellogg Foundation's Food and Fitness Initiative. Previously, Dr. Hamm was the director of the New Jersey Urban Ecology Program, the founding director of the Cook College Organic Farm, and a member and board president of the Northeast Organic Farming Association in New Jersey. His research is focused on community-based food systems as ways to improve food security, sustainable agriculture, and nutrition education and he is involved in community outreach programs to promote small scale organic farming.

John Ingram, Ph. D.

Dr. John Ingram is the Food Systems Programme Leader at the Environmental Change Institute of Oxford University, where he is tasked to develop and lead food systems research with emphasis on the multiple two-way interactions between food security and the environment. Dr. Ingram was appointed the Executive Officer Global Environment Change and Food Systems, an international research effort that culminated in 2011. He was then appointed the National Environmental Research Council's Food Security Leader and represents the council on the United Kingdom's Global Food Security Programme. Dr. Ingram contributed extensively to the Climate Change, Agricultural and Food Security Programme where he developed regional socioeconomic scenarios for East Africa, West Africa, and the North Indian Plain, which examined how the agricultural production and food security will change as a consequence of climate change to help inform decision making.

Kalidas Shetty, Ph. D.

Prof. Kalidas Shetty is a Professor of Plant Science & Founding Director of Global Institute for Food Security & International Agriculture at North Dakota

State University in Fargo and former Professor of Food Biotechnology at the University of Massachusetts Amherst. His research is focused on complex and integrative metabolic systems to improve food technologies and combat global diet- and environment-linked chronic disease and metabolic systems for sustainable community development. Dr. Shetty is involved in community development projects working for sustainable food systems for better health in indigenous communities in America, sustainable fruit and vegetable production in urban communities to improve diet and lead to better health and enhancing traditional food systems and food diversity to combat chronic diet-related disease in Asia, Africa, and the Americas. Dr. Shetty's academic and outreach efforts have been recognized with awards from the University of Massachusetts and the Asia-Pacific Clinical Nutrition Society. In addition to his research, Dr. Shetty has served as a Jefferson Science Fellow as the Science Advisor to the Bureau of Economic and Business Affairs, United States Department of State.

Donald Stoeckel, Ph.D.

Dr. Donald Stoeckel is a Biological Systems Modeller Research Scientist at Battelle Memorial Institute, a not-for-profit organization that focuses on applied science. Prior to joining Battelle, he spent 10 years as a hydrologist for the United States Geological Survey (USGS), where he focused microbial source tracking for water contamination and acted as the Principal Investigator for the USGS cooperative water program research projects. Dr. Stoeckel is a member of the American Society of Microbiology and the Water Management Association of Ohio. His research interests include microbial source tracking, traceback analysis to identify pathways of food product contamination, and transport of pathogenic microorganisms in the environment.

Jennifer Thomson, Ph. D.

Prof. Jennifer Thomson is Professor Emeritus at the University of Cape Town, South Africa, having previously been the Head of the Department of Microbiology. Her current research interests involve the development of maize resistant to African endemic maize streak virus and tolerant to drought. Dr. Thomson helped to draft South Africa's National Biotechnology Strategy and served on the National Council on Innovation for South Africa. She is on the board of the International Service for the Acquisition of Agri-Biotech Applications and African Agricultural Technology Foundation. She was also awarded the prestigious L'Oreal/Unesco award for women in science. Dr. Thomson is an advocate for genetically modified foods and writes and speaks regularly on the subject of genetically modified organisms, including two books geared toward making this technology accessible to the general public.

Wendy Wolford, Ph.D.

Prof. Wendy Wolford is a Professor of Developmental Sociology at Cornell University, and a coordinating member of the Land Deal Politics Initiative. She also serves as the Faculty Director for Economic Development at the Atkinson Center for Sustainable Futures (ACSF) at Cornell University and as Co-Leader for the Theme Project on Contested Global Landscapes for the Institute for Social Scientists at Cornell University. Dr. Wolford's research focuses on the political economy and geography of development, social movements and resistance, agrarian societies, political ecology, land use, land reform, and critical ethnography, all with a regional concentration in Latin America, particularly Brazil. She has worked extensively with Landless Rural Workers' Movement in Brazil where she works on the changing nature of the state and land reform. Dr. Wolford has published widely, including two books stemming from her work on land reform and social movements in Brazil. She is also the Principal Investigator of the ACSF Academic Venture Fund (AVF) project tasked with creating an indicator for assessing rural vulnerability.

Keynote Speakers

Kathryn Boor, Ph.D,

Dr. Kathryn Boor is Dean of the College of Agriculture and Life Sciences at Cornell University. Prior to her appointment, Dr. Boor served as Professor and Chair of the Department of Food Science at Cornell University. Her research focuses on identifying biological factors that affect transmission of bacteria in food systems, from the farm to the table. A Fellow of the American Academy of Microbiology, the International Academy of Food Science and Technology, and the Institute of Food Technologists, Dr. Boor serves on the editorial boards for the Journal of Food Protection, Applied and Environmental Microbiology and Foodborne Pathogens and Disease. She also served on the National Academy of Science/Institute of Medicine Committee on Review of the Use of Scientific Criteria and Performance Standards for Safe Food (December 2001 through May 2003) and completed a term on the National Advisory Committee on Microbiological Criteria for Foods in 2006. She was recently appointed to the United States Department of Agriculture's Foundation for Food and Agriculture Research. Presently, research in Dr. Boor's laboratory is funded by the National Institutes of Health, the USDA, the United States Department of Agriculture and the New York State Milk Promotion Advisory Board.

Julie A. Howard, Ph.D.

Dr. Julie Howard formerly served as the first Chief Scientist in the United States Agency for International Development's Bureau for Food Security, where she directed the agricultural research, policy and human and institutional capacity development programs of Feed the Future, the U.S. Government's global hunger and food security initiative. Previously, she was Feed the Future's Deputy Coordinator for Development, with responsibility for initiative-wide strategy and policy development, budget management, monitoring and evaluation, interagency coordination, and enhancing donor and non-governmental organization engagement. Dr. Howard served from 2003–2011 as Executive Director and Chief Executive Officer for the Partnership to Cut Hunger and Poverty in Africa, a Washington, D.C.-based nongovernmental research and advocacy organization that played a major role in identifying priorities and building support for increasing U.S. investments in African agriculture and food security prior to Feed the Future's launch in 2010. She was appointed as the nonprofit organization representative to the Global Agriculture and Food Security Trust Fund (GAFSP) Technical Advisory Council in 2010. From 1994–2011, Dr. Howard was adjunct and assistant professor international development in the Department of Agricultural, Food, and Resource Economics at Michigan State University. Her research interests include analysis of U.S. development assistance policies and programs relating to African agriculture and rural sector development; analysis of policies and programs related to the development and dissemination of improved technology, including constraints to seed and fertilizer sector development, and impact evaluation and planning of agricultural research and extension programs. She has carried out research in Zambia, Mozambique, Ethiopia, Uganda and Somalia. Dr. Howard served as a Peace Corps Volunteer in the Dominican Republic.

David W. Wolfe, Ph.D.

Dr. David Wolfe is Professor of Plant and Soil Ecology in the Department of Horticulture at Cornell University, and a leading authority on climate change impacts on crops, soils, and ecosystems. He has co-authored past and current national impact assessments sponsored by the U.S. Global Change Research Program, and was lead author of both the ecosystems and agriculture chapters of the 2011 "ClimAID" report, which focuses on vulnerabilities and adaptation strategies for New York. He currently leads a $4.7 million USDA project focused on new tools for carbon, nitrogen, and greenhouse gas management in agroecosystems, and contributes to several projects focused on building rural resilience to climate change in the U.S., Canada, Ethiopia, Malawi, and Tanzania. At Cornell he teaches "Climate Change and the Future of Food", chairs the Atkinson Center's Climate Change Focus Group, and co-chairs Cornell's Climate Change and Soil Health Program Work Teams. He occasionally writes for the popular press and is author of the soil ecology book for general audiences, "Tales From the Underground: A Natural History of Subterranean Life."

Biographical information of ISGP Board of Directors

Dr. George Atkinson, Chairman

Dr. George Atkinson founded the Institute on Science for Global Policy (ISGP) and is an Emeritus Professor of Chemistry, Biochemistry, and Optical Science at the University of Arizona. He is former head of the Department of Chemistry at the University of Arizona, the founder of a laser sensor company serving the semiconductor industry, and Science and Technology Adviser (STAS) to U.S. Secretaries of State Colin Powell and Condoleezza Rice. Dr. Atkinson is the current President of Sigma Xi, The Scientific Research Society. He launched the ISGP in 2008 as a new type of international forum in which credible experts provide governmental and societal leaders with the objective understanding of the science and technology that can be reasonably anticipated to help shape the increasingly global societies of the 21st century. Dr. Atkinson has received National Science Foundation and National Institutes of Health graduate fellowships, a National Academy of Sciences Post Doctoral Fellowship, a Senior Fulbright Award, the SERC Award (U.K.), the Senior Alexander von Humboldt Award (Germany), a Lady Davis Professorship (Israel), the first American Institute of Physics' Scientist Diplomat Award, a Titular Director of the International Union of Pure and Applied Chemistry, the Distinguished Service Award (Indiana University), an Honorary Doctorate (Eckerd College), the Distinguished Achievement Award (University of California, Irvine), and was selected by students as the Outstanding Teacher at the University of Arizona. He received his B.S. (high honors, Phi Beta Kappa) from Eckerd College and his Ph.D. in physical chemistry from Indiana University.

Dr. Ben Tuchi, Secretary/Treasurer

Dr. Ben Tuchi is chairman of the board of directors of the Arizona Research Park Authority. He received his B.S. and M.S. degrees in Business Administration from the Pennsylvania State University and his PhD in Finance from St Louis University. His full-time teaching career began in 1961 at St. Francis College and continued until 1976 at West Virginia University. From 1976 through 1996 he served in cabinet levels at West Virginia University, The University of Arizona, The University of North Carolina at Chapel Hill, and finally as Sr. Vice Chancellor for Business and Finance of the University of Pittsburgh. During those assignments he was simultaneously a tenured professor of finance. He retired from the last executive post in 1996 and returned to a full-time teaching position as Professor of Finance at the University of

Pittsburgh, until his retirement in 1999. For the two years prior to his retirement he was the Director of Graduate Programs in Business in Central Europe, at Comenius University, making his home in Bratislava, The Slovak Republic.

Dr. Janet Bingham, Member

Dr. Janet Bingham is President and CEO of the George Mason University (GMU) Foundation and GMU's Vice President for Advancement. GMU is the largest university in Virginia. Previously, she was President and CEO of the Huntsman Cancer Foundation (HCF) in Salt Lake City, Utah. The foundation is a charitable organization that provides financial support to the Huntsman Cancer Institute, the only cancer specialty research center and hospital in the Intermountain West. Dr. Bingham also managed Huntsman Cancer Biotechnology Inc. In addition, she served as Executive Vice President and Chief Operating Officer with the Huntsman Foundation, the private charitable foundation established by Jon M. Huntsman Sr. to support education, cancer interests, programs for abused women and children, and programs for the homeless. Before joining the Huntsman philanthropic organizations, Dr. Bingham was the Vice President for External Relations and Advancement at the University of Arizona. Prior to her seven years in that capacity, she served as Assistant Vice President for Health Sciences at the University of Arizona Health Sciences Center. Dr. Bingham was recognized as one of the Ten Most Powerful Women in Arizona.

Dr. Henry Koffler, Member

Dr. Henry Koffler is President Emeritus of the University of Arizona (UA). He served as President of the UA from 1982-1991. From 1982 he also held professorships in the Departments of Biochemistry, Molecular and Cellular Biology, and Microbiology and Immunology, positions from which he retired in 1997 as Professor Emeritus of Biochemistry. His personal research during these years concentrated on the physiology and molecular biology of microorganisms. He was Vice President for Academic Affairs, University of Minnesota, and Chancellor, University of Massachusetts/Amherst, before coming to the UA. He taught at Purdue University, where he was a Hovde Distinguished Professor, and the School of Medicine at Western Reserve University (now Case Western Reserve University). Dr. Koffler served as a founding Governor and founding Vice-Chairman of the American Academy of Microbiology, and as a member of the governing boards of Fermi National Accelerator Laboratory, the Argonne National Laboratory, and the Superconducting Super Collider Laboratory. He was also a board member of the Association of American Colleges and Universities, a member and Chairman of the Council of Presidents and a member of the executive committee of the National Association of Land Grant Colleges and Universities. He was also Founder, President and board member of the Arizona Senior Academy, the driving force in the development of the Academy Village, an innovative living and learning community. Among the honors that Dr. Koffler has received are a Guggenheim Fellowship and the Eli Lilly Award in Bacteriology and Immunology.

Mr. Jim Kolbe, Member

For 22 years, Mr. Jim Kolbe served in the United States House of Representatives, elected in Arizona for 11 consecutive terms, from 1985 to 2007. Mr. Kolbe is currently serving as a Senior Transatlantic Fellow at the German Marshall Fund of the United States, and as a Senior Adviser to McLarty Associates, a strategic consulting firm. He advises on trade matters as well as issues of effectiveness of U.S. assistance to foreign countries, on U.S.-European Union relationships, and on migration and its relationship to development. He is also Co-Chair of the Transatlantic Taskforce on Development with Gunilla Carlsson, the Swedish Minister for International Development Cooperation. He also is an adjunct Professor in the College of Business at the University of Arizona. While in Congress, he served for 20 years on the Appropriations Committee of the House of Representatives, was chairman of the Treasury, Post Office and Related Agencies subcommittee for four years, and for his final six years in Congress, he chaired the Foreign Operations, Export Financing and Related Agencies subcommittee. He graduated from Northwestern University with a B.A. degree in Political Science and then from Stanford University with an M.B.A. and a concentration in economics.

Dr. Charles Parmenter, Member

Dr. Charles Parmenter is a Distinguished Professor Emeritus of Chemistry at Indiana University. He also served as Professor and Assistant and Associate Professor at Indiana University in a career there that spanned nearly half a century (1964-2010). He earned his bachelor's degree from the University of Pennsylvania and served as a Lieutenant in the U.S. Air Force from 1955-57. He worked at DuPont after serving in the military and received his Ph.D. from the University of Rochester and was a Postdoctoral Fellow at Harvard University. He has been elected a Member of the National Academy of Sciences and the American Academy of Arts and Sciences, and a Fellow of the American Physical Society and the American Association for the Advancement of Science. He was a Guggenheim Fellow, a Fulbright Senior Scholar, and received the Senior Alexander von Humboldt Award in 1984. He has received the Earle K. Plyler Prize, was a Spiers Medalist and Lecturer at the Faraday Society, and served as Chair of the Division of Physical Chemistry of the American Chemical Society, Co-Chair of the First Gordon Conference on Molecular Energy

Transfer, Co-organizer of the Telluride Workshop on Large Amplitude Motion and Molecular Dynamics, and Councilor of Division of Chemical Physics, American Physical Society.

Mr. Thomas Pickering, Member

Mr. Thomas Pickering is Vice Chairman of Hills & Co, international consultants, and Strategic Adviser to NGP Energy Capital Management. He co-chaired a State-Department-sponsored panel investigating the September 2012 attack on the U.S. diplomatic mission in Benghazi. He served as U.S. ambassador to the United Nations in New York, the Russian Federation, India, Israel, El Salvador, Nigeria, and the Hashemite Kingdom of Jordan. Mr. Pickering also served on assignments in Zanzibar and Dar es Salaam, Tanzania. He was U.S. Under Secretary of State for Political Affairs, president of the Eurasia Foundation, Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs, and Boeing Senior Vice President for International Relations. He also co-chaired an international task force on Afghanistan, organized by the Century Foundation. He received the Distinguished Presidential Award in 1983 and again in 1986 and was awarded the Department of State's highest award, the Distinguished Service Award in 1996. He holds the personal rank of Career Ambassador, the highest in the U.S. Foreign Service. He graduated from Bowdoin College and received a master's degree from the Fletcher School of Law and Diplomacy at Tufts University.

Dr. Eugene Sander, Member

Dr. Eugene G. Sander served as the 20th president of the University of Arizona (UA), stepping down in 2012. He formerly was vice provost and dean of the UA's College of Agriculture and Life Sciences, overseeing 11 academic departments and two schools, with research stations and offices throughout Arizona. He also served as UA Executive Vice President and Provost, Vice President for University Outreach and Director of the Agricultural Experiment Station and Acting Director of Cooperative Extension Service. Prior to his move to Arizona, Dr. Sander served as the Deputy Chancellor for biotechnology development, Director of the Institute of Biosciences and Technology, and head of the Department of Biochemistry and Biophysics for the Texas A&M University system. He was Chairman of the Department of Biochemistry at West Virginia University Medical Center and Associate Chairman of the Department of Biochemistry and Molecular Biology at the College of Medicine, University of Florida. As an officer in the United States Air Force, he was the assistant chief of the biospecialties section at the Aerospace Medical Research Laboratory. He graduated with a bachelor's degree from the University of Minnesota, received his master's degree and Ph.D. from Cornell University and completed postdoctoral study at Brandeis University. As a biochemist, Dr. Sander worked in the field of mechanisms by which enzymes catalyze reactions.

Mr. Richard Armitage, Special Adviser

Mr. Richard L. Armitage is the President at Armitage International, where he assists companies in developing strategic business opportunities. He served as Deputy Secretary of State from March 2001 to February 2005. Mr. Armitage, with the personal rank of Ambassador, directed U.S. assistance to the new independent states (NIS) of the former Soviet Union. He filled key diplomatic positions as Presidential Special Negotiator for the Philippines Military Bases Agreement and Special Mediator for Water in the Middle East. President Bush sent him as a Special Emissary to Jordan's King Hussein during the 1991 Gulf War. Mr. Armitage also was Deputy Assistant Secretary of Defense for East Asia and Pacific Affairs in the Office of the Secretary of Defense. He graduated from the U.S. Naval Academy. He has received numerous U.S. military decorations as well as decorations from the governments of Thailand, Republic of Korea, Bahrain, and Pakistan. Most recently, he was appointed an Honorary Companion of The New Zealand Order of Merit. He serves on the Board of Directors of ConocoPhillips, ManTech International Corporation, and Transcu Ltd., is a member of The American Academy of Diplomacy as well as a member of the Board of Trustees of the Center for Strategic and International Studies.

Biographical Information of ISGP Staff

George Atkinson, Ph.D.

Dr. George Atkinson is the Founder and Executive Director of the Institute on Science for Global Policy (ISGP) and is an Emeritus Professor of Chemistry, Biochemistry, and Optical Science at the University of Arizona. His professional career has involved academic teaching, research, and administration, roles as a corporate founder and executive, and public service at the federal level. He is former Head of the Department of Chemistry at the University of Arizona, the founder of a laser sensor company serving the semiconductor industry, and Science and Technology Adviser (STAS) to U.S. Secretaries of State Colin Powell and Condoleezza Rice. In 2014, Dr. Atkinson was elected President of Sigma Xi, The Scientific Research Society. Based on principles derived from his personal experiences, he launched the ISGP in 2008 as a new type of international forum in which credible experts provide governmental and societal leaders with the objective understanding of the science and technology that can be reasonably anticipated to help shape the increasingly global societies of the 21st century.

Jennifer Boice, M.B.A.

Jennifer Boice is the Program Coordinator of the ISGP. Ms. Boice worked for 25 years in the newspaper industry, primarily at the Tucson Citizen and briefly at USA Today. She was the Editor of the Tucson Citizen when it was closed in 2009. Additional appointments at the Tucson Citizen included Business News Editor, Editor of the Online Department, and Senior Editor. She also was a business columnist. Ms. Boice received an M.B.A. from the University of Arizona and graduated from Pomona College in California with a degree in economics.

Marie Buckingham, B.S.

Marie Buckingham is a Senior Fellow with the ISGP. She is currently enrolled in the Environmental Science and Policy program at the School of International and Public Affairs (SIPA) at Columbia University, New York City. She received her B.S. in Public Affairs with a concentration in Environmental Management and Economics from Indiana University Bloomington. Previously, she worked at King & Spalding LLP as a project assistant under the Environmental Practice Group in Washington, D.C.

Samantha Cermignano, B.S.

Samantha Cermignano is a Senior Fellow with the ISGP. She received her B.S. in

Biology with a concentration in Pre-Health from Ursinus College. She previously held positions at the University of Pennsylvania as a visiting undergraduate researcher in hematology, at Critical Point Test Prep and Let's Get Ready as an SAT/ ACT preparatory coach, and at Ursinus College as a Resident Advisor and office assistant. Ms. Cermignano has been published in the journal *Blood*.

Sweta Chakraborty, Ph.D.

Dr. Sweta Chakraborty is Associate Director at the Institute on Science for Global Policy. She is also an adjunct assistant professor at Columbia University and a program associate on pharmaceutical regulation and product liability at Oxford University's Centre for Socio-Legal Studies. Prior to joining the ISGP, Dr. Chakraborty served as the resident cognitive behavioral scientist at Lootok Ltd., a risk management consulting firm. She received her doctorate in Risk Management from King's College London and her undergraduate degrees are in Decision Science and International Relations from Carnegie Mellon University. She has more than 20 published articles, has contributed to 3 books, and is author of *Pharmaceutical Safety: A Study in Public and Private Regulation.*

Adam Kuszak, Ph.D.

Dr. Adam Kuszak is an Adjunct Fellow with the ISGP. He is a pharmacologist dedicated to promoting the improvement of public health. His graduate training is in pharmacology and toxicology, where he studied the cellular and molecular basis of HIV infection and opioid addiction. He recently completed post-doctoral training at the National Institute for Diabetes and Digestive and Kidney Diseases at the National Institutes of Health, where he studied essential protein transporters in bacteria and mitochondria. Dr. Kuszak received his Ph.D. in pharmacology from the University of Michigan.

Clyde F. Martin, Ph.D.

Dr. Clyde Martin is a Senior Fellow with the ISGP. He has been appointed the Ex-Students Association Distinguished Visiting Professor of Mathematics at Texas Tech University, and as a Paul Whitfield Horn Professor. In 2012-2013, he served as a science advisor in the United States Department of State, primarily in the Secretaries' Office of Global Food Security. His main area of focus was science and technology and research and development as they relate to food and nutrition security, especially within the United States' global hunger and food security initiative, Feed the Future, and the G-8 New Alliance for Food Security and Nutrition. Dr. Martin is a Fellow of the Institute of Electrical and Electronic Engineers, a Fellow of the American Statistics Association, and an elected member of the International Statistics Institute.

In November of 2001 he received an honorary doctorate for his work in engineering from the Royal Institute of Technology in Stockholm, Sweden. He has received distinguished alumni awards from both Emporia State University and the University of Wyoming, where he received his Ph.D.

Christina Medvescek, B.A.

Christina Medvescek is Assistant Program Administrator at ISGP. A longtime journalist, editor and former director of public health education publications at the Muscular Dystrophy Association, Ms. Medvescek also is a certified mediator for the U.S. Postal Service and Equal Employment Opportunity Commission, a member of the Leadership Council of the Center for Community Dialogue (Tucson), and a volunteer community mediator for 31 years. A former instructor of cooperative problem-solving skills for children and families, she is currently earning a masters degree in Negotiation, Conflict Resolution and Peacemaking.

Sean Mulderrig, M.A.

Sean Mulderrig is a Fellow with the ISGP. He is currently pursuing a Master of Public Affairs in Environmental Science and Policy at Columbia University. His academic interests are focused on climate change mitigation policy, specifically renewable energy market incentives and carbon capture and storage technology research and development. Prior to enrolling at Columbia, he worked in the field of international immigration policy. Mr. Mulderrig earned his M.A. in Philosophy from Boston College in 2006

Aubrey Paris

Aubrey Paris is a Fellow with the ISGP and a Fellow with the Center for Science and the Common Good at Ursinus College, where she is a senior majoring in Chemistry and Biology and minoring in French. She was a 2014 AMGEN Scholar at the University of California, Berkeley, where her research involved the catalytic chemistry of alternative energy strategies. A co-founder of Globalized Ethics for Medical Science (GEMS), a nonprofit and publicly accessible infectious-disease reporting database, she also has worked for the advancement of the biotechnology industry at BioNJ, in Trenton, New Jersey.

Raymond Schmidt, Ph.D.

Dr. Raymond Schmidt is a Senior Fellow with the ISGP and a physical chemist/ chemical engineer with a strong interest in organizational effectiveness and community health care outcomes. While teaching at the university level, his research focused on using laser light scattering to study liquids, polymer flow, and biological transport phenomena. Upon moving to the upstream petroleum industry, he concentrated on research and development and led multidisciplinary teams from numerous companies to investigate future enhanced oil recovery ideas and to pilot/commercialize innovative recovery methods in domestic and foreign locations. Dr. Schmidt received his Ph.D. in chemistry from Emory University.

ISGP Academic Partnership (IAP) Interns and Faculty

Liza Conrad, Ph.D., Eckerd College

Dr. Liza Conrad received her B.S in Biological Sciences from the State University of New York College at Cortland, followed by a Ph.D. in Plant Breeding and Genetics from Cornell University. She is an Assistant Professor of Biology at Eckerd College in St. Petersburg, Florida. Her research focuses on genetic regulation of flower development in cereal crops, such as rice and maize.

ISGP Interns from Eckert College

Barbara Del Castello, Senior, majoring in Biology with a minor in Anthropology
Derek Godshall, Junior, majoring in International Relations and Global Affairs and Environmental Studies
Julia Sparks, Junior, majoring in Environmental Studies and Economics with a minor in Spanish
Cleo Warner, Senior, majoring in Environmental Studies and Literature and minoring in Psychology

Akshaye Dhawan, Ph.D., Ursinus College

Dr. Akshaye Dhawan is an Assistant Professor at Ursinus College. He received his Ph.D. in Computer Science from Georgia State University in 2009. He received his M.S. in Computer Science from Georgia State and his Bachelor of Engineering in Computer Science and Engineering from Visvesvaraya Technological University, India. His research work has focused on distributed algorithms for Wireless Sensor Networks and Social Networks.

Anthony Lobo, Ph.D., Ursinus College

Dr. Anthony Lobo is an Associate Professor of Biology at Ursinus College. His research involves studying the physiology, biochemistry, and molecular biology of archaea, and he teaches courses in microbiology, cell and molecular biology, and immunology. Dr. Lobo formerly was a postdoctoral research scientist at the University of Wisconsin-Madison. He received his Ph.D. from Cornell University in Microbiology and his Bachelor's degree in Microbiology from Pennsylvania State University.

ISGP Interns from Ursinus College

Tamas Budner, Junior, majoring in Physics
Rebecca Keenan, Junior, majoring in Biology and minoring in French
Edward Lee, Junior, majoring in Biochemistry and Molecular Biology and minoring in Philosophy
Elana Roadcloud, Junior, majoring in Biology
Mary Kate Speth, Senior, majoring in Biology and Environmental Studies and minoring in Peace and Social Justice and Applied Ethics