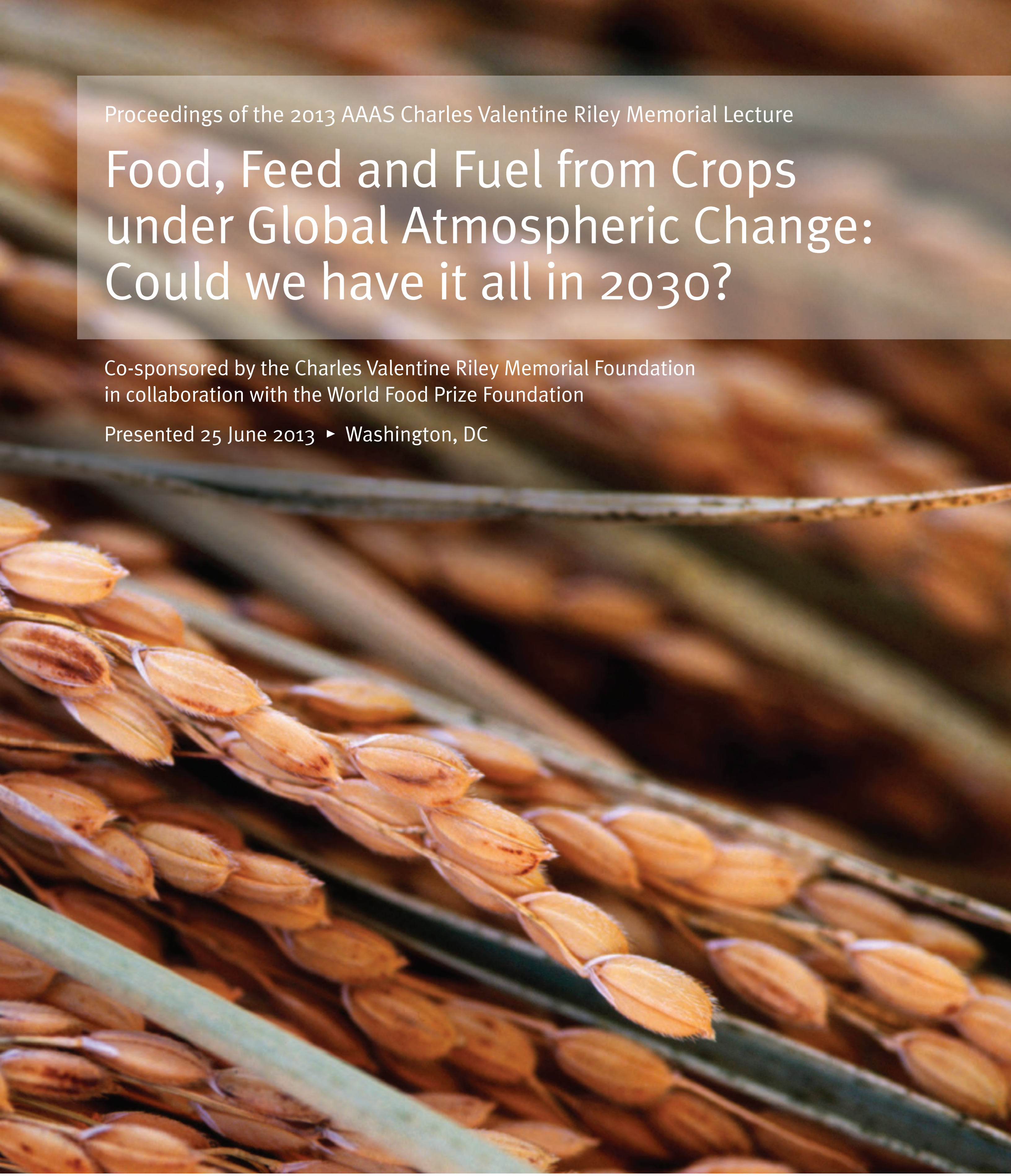

Proceedings of the 2013 AAAS Charles Valentine Riley Memorial Lecture

Food, Feed and Fuel from Crops under Global Atmospheric Change: Could we have it all in 2030?

Co-sponsored by the Charles Valentine Riley Memorial Foundation
in collaboration with the World Food Prize Foundation

Presented 25 June 2013 ▸ Washington, DC

AAAS

American Association for the Advancement of Science
1200 New York Avenue, NW
Washington, DC 20005
USA

Tel: (202) 326-6400
http://www.aaas.org

Foreword

"Could we have it all in 2030?"

Dr. Stephen P. Long, the 2013 AAAS Charles Valentine Riley Memorial Lecturer, says maybe. While not the most encouraging answer, he does suggest that with appropriate commitment and enhanced cooperation and collaboration from key stakeholders in the public and private sphere, there is a possibility that we might—as a global community—meet our needs. But, as Dr. Long and his fellow panelists emphatically stated, there are significant roadblocks to overcome and the changes have to start now.

From a global perspective, the world is heading towards a food shortage. Even though there have been technological advances that, for example, have allowed U.S. farmers to roughly triple corn and soybean production in the past five decades, population and economic growth are placing a surging demand on food. Additionally, we are also confronting rising temperatures, increased drought, and increases in atmospheric carbon dioxide and surface ozone concentrations.

Domestically, we are faced with the challenge of having to reinvigorate the federal agricultural R&D portfolio. A 2012 study by the President's Council of Advisors on Science and Technology (PCAST) concluded that America's agricultural research enterprise is no longer prepared to meet the challenges it will face in this century and that the country's "innovation ecosystem for agriculture" requires a fundamental restructuring.[1] The report offered several possible solutions that include rebalanced funding strategies, more efficient technology transfer, and increased investments in scientific workforce development. It also stressed the need for new multidisciplinary collaborations that would be supported by public/private partnerships.

The AAAS Charles Valentine Riley Memorial Lecture is an opportunity to explore the environmental and societal challenges facing our planet through the lens of agricultural innovation and its applications in a global context. Together with our colleagues at the Charles Valentine Riley Memorial Foundation and the World Food Prize Foundation, we aim to raise awareness about the importance of increased agricultural research, both in the U.S. and elsewhere, so that everyone may benefit and thrive in today's world.

I hope that you will find these proceedings useful.

Alan I. Leshner
Chief Executive Officer, AAAS and
Executive Publisher, *Science*

1 PCAST, Executive Office of the President, *Report to the President on Agricultural Preparedness and the Agriculture Research Enterprise* (Washington, DC, 2012).

Acknowledgements

This year's lecturer was chosen by a distinguished Selection Committee. We would like to thank the committee members for their efforts:

Jeffrey D. Armstrong
President, California Polytechnic State University

Daniel Bush
Professor and Vice Provost for Faculty Affairs,
Colorado State University

Edward Derrick
Chief Program Director, Center of Science, Policy & Society Programs,
American Association for the Advancement of Science

Ambassador Kenneth Quinn
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Richard Ridgway
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Wendy Wintersteen
Dean of the College of Agriculture and Life Sciences,
Iowa State University

We would also like to recognize and thank the following sponsors for their generous support of this year's lecture:

Charles Valentine Riley Memorial Foundation

Agricultural Research Service

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Participant Bios

Stephen P. Long is the Gutgesell Endowed University Professor of Plant Biology and Crop Sciences at the University of Illinois. His research has concerned maximizing crop photosynthetic productivity from the molecular to the field level, both via theoretical modeling and field scale experimental manipulations. His group has developed dynamic and steady-state models for analyzing and guiding improvement of crop photosynthetic efficiency. He has identified the most productive plants so far known from the wild and much of his work has focused on identifying the attributes that set these plants apart. With over 12,600 citations of his publications, Dr. Long was recognized by Thomson-ISI as one of the 250 most cited authors in Animal & Plant Biology, and one of the 20 most cited on Global Climate Change. He is Chief and Founding Editor of *Global Change Biology,* which is now ranked as the most cited journal on global change, after *Nature* and *Science*. He has provided briefings on opportunities for increasing food and fuel crop productivity through engineering photosynthetic efficiency to the White House, the Vatican, and the Bill & Melinda Gates Foundation. He serves on the Federal Bioenergy Technical Advisory Board, reporting to the Secretaries of Agriculture and of Energy; he is an External Advisor to the Wheat Yield Consortium, CIMMYT/USAID; and he is an elected advisor for BBSRC UK, Joint Programming Initiative of the European Commission on "Agriculture, Food Security and Climate Change" reporting to the EU Commissioner for Agriculture in Brussels, Belgium. In addition, he directs a multi-national Gates Foundation supported project to increase the photosynthetic productivity of rice and cassava.

Dr. Long obtained a B.S. in agricultural botany at the University of Reading, UK and a Ph.D. in plant environmental physiology from the University of Leeds, also in the UK. He received the 2012 Marsh Award for Climate Change Research from the British Ecological Society and the 2012 Kettering Award for Excellence in Photosynthesis Research from the American Society of Plant Biologists. He is a Fellow of the AAAS and of the Royal Society.

Richard Bonanno is the President of the Massachusetts Farm Bureau Federation where he leads their efforts to advocate for agriculture, aquaculture, and forestry interests before the Massachusetts legislature and executive agencies, while assisting members on municipal issues. He is the owner and operator of Pleasant Valley Gardens in Methuen, MA where he raises one acre of greenhouse potted flowering plants, bedding plants, and vegetable transplants; five acres of hardy mums; and 50 acres of fresh market vegetables. Dr. Bonnano has held leadership positions with many organizations including: Past President, New England Vegetable & Berry Growers; Past President, New England Council for Plant Protection; Past President, Northeastern Weed Science Society; Chair, Weed Science Society of

America Science Policy Committee; Public Member, Massachusetts Pesticide Board; and Member, EPA Farm, Ranch, and Rural Communities Committee. Prior to returning to the family farm in 1989, he was Associate Professor at North Carolina State University. He is a Senior Extension Specialist at the University of Massachusetts responsible for vegetable and small fruit weed management and on-farm food safety. He holds multiple scholarly and professional memberships and honors, including membership in the AAAS. He received his B.S. and M.S. degrees from Cornell University and his Ph.D. in plant physiology from Oregon State University.

Pam Johnson serves as President of the Corn Board of the National Corn Growers Association (NCGA), a farmer-led trade association with offices in St. Louis, MO and Washington, DC. She is also a member of the Agri-Industry Council Executive Committee and represents NCGA with the National Coalition for Food and Agriculture Research and the National Corn-to-Ethanol Research Center. She is a delegate to the U.S. Grains Council. Previously, Ms. Johnson chaired NCGA's Research and Business Development Action Team and its Bylaws Committee. She also served as the board liaison to the NCGA Grower Services Action Team and the organizational liaison to the National Pork Producers Council. In her home state, she is a Director of the Iowa Corn Growers Association and former Chairwoman of the Iowa Corn Promotion Board. She also serves as President of Iowa Corn Opportunities and is a former member of the U.S. Grains Council Biotech and Trade Policy A-Teams. She is a sixth generation famer who raises corn and soybeans with her husband, two sons and their young families. They also manage a seed business and are member investors in ethanol and biodiesel plants.

Per Pinstrup-Andersen is the H. E. Babcock Professor of Food, Nutrition and Public Policy, the J. Thomas Clark Professor of Entrepreneurship, and Professor of Applied Economics at Cornell University. He is also an Adjunct Professor at Copenhagen University. He is past Chairman of the Science Council of the Consultative Group on International Agricultural Research (CGIAR) and Past President of the American Agricultural Economics Association (AAEA). He served 10 years as the International Food Policy Research Institute's Director General and seven years as department head; seven years as an economist at the International Center for Tropical Agriculture, Colombia; and six years as a distinguished professor at Wageningen University. He is the 2001 World Food Prize Laureate and the recipient of several awards for his teaching, research and communication. His recent publications include "The African Food System and its Interaction with Human Health and Nutrition" (Cornell University Press 2010) and

“Food Policy for Developing Countries” (Cornell University Press 2011) coauthored with Derrill Watson. He has a B.S. from the Danish Agricultural University, an M.S. and Ph.D. from Oklahoma State University, and honorary doctoral degrees from universities in the United States, United Kingdom, Netherlands, Switzerland, and India. He is a fellow of the AAAS and the American Agricultural Economics Association.

Sonny Ramaswamy was appointed to serve as Director of the USDA’s National Institute of Food and Agriculture (NIFA) in 2012. As part of USDA’s Research, Education, and Economics mission area, he oversees NIFA funds for a wide range of extramural research, education, and extension projects that address the needs of farmers, ranchers, and agricultural producers. Prior to joining NIFA, Dr. Ramaswamy served as Dean of Oregon State University’s College of Agricultural Sciences and Director of the Oregon Agricultural Experiment Station. He provided overall leadership for the college’s academic programs at the Corvallis campus and OSU programs at Eastern Oregon University in La Grande, for-credit extended education, informal education through the Agricultural Sciences and Natural Resources Extension Program, and research at OSU’s main campus and 11 branch experiment stations throughout the state. Previously, he was Associate Dean of the Purdue University College of Agriculture and directed the university’s agricultural research programs from 2006 to 2009. He received a B.S. in agriculture and an M.S. in entomology from the University of Agricultural Sciences in Bangalore, India, and his doctorate in entomology from Rutgers University. He is also a graduate of the University of Nebraska’s New Academic Chair’s Program and Harvard University’s Management Development Program.

Lecture and Panel Discussion Highlights

Dr. Long's presentation focused on three challenges facing U.S. agriculture: 1) addressing food security under global change; 2) exploring opportunities in bio-energy without competing with food production; and 3) identifying barriers to achieving sustainable food and bio-fuel production by 2030. His lecture was followed by a discussion of these issues by a distinguished panel of stakeholders in the agricultural community.

Each panelist gave a brief opening statement in support of the challenges Dr. Long identified and underscored the importance of increased research in meeting those challenges in the years ahead. The panel then opened the floor for questions and comments from the audience.

Below are some highlights from the discussion that capture the essence of the thoughtful exchanges with the panel.

> "All the panel members seem to agree that we can produce enough food sustainably to feed everybody by 2050, but to do that we must invest more in rural infrastructure and agricultural research."
>
> –Per Pinstrup-Andersen

Funding for food and agriculture research, extension and education is stagnant; we need champions (in Washington) because there are many challenges to getting money for agriculture research.

> "The Farm Bureau believes that if farmers and ranchers have access to the proper tools, practices, technologies and markets, agriculture can continue to meet the challenges of food, feed and fuel for a growing population."
>
> –Richard Bonnano

> "For me the question, 'Food and fuel, can we have it all?' in the context of 9 billion people by 2050 is one that I could say 'Yes' we can IF. I believe the answer to that 'if' question was framed very well by Charles Riley when he said, 'You have to enhance agriculture through scientific knowledge.' Corn yields have gone up because of investments in science and technology brought back to the farm. We are up to the challenge."
>
> –Pam Johnson

Technology and tools are needed, coming out of research, extension and education.

> "There are wicked problems facing agriculture – scientists might have the most fantastic science and technology and tools available, but aren't able to deploy these tools in part because mere humans become involved in it and we cannot agree…"
>
> –Sonny Ramaswamy

Global competitiveness of agriculture in world markets demands continued support and expansion of technology.

> "Public-private partnerships work in research. It is important to farmers; we must get practices on the farm. Alliances among corn growers globally have worked."
>
> –Pam Johnson

> "The United States, particularly with the capabilities that we've got, whether it's the USDA's Agricultural Research Service… or this unbelievable enterprise of land grant universities… we've got a demonstrable capability and a track record of literally feeding the world…"
>
> –Sonny Ramaswamy

Investments we need to make as a nation, whether it is the public investments or the investments from private enterprise and NGOs, ALL THESE NEED to be deployed fully across the pipeline.

We are optimistic!

Food, Feed and Fuel from Crops under Global Atmospheric Change: Could we have it all in 2030?"

Stephen P. Long
Gutgesell Endowed University Professor of Plant Biology and Crop Sciences,
University of Illinois

First, my thanks to the Riley Foundation and to the AAAS for the great honor of this invitation and thank you all for coming. My work-home is the Institute of Genomic Biology at the University of Illinois. In front of the Institute are the Morrow Plots, which represent the oldest agricultural experiment, outside of Europe, anywhere in the world. Since 1876, crops have been grown there to look at the impacts of crops on soil and vice versa. As such, sustainability issues have been very much a part of the University since then. I mention this to show the connection between, on the one hand, the fundamental science in genomics and the other hand, practical agricultural research sciences. It will become increasingly important to us over the next decade to make a very firm connection between these two levels of investigation if the benefits of the genomic revolution are going to truly be translated into our major crops.

Today I am going to address three topics: food security under global change; exploring the U.S. opportunities in bio-energy without conflict with food production; and policy barriers to achieving this by 2030.

In addressing food security under global change, what are the most important crops, and what are the ones we have to care about most in the global context? If we look at global production today, corn is number one—that's relatively new—followed by rice, wheat and then soy, which is a very important protein source on global markets.

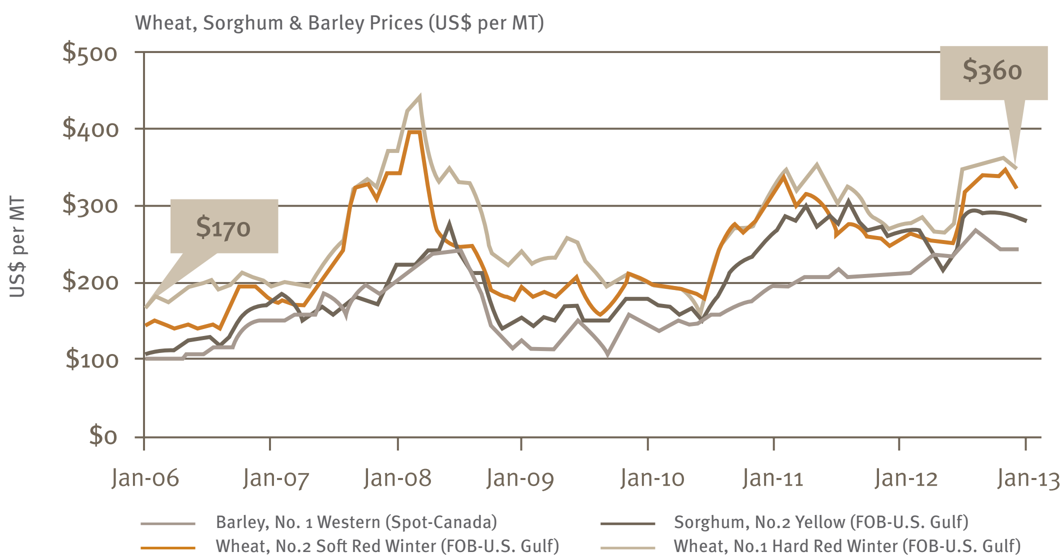
The U.S. makes a major contribution to these. In fact, almost a third of global soy production, over a third of global corn production and a very significant part of wheat production as well. What, perhaps, those figures don't show though is that in international markets, the U.S. is even more important as the largest exporter of these primary food-stuffs that are key to feeding the world — as it has been for well over a hundred years.

So if we look at exports minus imports in the first half of the 1990s; the U.S. was exporting just under a hundred million tons of those four crops. That compares with other major global exporters—Canada, Argentina, and Australia— at that time. If we move forward to the last half of the first decade of the twenty-first century, U.S. net exports have continued to climb by almost another 20 million tons, Canada and Australia have more or less stayed the same and we've seen the emergence of Argentina and Brazil as major net exporters.

On the other side of the equation we've seen Africa's demand grow substantially, but most notably China's, which appears to be rising almost exponentially at the present time. I should add that U.S. agricultural exports in 2011, the most recent figures we have, were worth $137 billion. That is about 10 percent of all our nation's exports now and it's almost doubled over the last 10 years. And if we look at projections for world food prices and demand, it could well double again over the next 10 years, becoming a most significant part of our exports.

Now despite these increases in production and exports, demand, at the present time, is growing faster than supply. This has resulted in wheat prices more than doubling in just seven years and sorghum prices almost tripling over that time. If we go further forward, looking at the UN Food and Agricultural Organization (FAO) report on how to feed the world in 2050, it projects there will be 34 percent more people, but the proportion of those who are urban will be much higher than today. They will have increased buying power, driving more demand for meat, in turn driving even more demand for grain. So FAO projects that by 2050 we'll need 70 percent more primary food-stuffs, particularly those four major crops I highlighted. Even by 2030, we'll need 30 percent more than we have today. There isn't a great deal more land that we can expand on to grow these particular crops, so at least 80 percent of this increase will have to come from more yield per acre of land. Some would even argue that land capacity for these crops is going in the opposite direction and these projections are soft on what we really need.

Grain Prices Doubled and Tripled in 7 Years

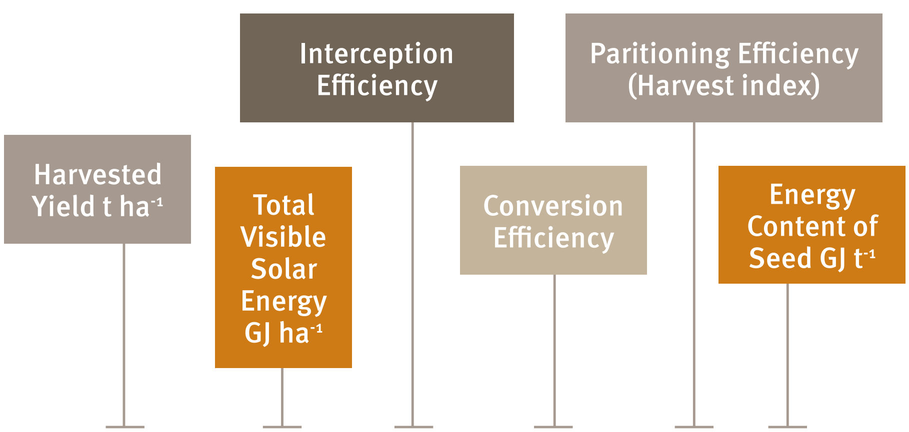


International Grain Prices as reported at http://chinaag.org/prices/international-prices/grain-prices-global

Unfortunately the gains we're making at the present time are too small. If we look at the Green Revolution maize, rice, and wheat were increasing in yield per acre of land globally by 30 percent per decade. If we fast forward to the first decade of the twenty-first century, the increase for wheat was zero, rice was in decline, and only maize was really holding its own. If we look at where in the world this yield stagnation is happening, for wheat this is much of Europe, India, and China. The hard red wheat growing areas of the U.S. are also seeing the same stagnation, while Australia is in reverse, because of what is believed to be climate change impacts. So why might we have had yield stagnation? Why isn't genetics improving yields of these crops as much as we'd like and as much as it did in the Green Revolution years?

The potential yield of a crop at a given location is the yield you would obtain with good nutrition in the absence of pests and diseases. From a first approximation this is determined by the amount of sunlight energy that's available to grow a plant, multiplied by the efficiencies with which that crop actually captures the sunlight energy, the efficiency with which it converts the captured energy into biomass, and the efficiency of partitioning that biomass into the grain or tubers, i.e. the part of the plant that we harvest. For a modern soybean cultivar growing on our university farm, sunlight interception efficiency was 89 percent, the efficiency with which the intercepted sunlight energy was converted into biomass was 3 percent and the efficiency of partitioning biomass into seed was 60 percent.

Understanding Potential Yield Stagnation



$$W_h = S \times \varepsilon_i \times \varepsilon_c \times \varepsilon_p / C$$

$$4.6 = 6200 \times 0.89 \times 0.032 \times 0.60/23$$

Morgan, Bollero, Nelson, & Long (2005) *Global Change Biology* 11, 1856–1865
Dermody, Long, McConnaughay, Delucia (2008) *Global Change Biology* 14, 556–564

According to these numbers, we're reading the biological limits in some of these areas. Crops cannot really intercept much more than 90 percent of the available sunlight and if we're going to have some stems and leaves, we're not going to see much more than 60 percent in the soybean seed. These are the two factors that we improved so effectively during the Green Revolution—to the point where they cannot be improved much further.

So what is left for us to improve? If we look at these factors, interception, conversion and partitioning, and we look at the theoretical maxima; the theoretical conversation efficiency is about 10 percent. But the achieved is only about a third of that, so this is one area where we do have the prospect of improvement. Conversion efficiency comes down to the process of photosynthesis—converting that intercepted sunlight into biomass. Now you might say, "If this is so important, breeders must have selected for this as they go out looking for more productive lines, indirectly they would have selected from increased photosynthesis?" And yes, indeed, we can see examples of that such as the Australian wheat cultivars.

Over many years leaf photosynthesis was gradually increased in that selection process, but it's increased at the rate of about 1 percent per decade. Yet, the FAO projects that we need 30 percent more by 2030. Of course a major reason why selection is so slow is that there is little variation in photosynthetic efficiency across the different forms of wheat germ and its relatives to select from, but we can engineer in variation from other species or by actually tweaking the process itself. But if we do this what practical evidence do we have that increasing photosynthesis is really going to increase yields?

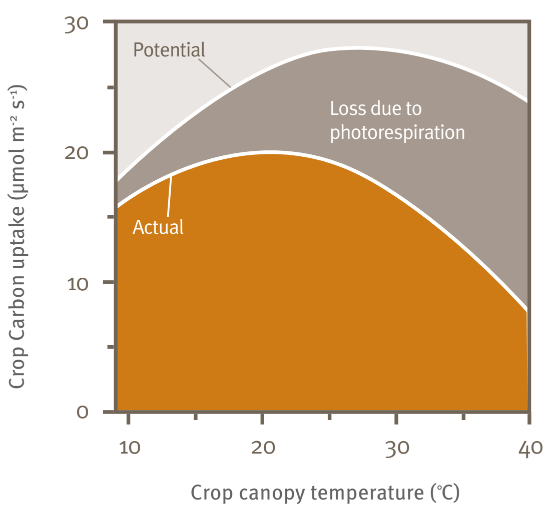
We have been conducting this unique experiment on the South Farms of the University of Illinois. Thirty-six rings within an 80 acre crop field have been engineered to simulate, under fully open air conditions, the future atmosphere. Some of these are elevating carbon dioxide to the level expected for the year 2050. Carbon dioxide is elevated by measuring second-by-second wind-speed and wind direction and then releasing carbon dioxide from the pipes via feedback computer control to maintain a constant elevation from sowing the crop until harvest. Since carbon dioxide is a limiting substrate for photosynthesis in soybean, wheat, and rice, we are in effect boosting photosynthesis. Does it result in an increase in yield?

Measuring leaf photosynthesis over the course of a year we get a 25 percent boost. What does that do to yield? What we find in soybean is yield goes up about 16 percent. Parallel experiments using the same technology that we've exported to China and Japan have shown rice increases 12 percent and experiments with wheat have shown a 15 percent increase. So this proves that if we can boost photosynthesis we can boost the yield of these crops. Can we do anything but wait for the carbon dioxide concentration of the atmosphere to rise? We think we can by engineering photosynthesis. Beside the need to accelerate crop yield improvement, why is this scientifically timely?

Three advances make this timely. 1) Photosynthesis is probably the best known of any plant process. We know every step of the process in plants and we know every gene involved as well. 2) The advent of high performance computing allows us to simulate the whole metabolic and biophysical process *in silico* so we can test potential modifications in a virtual leaf and inform us where we should focus our crop transformation effort. 3) As you will be aware from this year's World Food Prize, genetic transformation of plants is becoming increasingly more routine and more crops today can be transformed more efficiently.

One process I want to just make a diversion into is photorespiration. Photosynthesis takes up carbon dioxide by combining it with a sugar phosphate molecule containing five carbon atoms. This reaction is catalyzed by an enzyme called Rubisco, it is the most abundant protein on Earth. Every molecule of carbon in your body has been through this reaction catalyzed by Rubisco. Unfortunately that enzyme evolved at a time when there was no oxygen in the atmosphere. It also, we believe by accident of origin, catalyzes another reaction. It is oxygenation of this five-carbon initial acceptor of carbon dioxide. If this occurs, oxygen instead of carbon dioxide, reacts to produce a molecule called phosphoglycolate, which is then metabolized by the plant releasing carbon dioxide and burning energy. In effect it is the reverse of photosynthesis. It consumes oxygen and releases carbon dioxide, but like photosynthesis, it uses sunlight energy, hence its name - photorespiration. The net result is a decreased efficiency of net carbon dioxide uptake and carbohydrate formation.

Photorespiration = Large Loss



Photorespiration

- Large losses for cotton, rice, soy, wheat, trees
- Absent in C4 crops–Corn, Sorghum, Sugarcane
- Absent in many algae
- Reduced in glasshouses by elevating CO_2

Long et al. (2006) *Plant, Cell & Environment* 29, 315–330.

This reaction was discovered almost by accident by a graduate student at the University of Illinois, who didn't realize that oxygen wouldn't react with Rubisco and found it would when he was starting out with his Ph.D. studies. Together with USDA ARS scientist Bill Ogren, they were working on a fundamental problem, and they never thought at that stage it would have any application. In fact, one of the things we learned from their research was carbon dioxide inhibits this oxygenation reaction. It's a competitive inhibitor and today it's used in the glasshouse industry with many expensive crops to boost production. It is a finding now worth billions to the glasshouse industry and emphasizes the importance of fundamental plant sciences working side-by-side with crop production.

For crops in the open, losses due to photorespiration increase with temperature, because Rubisco becomes less effective at discriminating against oxygen as temperature rises. While it may cause crop losses of around 20 percent at 60°F, this will reach 50 percent at 90°F. Can we do anything about it? There are plants which do not photorespire. For example, blue-green algae have a series of proteins which allow them to concentrate carbon dioxide internally at Rubisco preventing photorespiration. So working together with the University of Nebraska, my former graduate student Will Hay and Professor Tom Clemente at Nebraska engineered one of these proteins that we thought might have an impact into soybean. There's a lot more to do on this but it's just an example of what is possible. Will found that with this protein carbon dioxide could reach Rubisco more easily, leaf photosynthesis was significantly increased, photorespiration was decreased and most importantly there was a significant increase in seed yield. This is just one example of how bioengineering can increase photosynthesis and in turn crop yields. There are many more that we could explore.

Another approach is to modify what's already in the plant. I'm obviously not going to bore you with all of the details of photosynthesis but we know the details of each of these 100 plus reactions so we can simulate these *in silico*. Once we have the process mimicking the behavior of a crop leaf, we can apply an evolutionary algorithm to tell us "Okay, what are the best bets for improvement?" When we did this one of the things that really stood out to us was an enzyme we call SBPase. The computer simulation said we would benefit by increasing this enzyme ten-fold and as a small protein it would require little resource to increase.

A colleague of mine in England engineered such an increase into tobacco. He used tobacco because it is easy and quick to engineer, so it makes a good test bed, before moving onto the less easily engineered but far more important food crops. My colleague found a 20 percent increase in the yield. We've now done the same in soybean and also found a significant increase in the yield. Why hasn't evolution already done this? Well it turns out that at the pre-industrial concentration of carbon dioxide this enzyme was not a limitation, but at today's level it is. One hundred years has been far too short a time for evolution and crop selection to catch up. We can apply this computational approach to a crop canopy and we can ask, "Tell us the optimal form for productivity?" What the computer comes up with is that we should have light green leaves at the top; dark green at the bottom; you should have fewer leaves (we have too many leaves); and the upper leaves should be vertical. This spreads the sunlight energy more evenly between the leaves and gives a very large increase in canopy photosynthesis from the simulation; but of course we know that most crops look very different to this simulated optimal form, they have dark green leaves at the top, so why this difference?

If you think about it, our crop plants have 25 million years of history of evolution as wild plants and in evolution it's about survival of the individual. If a plant captures much more light than it can use in photosynthesis in its upper leaves, it prevents its competitors below from capturing this light, growing and taking away water and nutrients. Yet, in a farmer's field we want the plants to cooperate with each other, not compete.

So do we have any evidence that this might be true? One thing the computer predicted was that there were too many leaves. So one of our graduate students took replicated plots, cut off every fifth developing leaf so that the actual leaf area index— that's the amount of leaf area, per unit of ground area— was reduced from five to four, which the computer said would be optimal. He found that as a result of this partial defoliation the seed yield was increased by eight percent which gives us some faith in the computational prediction. Through computational modeling, we have formulated a list of different ways we could increase photosynthesis. The Bill & Melinda Gates Foundation has now given our multi-national consortium $25 million over five years to see if we can begin to realize that through actual bioengineering of key food crops.

Gates Foundation Ripe Project

Alteration	% Increase Relative to Current Value	Time Horizon (years)	Lead
Photorespiratory bypass	15% (5–40%)	2–10	Illinois
Improved canopy architecture and chlorophyll distribution	40% (0–60%)	0–10	Illinois
Increased rate of recovery from photorespiration	15% (6–40%)	1–10	UC Berkley
Introduction of higher kcate foreign Rubisco	31% (17–40%)	+10	Rothamsted
Altered allocation of resources within the photosynthetic apparatus	40% (0–60%)	0–10	Essex
Introduction of cyanobacterial CO_2 concentrating mechanisms	40% (5–40%)	0–10+	Australian Natl Univ.

Updated from: Zhu, Long & Ort (2010) *Ann. Rev. Pl. Biology.* 61:235-261.

I don't want to give the impression that addressing improving crop production is going to be easy. Even if we succeed, it will be some time before these crops can be in farmers' fields. And we must recognize that we have a very poor picture of how global climatic and atmospheric change will affect crops. There is a serious lack of detailed science behind the predictions that are being made about yields under climate change. There have been very few field experiments at any scale, and when predictions are tested in the field they are often very different in result to the greenhouse and laboratory experiments on which we have to depend.

We now know from events of rising temperature that negative impacts on wheat may be much larger than previously predicted because high temperature events affect fertility and, as yet, we don't know of a way around it. Tropospheric ozone (surface ozone) is rising quite dramatically in Asia; that will cause quite large negative impacts on crop yields. Our certainty about this is low because we have very few field scale studies and interactions between rising carbon dioxide, ozone and temperature are almost unknown at field scale. I mentioned that the University of Illinois' Soy-FACE facility is the largest of its type and it is run largely on gifts to the University and by the USDA Agricultural Research Service. It is hard to keep it going by these means as we have no national effort to experimentally understand our future with respect to global change impacts on our crops under farm conditions. So while we are looking at other planets, we are not willing to spend several orders of magnitude less looking at the future of our own planet, and its ability to feed us.

When you do investigate the effects of climatic and atmospheric change on crops in the open air in a crop field there are many surprises. One that we found in our SoyFACE facility on our University South Farms is very relevant when we're thinking about Charles Valentine Riley.

The predictions from theory, greenhouse, and laboratory experiments were that rising carbon dioxide would decrease insect pest damage because it makes the material slightly less nutritious and therefore the pests would not perform as well. Unfortunately the pests didn't read this work and we've actually found the opposite. An example of this is the western corn root worm which is a major pest of corn that can cause considerable damage. We found under elevated carbon dioxide, the number of eggs laid more than doubled and if we combine carbon dioxide and ozone it almost tripled. It's not just this pest, we've seen that Japanese beetle damage of soybean has doubled and soybean aphid populations have also doubled. These are completely unexpected but show the importance of actually conducting these experiments under real field conditions with current crops, if we truly want to understand future threats to our food supply.

Now I want to move on to a different topic, bioenergy without conflict with food production. If we look at where we're getting bioenergy today, 86 billion liters of ethanol, the largest share of that comes from U.S. corn. The next largest share comes from the Brazilian soybean. Oil is obviously much smaller, with Germany as the largest biodiesel producer, much of that coming from rape seed, a close relative of canola. Obviously the corn ethanol has had a lot of criticism but I point out that what we've seen in last year's drought has actually shown it can provide to global markets. This is because if you're a co-op making corn ethanol and there's a shortage of corn such that global prices rise, what do you do? You can mothball your ethanol plant and sell your corn on the global market. While in a surplus year the ethanol plant will take up the slack. This price stabilizing effect encourages investment and in turn a rise in yields, as well as revitalizing our rural economies in the Midwest. When I first moved to Illinois, every day there was farm sale. A farm could no longer make it with $1.80 per bushel for corn. That's just not happening today, those family farms are staying in place with $4 to $6 per bushel of corn. So it's good for global stability of prices and it's good for our rural economies in these areas. Brazil has obviously been the big success story. In 2010, for the first time, Brazilians pumped more ethanol on the forecourts than gasoline. We projected looking at land opportunities and in improvements in the overall process, that by 2030 Brazil could be producing 15 percent of global liquid fuel use, so a Saudi Arabia in terms of its ability to provide liquid fuels.

There is a real opportunity for the U.S. to do the same, but crop choice matters and how we get our ethanol matters. If we look at liters per hectare that we can obtain, corn will provide many more gallons of ethanol per acre than biodiesel alternatives such as soybean and canola. Sugarcane will provide even more. However, as we become able to release the sugars that make up the celluloses of every plant part, then much more ethanol could be made and from any plant material. This opens important new opportunities for obtaining cheaper sugars for fermentation.

With the investment we've seen over the last five years, those technologies are now moving forward very rapidly. In the early 1900s German scientists managed to develop a system where they could make 45 gallons of ethanol from a ton of wood or straw. What we're seeing achievable today is about 100 gallons per ton, and the costs are coming down. We know it's do-able because biology does it. Cellulose is digested to sugars in a cow's rumen and in the guts of termites, and many other organisms. It is now just a question of translating that natural biology into an industrial process. We're hopefully going to see the Poet plant in Iowa coming online very soon to produce cellulosic ethanol.

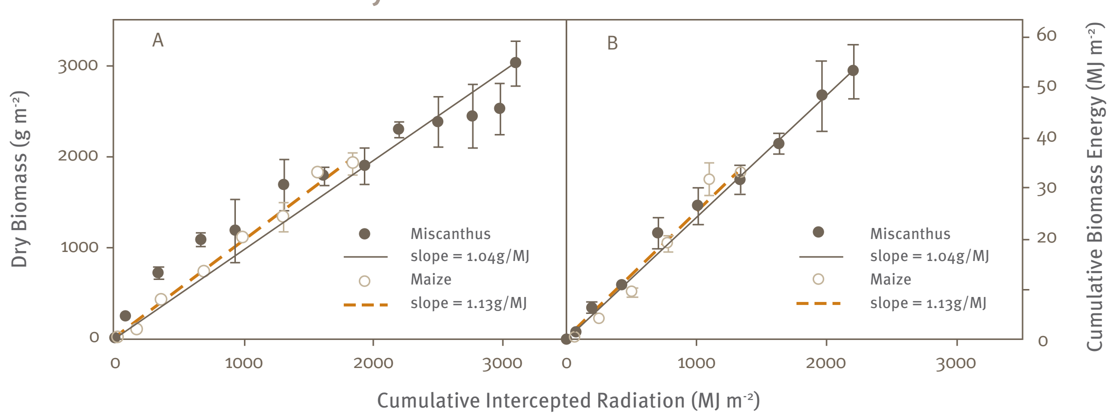
This technology allows us to use vegetable waste, straw, wood, or basically any plant material. This gives us the opportunity to re-imagine the crops we use for this purpose. What would the ideal bioenergy crop for this technology look like? What properties would it have? It would use C4 photosynthesis, the most efficient form of photosynthesis known. It would have a long growing season to capture as much sunlight as possible; it would be perennial to avoid repeated planting costs; it would bind the soil to avoid erosion; and it would not be an invasive risk. It would recycle nutrients since unlike food crops, these are not needed in the harvested product. And it will be productive on land unsuited to food crop production.

Why C4 photosynthesis? C4 plants, this includes maize, sugarcane, sorghum, are the most productive plants we know. I had the good fortune to be able to work for the United Nations Environment Programme in the late 80s to search for new plant resources. We were lucky enough to find after several years of investigation a highly productive grass growing on the Amazon floodplain. It produced 100 dry metric tons of biomass per hectare or 45 tons per acre. It is the highest productivity known for any plant and it uses C4 photosynthesis. The plant is now being investigated as a bio-resource in Brazil.

Why do we want a plant that will keep green leaves as long as possible? We are very proud of our corn yields in the Midwest; they are among the highest in the world. But if we look at our corn crop's use of solar energy at the University of Illinois, then we see that the crop captures less than half of the sunlight available during the freeze free period. The crop has not even covered the ground by Midsummer's day, when sunlight is at its peak. Our wheat crops capture early spring sunlight, but are mature by June and so miss most of the late summer sunlight. Perennials, on the other hand, leaf out as soon as spring warmth returns and will retain leaves into the early fall. Some temperate grasses are both C4 and perennial. The sterile hybrid grass *Miscanthus x giganteus* is a particularly productive example. It has given up to 27 dry tons per acre, although 15 would be more typical.

I originally worked with this crop in England, where it produced 13 dry metric tons per acre – a record for the cool climate of England. As a reference, southern England (where these trials took place) is the same latitude as the southern edge of the Hudson Bay. Today this crop is a significant bioenergy source in Britain. It is mainly used for combustion in electrical power stations. Like other perennial C4 grasses being considered for bioenergy, switchgrass and cord-grass, this plant recycles its nutrients. Nutrients are mobilized from the roots to the shoots in the spring and then returned as the shoots die back in the fall. The shoots are harvested dead, leaving most nutrients behind.

We've now conducted replicated trials across the state of Illinois, from north to south, east to west, on very different soils and we routinely find really high yields getting up to and above 15 tons per acre. This is typically double what we have obtained from switchgrass, but more importantly it is not just producing a lot of shoot biomass that can be harvested, it is also putting a lot of biomass into the soil. After five years, 30 tons of biomass had accumulated in the soil; so it is a good source of soil organic matter. We've compared it with corn and it will produce about 60 percent more biomass than a corn crop. This is because if we look at radiation interception Miscanthus starts earlier than corn and finishes later. It converts that intercepted sunlight into biomass at a similar efficiency, but does it for longer, giving it 60 percent more biomass yields. It can form leaves at lower temperatures than corn and it can maintain efficient photosynthesis in leaves at temperatures where corn cannot. We have conducted physiological and molecular studies to understand the basis of this difference. This is providing clues as to how we could modify corn, sorghum, and sugarcane to tolerate colder conditions and achieve a longer growing season.



Dohleman FG, Long SP. 2009. More Productive Than Maize in the Midwest: How Does Miscanthus Do It? *Plant Physiology* 150:2104-15

Miscanthus can be grown on land unsuited or marginal to annual row crops. It is good on slope land as its dense roots system binds the soil to protect against erosion. It will grow on soils where food crops have never been successfully cultivated. For example, we had trials in the west of Ireland, on land that as far as we know has never been used for arable crops, and yet gave very good yields. Our trials in Illinois actually show the highest yields in the south, on poor soils where corn or soybean would not normally be grown. It actually yielded slightly less on our good corn and soy soils in the center and north of the state. So this really tells us that this crop could be grown on land we're not using for corn and soy; in fact, we've now projected with wider trials what yields we might achieve across the country. Without irrigation, high yields are predicted for much of the area east of the Mississippi, including the area south of the corn belt where historically much land has been abandoned from row crop production or is now in low intensity pasture.

So what could this do towards achieving the Energy Independence and Security Act (EISA) of 2007 target of producing 35 billion gallons by 2030? Do we have the land resource? The area of the 48 contiguous States is 2211 million acres, out of which 390 million acres are in row crop agriculture, mainly food and feed crops, but also cotton. 27 million acres are in the conservation reserve program (CRP), i.e. we are paying land owners not to produce crops on this land. And more than twice that amount simply dropped off the latest agricultural census compared to the previous one 10 years earlier. Assuming we could make 100 gallons of ethanol from one metric ton of biomass, with a crop like Miscanthus we could reach the EISA 2030 target, that's a third of U.S. liquid fuel, with 15 million acres, about a quarter of the combined land area in CRP and recently abandoned. It doesn't have to be Miscanthus. There are productive cord-grasses that will grow on salt affected land of which we have many acres, for example in Texas and the Dakotas. Or we could use Agaves which are quite productive, without irrigation, in the semi-desert of the southwest. Short-rotation willows and aspen are another option. And as our demand for printing paper declines, there are sustainably managed forests. Indeed I would argue that if as a nation, there was the will we could replace all of our current petroleum use in transportation. We have the land resource and this does not require irrigation, good soil or intensive fertilization.

There would be very significant greenhouse gas benefits to this. Not only does the product replace the use of fossil fuels, but these crops add substantial amounts of carbon to the soil.

Now this is thinking about biomass for fermentation and chemical conversion to fuels, but we can go one step further and say, "What about the plant making the oil?" Now of course one of the problems with our current oil crops is that they do not produce enough per acre to be viable solutions. For example, soybean provides less that 1 barrel of oil per acre. But if we could make sugarcane produce oil instead of sugar it would produce over 30 barrels per acre which would make it very viable. The Advanced Research Projects Agency-Energy (ARPA-E) has provided support for us, as part of a national consortium of universities and national laboratories to look into this. We have a project called PETROSS where we're engineering oil accumulation into the stem of sugarcane and sweet sorghum, increasing photosynthesis and improving cold-tolerance. The progress has been faster than we thought. We've already achieved a 27-fold increase in oil accumulation in the stem, a 30 percent increase in photosynthesis and we've managed to hybridize with Miscanthus, creating a first hybrid that is considerably more cold-tolerant.

So in conclusion to this I'd say there are sufficient feed stocks capable of production on non-crop land to allow substantial offset of transportation liquid fossil fuel use. It requires the use of high productivity and low input crops that can grow on marginal or non-food crop land.

So finally, why do I think we may not realize these amazing opportunities for our nation? Barriers beyond science and technology. As a nation we are pretty good at inhibiting new technologies. Florida and Mississippi have actually enacted laws which state that if you want to grow a crop for energy, you have to take out a very expensive bond against that crop becoming invasive; if you grow the exact same crop for agriculture (we assume this means a non-energy use) you are exempt. This makes absolutely no sense. Biologically if a crop is an invasive plant - it will be so whatever the end-use.

The low carbon fuel standard requires indirect land use change to be taken into account, yet if we are making high fructose corn syrup we don't have to take this into account. And, of course, one which plant molecular biologists will be very familiar with is, if we precisely put one gene into a plant, we know exactly what we've put in, where it goes and what it does; we have to go through a huge number of very expensive regulatory hurdles governed by three different agencies. Yet if I cross my wheat plant with a wild distant relative, then back-cross introducing many genes about which I have little idea of the function, I can do that without any of those regulatory hurdles.

There are structural issues too. We are doing a bad job at horizontal integration, specifically tying our molecular sciences, our fundamental science, together with farm level production. We can produce great plant molecular biologists studying the basics with model species, but far fewer who can translate this effectively into a crop in the field situation. We're very good at vertical integration within our disciplines but not horizontal. We have few examples of integration with industry, where interaction on both sides is far less effective than it needs to be. And, most importantly, we're certainly lacking funding for basic and translational research in agriculture, particularly in the plant sciences and we are beginning to be out-competed by other countries in an industry we have led for at least the past 100 years.

So in conclusion from a scientific perspective we could have it all in 2030, with the right investment and with the right policies for the benefit of the USA, but will policy allow us?

Thank you.

To view Dr. Long's full presentation, please go to www.aaas.org/go/Riley.

Federal Food, Nutrition, Agriculture and Natural Resource Sciences Funding Update

Matt Hourihan
Director, R&D Budget and Policy Program
American Association for the Advancement of Science

During a year of marked divergence in House and Senate appropriations decisions, USDA R&D funding presents something of a mixed bag. Following a relatively strong Administration request seeking notable R&D increases through the agency, both the House and the Senate have fallen short, with the House R&D appropriation nearly $300 million below the Senate. The House would make minimal adjustments from FY 2013 post-sequestration funding, with the Agricultural Research Service (ARS) getting a small increase above inflation, and the National Institute of Food and Agriculture (NIFA) getting a small decrease. Meanwhile, the Senate – operating under a much higher overall spending target – would grant both agencies funding increases above FY 2012 levels prior to sequestration. Notably, both chambers would grant an increase to the Agriculture and Food Research Initiative, continuing recent growth in the competitive research program. Both chambers have also declined to provide a requested $155 million for construction of a new poultry science center in Georgia. Elsewhere in USDA, while the Senate would grant the request for Forest Service R&D budget, the House would cut it in half.

Other food, nutrition, agriculture, and natural resource related agencies show a similar funding record so far. The National Science Foundation and the Department of Energy's Office of Science receive generous increases in the Senate, at or near the request, but little to no gain from post-sequestration levels in the House. The House has yet to introduce its NIH spending bill at the time of this writing, but the adopted spending target for that bill is 26 percent below the Administration's request. With substantial controversy and uncertainty plaguing the spending debate this year, it remains to be seen whether any of these appropriations outcomes will stand up in any ultimate agreement.

This table and analysis present updated figures from "AAAS Report XXXVIII: Research and Development FY 2014." Figures have been updated based on additional agency reporting and appropriations bills and reports from Congress. To read the entire analysis of the FY 2014 budget, go to www.aaas.org/spp/rd/rdreport2014/.

Federal Food, Nutrition, Agriculture, and Natural Resource Sciences Funding Update

Federal Food, Nutrition, Agriculture, and Natural Resource Science Investments

(budget authority in millions of dollars)

	FY 2012	FY 2013	Change FY 12-13		FY 2014	FY 2014	Change FY 13-12		FY 2014	Change FY 13-14	
	Actual	Estimate	Amount	Percent	Budget	House**	Amount	Percent	Senate**	Amount	Percent
Selected USDA Program R&D*											
Agricultural Research Service (ARS)*	1,125	1,048	-77	-6.8%	1,303	1,098	50	4.7%	1,147	99	9.4%
Natl Inst of Food & Agri (NIFA)	750	687	-63	-8.4%	753	678	-9	-1.4%	729	-42	6.1%
Agri & Food Research Init (AFRI)	264	276	12	4.5%	383	291	15	5.3%	316	40	14.7%
Forest Service	326	317	-9	-2.9%	341	167	-149	-47.1%	341	25	7.8%
Forest and Rangeland Research	322	307	-15	-4.6%	337	163	-144	-46.8%	337	30	9.7%
U.S. Dept of Agriculture R&D*	2,331	2,167	-164	-7.0%	2,523	2,066	-101	-4.6%	2,345	178	8.2%
Other Related Agencies (Includes Non-R&D Components)											
National Institutes of Health	30,010	28,360	-1,651	-5.5%	30,490	NA	- -	- -	30,339	1,980	7.0%
National Science Foundation	5,705	5,510	-196	-3.4%	6,240	5,697	188	3.4%	6,059	550	10.0%
Dept of Energy - Office of Science	4,463	4,281	-182	-4.1%	4,744	4,284	3	0.1%	4,744	463	10.8%

Source: AAAS estimates based on OMB R&D data, agency budget documents, and Congressional reports. All figures refer to committee bills, except for Dept. of Energy Office of Science, which has passed full House. Figures include mandatory and discretionary R&D.

*FY 2013 are estimates based on agency budget documents, final appropriations, and sequestration.

**FY 2012 includes $40 million for Biomass R&D program.

About Charles Valentine Riley

Charles Valentine Riley Examining an Insect.

Undated. Charles Valentine Riley Collection. Special Collections, National Agricultural Library, Beltsville, Maryland. http://www.nal.usda.gov/speccoll/.

Charles Valentine Riley (1843-1895)

"Professor Riley," as he was generally known, was born in Chelsea, London, England, on September 19, 1843. He attended boarding school at Dieppe, France; and Bonn, Germany. Passionately fond of natural history, drawing, and painting, he collected and studied insects and sketched them in pencil and in color. At both Dieppe and Bonn, he won prizes in drawing and was encouraged to pursue art as a career.

At the age of 17, he came to the United States and settled on an Illinois farm about 50 miles from Chicago. Soon his attention was drawn to insect injuries of crops, and he sent accounts of his observations to the *Prairie Farmer*. At the age of 21, Riley moved to Chicago and worked for this leading agricultural journal as a reporter, artist, and editor of its entomological department. His writings attracted the attention of Benjamin D. Walsh, the Illinois State entomologist. It was through Walsh's influence as well as the recommendation of N.J. Coleman of *Coleman's Rural World* that Riley was appointed in the spring of 1868 to the newly created office of entomology of the State of Missouri. From 1868 to 1877, in collaboration with T. W. Harris, B. D. Walsh, and Asa Fitch, Riley published nine annual reports as State Entomologist of Missouri, which unequivocally established his reputation as an eminent entomologist. Today, authorities agree that these nine reports constitute the foundation of modern entomology.

From 1873 to 1877, many Western States and territories were invaded by grasshoppers from the Northwest. In some states their destruction of crops was so serious that it caused starvation among pioneer families. Riley studied this plague and published results in his last three Missouri annual reports and worked to bring it to the attention of Congress. In March 1877, he succeeded in securing passage of a bill creating the United States Entomological Commission, the Grasshopper Commission administered under the Director of the Geological Survey of the U. S. Department of the Interior. Riley was appointed chairman, A. S. Packard, Jr., secretary; and Cyrus Thomas, treasurer.

All this time, Riley, with the help of Otto Lugger, Theodore Pergrande, and others, was also making brilliant contributions to the knowledge of the biology of insects. Besides studying the life cycles of the 13 and 17 year cicadas, he also studied the remarkable *Yucca* moth and its pollination of the *Yucca* flower, a matter of special evolutionary interest to Charles Darwin. In addition, he conducted intensive life history studies of blister beetles and their unusual triungulin larvae, and the caprification of the fig.

In the spring of 1878, Townend Glover retired as entomologist to the U. S. Department of Agriculture and Riley was appointed his successor. After a year in this position, Riley resigned owing to a disagreement with the Commissioner of Agriculture over Riley's practice of making independent political contacts; he then continued the work of the U. S. Entomological Commission with others, from his home. Two years later, after the inauguration of President James A. Garfield in 1881, Riley was reappointed and remained chief of the Federal Entomological Service until June 1894, when the Service was renamed the Division of Entomology of the U.S. Department of Agriculture. In 1882, Riley gave part of his insect collection to the U. S. National Museum, now The Smithsonian Institution, at which time he was made honorary curator of insects. In 1885, he was appointed assistant curator of the Museum, thus becoming the Museum's first curator of insects, whereupon he gave the Museum his entire insect collection consisting of 115,000 mounted specimens (representing 20,000 species), 2,800 vials, and 3,000 slides of specimens mounted in Canadian balsam.

One of Riley's greatest triumphs while Chief of the Federal Entomological Service was his initiation of efforts to collect parasites and predators of the cottony cushion scale, which was destroying the citrus industry in California. In 1888, he sent Albert Koebele to Australia to collect natural enemies of the scale. A beetle, *Vedalia cardinalis,* now *Rodolia cardinalis,* was introduced into California and significantly reduced populations of the cottony cushion scale. This effort gave great impetus to the study of biological control for the reduction of injurious pests and established Charles Valentine Riley as the "Father of the Biological Control." For a review of the cottony cushion scale project, see Doutt, 1958.

A prolific writer and artist, Riley authored over 2,400 publications. He also published two journals, the *American Entomologist* (1868-80) and *Insect Life* (1889-94). Riley received many honors during his lifetime. He was decorated by the French Government for his work on the grapevine *Phylloxera*. He received honorary degrees from Kansas State University and the University of Missouri. He was an honorary member of the Entomological Society of London and founder and first president of the Entomological Society of Washington. He and Dr. L. O. Howard, Riley's assistant in the Federal Entomological Service, were among the founders of the American Association of Economic Entomologists, which became part of Entomological Society of America in 1953.

Tragically, on September 14, 1895 Riley's life was cut short by a fatal bicycle accident. As he was riding rapidly down a hill, the bicycle wheel struck a granite paving block dropped by a wagon. He catapulted to the pavement and fractured his skull. He was carried home on a wagon and never regained consciousness. He died at his home the same day at the age of 52, leaving his wife with six children.

ACKNOWLEDGEMENTS

We would like to thank the U.S. Department of Agriculture, National Agricultural Library (NAL) for providing Riley's biographical information and accompanying image. The Charles Valentine Riley Collection at NAL includes correspondence, unpublished lectures, photographs, news clippings, drawings, reprints, books, and artifacts covering the time period from 1868 to 1919.

About the Partner Organizations

In 2008, the Charles Valentine Riley Memorial Foundation (RMF) selected the American Association for the Advancement of Science (AAAS) to receive an endowment to establish the annual AAAS Charles Valentine Riley Memorial Lecture "to promote a broader and more complete understanding of agriculture as the most basic human endeavor and … to enhance agriculture through increased scientific knowledge."

Concurrently with establishment of the endowment, a collaborative agreement between RMF, AAAS, and the World Food Prize Foundation (WFPF) was signed to implement the annual lecture. Collaboration between AAAS, RMF, and WFPF provides a unique opportunity to build upon Charles Valentine Riley's legacy as a "whole picture" person with a vision for enhancing agriculture through scientific knowledge. Professor Riley's involvement with AAAS, beginning as a member in 1868, being elected a Fellow in 1874, and serving as Vice President for the biology section in 1888, brings into the perspective his broad view of how science impacts on agriculture when placed in the broadest context.

AAAS
ADVANCING SCIENCE, SERVING SOCIETY

The American Association for the Advancement of Science (AAAS)

The American Association for the Advancement of Science (AAAS) is the world's largest general scientific society and publisher of the journals *Science* (www.sciencemag.org), *Science Signaling* (www.sciencesignaling.org), and *Science Translational Medicine* (www.sciencetranslationalmedicine.org). AAAS was founded in 1848, and serves 262 affiliated societies and academies of science, reaching 10 million individuals. The non-profit is open to all and fulfills its mission to "advance science and serve society" through initiatives in science policy, international programs, science education, and more. More information on AAAS and its diverse portfolio of activities can be found at www.aaas.org.

Charles Valentine Riley Memorial Foundation

The Charles Valentine Riley Memorial Foundation (RMF) is committed to promoting a broader and more complete understanding of agriculture and to building upon Charles Valentine Riley's legacy as a "whole picture" person with a vision for enhancing agriculture through scientific knowledge. Founded in 1985, RMF recognizes that agriculture is the most basic human endeavor and that a vibrant, robust, food, agricultural, forestry, and environmental-resource system is essential for human progress and world peace. RMF conducts a wide range of program activities that include discussion groups, forums, round tables, workshops, briefing papers, and lectures on various parts of the food, agricultural, forestry, and environmental-resource system. RMF's goal is to have all world citizens involved in creating a sustainable food and agriculture enterprise within a responsible rural landscape. More information is available at www.rileymemorial.org.

World Food Prize Foundation

Founded by Nobel laureate and "Father of the Green Revolution" Dr. Norman E. Borlaug, the World Food Prize is a $250,000 award presented annually for breakthrough achievements in science, technology, and policy that have improved the quality, quantity, and availability of food in the world. Termed "the Nobel Prize for Food and Agriculture" by several heads of state, it is presented each October in conjunction with a week of events that includes the international "Borlaug Dialogue" symposium and gathers pre-eminent global leaders and experts representing over 65 countries. The 2013 World Food Prize events will take place October 16 to 19 in Des Moines, Iowa. Information about the World Food Prize events, highlights from past Borlaug Dialogue symposia, and nomination criteria are available at www.worldfoodprize.org.