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Speaker: *Kenneth Cassman*

Introduction:

Ambassador Kenneth M. Quinn
President - World Food Prize Foundation

As we wanted to formulate the process to have somebody come and answer that question at least from his or her point of view of—How are we doing? What are the trendlines? Are we on course to be able to feed nine billion people. Looked around, I consulted with my Council of Advisors, and had Peter McPherson and Steve Leath and Gordon Conway and others. And the name we came up with was Ken Cassman, who's just down Interstate 80 to the west in Nebraska and who has been doing really incredible and insightful work. He's now also the chair of the editorial board of a wonderful new publication by Elsevier, *Global Food Security,* where the ideas are out there being formulated, being put forward. The challenges are there, and this is to bring to the fore these critical questions. So please join me in welcoming Dr. Ken Cassman.

THE BORLAUG REPORT:
ASSESSING THE GREATEST CHALLENGE – WHAT ARE THE TRENDLINES? ARE WE ON COURSE?

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So thank you, Ambassador Quinn, thank you, Dr. Nwanze, for setting the stage. And, beware, it's hard to follow someone that can give such an eloquent talk without slides. University professors can't do that. So, and I want to thank the committee, the Advisor Council for the World Food Prize for inviting me to address you. And, acknowledge my co-author on this presentation, Professor Kendall Lamkey from Iowa State University, head of the Department of Agronomy. And we were asked to provoke, to lay the foundation for a robust dialogue. And, as noted by Ambassador Quinn, it's our views, and certainly hopefully open for discussion.

So I want to talk about briefly the broader challenge of food security. It's not just the pile of food—and you've heard Dr. Nwanze talk about it in depth—but it's nutritious food, it's affordable, it's accessible. But I wanted to add something that worries me in the twilight of my career, and having worked on global food security for quite a while, is the trend of the debate to be looking for the minimum of food that we have to produce to feed nine to ten billions, as if humans are amoebas on petri dishes.

And I think it's very dangerous, because I think, particularly when you couple it with the need to stabilize human population and achieve a certain degree of wealth to do that, we can undershoot badly. But I want each of you to think that every human being on this planet by mid-century has a right to a bottle of wine, a dinner that includes beautiful, diverse foods and a diet also in that way. Because food is such an important part of culture, of our happiness, of being human beings. And if we start thinking about, oh, 2500 calories per capita, how do we get 9.5 billion people…that's the wrong way to think about this.

It's likely that, as we develop and as these countries that are taking off in their economic rate of growth, it's likely that we will overshoot consumption, not undershoot it. That was clearly what happened after World War II when so many people in the developed world had been deprived of food for quite some time during the war. After the war, everyone overshot. Everyone that had children in the Baby Boom wanted their children never to experience the deprivation they experienced. So let's be thinking about a flourishing humanity with a diverse and nutritious food supply.

At the same time I want to mention that it's not just again the amount of food or its nutrition, but to do it sustainably, and I would suggest even improve environmental quality, not just maintain it and conserve natural resources. And of course food systems have to be part of the economic vibrancy of society. A part of this, I would contend is also a vision that, by mid-century, human population stabilizes for the first time in many thousands of years.

So on the road to food security, and particularly in the last ten years, I think we've seen an abrupt change in what had been very predictable linear trends. And I don't think we have yet assimilated these trends into our strategic thinking. And I'll talk more about them, but I'll quickly go over them.

We've seen slowing rates of crop yield increase. We've seen rapid expansion of crop area. We've seen increasing real food crises. We have seen accelerating carbon dioxide emissions, even with all the international dialogue about curtailing them. And we've all of a sudden found ourselves awash in fossil fuels, particularly natural gas.

Now, this is the first point about slowing rates of growth in yield. And it's simply the tyranny of linear growth rates; it's not that yields themselves are coming down, but on average these are just data from the Food and Agriculture Organization showing average yields for the major cereal crops. And remember they account for nearly 60% of all human calories, either directly as consumed or through livestock.

And so if you take maize, which are the red data points… the red is maize, the green is rice, and the blue is wheat. If you simply take the linear rate of growth that you see there, which is 65 kilograms per hectare per year on average, fairly steady, and if you divide that by the average yields at the beginning of that time series, which is about 2,000 kilograms per hectare, you get about a relative yield of 3% per year. But because that rate is linear—it doesn't change—as yields rise, the relative rate of increase decreases, so that by recently 2010, 2011 when average maize yields are over 5,000 kilograms per hectare, that same average rate of gain is falling to 1% or less.

What's more is we see even more disturbing trends when we look more closely at national yield trends. So we see, for instance, rice in South Korea plateauing all of a sudden back in the 1980s. Later rice yields in China began to plateau. We see wheat yields plateauing in West Europe; that includes Germany, France, the UK, Netherlands, Denmark. And we see an abrupt decrease in the rate of gain in wheat yields in India. More recently we're seeing stagnation in yields of irrigated maize in the United States, and we think that it's very close to being a yield plateau as well.

And if we use rigorous statistical analysis—so you don't just, yup, looks like it's stagnating, but rigorous statistical analysis—and get it published in a good journal, 31% of current global cereal supply is coming from countries which have statistically significant plateaued yields or market decrease in the linear rate of gain that was enjoyed earlier—31%.

At the same time—this is that other abrupt change—after a period from 1980 to a little after 2000 when land used for all crop production in terms of harvested crop area, it was stagnant for over 20 years. A period when real food prices were decreasing, farmers had little incentive to expand production. But within the last ten years, as we all know, food prices spiked, particularly for a period of four or five years there, and it sent a signal to the global farm community that we need more. And as a result, there has been an abrupt and, by the way, if you apply a spline regression, a statistically significant abrupt increase in crop-harvested area, beginning in early 2000 at a rate of 10 million hectares per year… and this is the fastest rate of increase in harvest crop area in human history. Of that, over 80% is for four crops—maize, rice, wheat and soybeans. So 82% of that 10 million hectares per year is just due to the increased harvested area of four crops.

Some have called this an agricultural time bomb, because it's not sustainable, that is, during the 1980s and 1990s, nearly all of the increase in food production was met on existing land by increasing yields. Currently, we have an oversupply for a year or two, but such a large amount of that is not due to increased yields but rather to expansion of crop area as shown by these FAO data.

And of course we all know that there's only so much good land left, and so in Brazil we can clear forest for soybeans. It also, when prices are high, forces poor farmers to farm on land that simply isn't suitable for annual staple food production. And of course the other force opposing this is the massive increase and coverage of existing farmland by expanding cities. Often the best farmland is covered up, because they are in close to cities for logistical reasons. And to replace them and just hold harvested area constant, it comes from marginal land, drier, poorer soils than the land that was lost.

Another abrupt change—well, there was a very steady linear increase in carbon dioxide. Kyoto Agreement was signed in the early 1990s there. But there's a more rapid increase in carbon dioxide emissions in the last 10 to 15 years, despite the efforts being made.

And a fourth, a final point is that we've found, rather than peak oil, we've found increasing global supplies of natural gas, particularly by a process called fracking. And in the United States, but this would be true anywhere people have the motivation to look, there are masses amounts of this, what we call "tight gas." And this is a projection from the U.S. Energy Agency, and you can see for the next human generation a doubling of supplies.

Now, just to summarize this part of the talk, so I'm going to call these… is that visible? Yes, you can see the D. So I'm going to call it not abrupt changes but disruptive changes. And my contention is, for discussion, that we have not adequately taken these abrupt changes, these disruptive changes, into account as we try to prioritize research, as we try to invest in research and development, partnership with private sector into account in planning the future.

So we've had a slowing of growth rates for the major food crops, which means only that, if you don't want to continue clearing land, which has feedback into climate change, by the way, to meet demand through significant increase in crop area, the only way is to meet demand on existing farmland. And that also includes compensating for land taken out by urban growth.

We've then seen this rapid expansion of crop area, but we've got to stop it; and we do so by accelerating, and that's a very challenging work. We do that by accelerating the rate of gain on existing farmland and of course with policies, conducive policies and investment in research and so forth. We've seen increasing real food prices, and of course the only way to keep them in check over the long term – it's going to go up and down, no question – but over the long term, the only way to keep it in check is to produce adequate food; and to do that we need accelerating yield gains and appropriate policies.

And we've talked about the accelerating CO_2. Solving that requires holding agriculture on existing area, not clearing new land and losing the incredible vast storage of carbon dioxide and carbon resources that rain forests, wetlands have, and increasing supplies of natural gas, which, they hold promise in two ways. How many have heard about – we prioritize research because fertilizer prices were going to go through the roof in the next 20 or 30 years? Well, this tells us that's probably not going to happen, and it's probably more likely that food prices rise faster than the price of energy inputs going forward for the next generation, exactly the opposite of what we've had.

And it also means we can replace some of the high-carbon energy sources—coal, deep water petroleum—with a much lower carbon-sourced fossil fuel.

So those are the disruptive changes, and I want to then bring it all together that, if we play our cards right, we can maintain sufficient economic growth rates to raise incomes that allow people to invest in environmental protection, conservation resources—the old saying, "You can't be green if you're in the red"—and in creating that wealth, contributing to stable human population. And we all know that at some level of income, regardless of culture, regardless of religion or nationality, population growth stabilizes as incomes reach a certain level. Now, it varies by country. Some have suggested a per capita income about 4,000—but it varies.

But the point is, there comes a point at which a certain level of family income, a family will educate their firstborn son; little more income, they'll educate their other sons; and it's only until a certain level of income is reached that they'll educate their daughters. And we know the single most sensitive factor affecting female fertility rate is the age at which a woman has her first child, and the only way to give women opportunities other than childbearing is education—and that's the strongest force to work towards stable human population.

Food security is important at the center, because the poor in developing countries expend a large portion of their disposable income on food. If food prices rise too high, there is less income to purchase other goods and services, which contribute to economic growth rates more generally. We have seen it in certain areas that this can be a cycle of degradation if we don't create wealth and economic growth rates fall. So this is our model.

Are we on course? I'm going to say no, and Kendall Lamkey joins me—put it out there—but we can get back on track. And we have powerful tools, so there is exciting progress in the basic sciences and applied sciences that determine innovation in agriculture, I mean, everything from biology, chemistry, mathematics to the applied sciences, earth sciences, water science, and so forth. The progress is astounding.

We have also at the same time rapidly evolving communication technologies. We can leapfrog. You don't have to put in hard structure, telephone systems and so forth. If we have the information, we can get it to every farmer on this planet.

I'm going to end with some ideas about then the important role of big, open, publicly available data.

So good data is the grist of closing knowledge gaps. And you've heard Dr. Nwanze mention a few, but you'll hear others discuss many others. There are many important research scientific issues we need to address. So these are some:

What is the production potential of every hectare of existing farmland and the size of the exploitable yield gap? What's the rate of climate change and the expected impact on food production? How much can we reduce food demand by behavioral changes, human behavioral changes, in diets and food waste?

And what are the pathways from agricultural research to improving nutrition? This has been a question when I was head of the Independent Science Partnership Council of the CGIAR. We spent considerable time on it, because it's assumed that, if you invest in agriculture, it improves nutrition. Fact is that we know that the pathway to improving income is very strong on improving nutrition, and again Dr. Nwanze mentioned that. That is, if you raise incomes of smallholder farmers in rural areas in developing countries, their nutrition will improve. And if you improve their incomes through increased agricultural productivity, that's a very powerful pathway. But the question is—What else can you invest in in agricultural research that does it? And there the information is much less certain and more opaque. And more effectively prioritize research investments and investments in R&D. Again to get the knowledge to do that, I'm going to argue we need big, open, publicly available data.

And another issue—how to capture the benefits of globalized trade and free markets for low-income agrarian developing countries?

Well, so to have big open data, it has to be at a certain level of spatial density. You can't have a weather station in Los Angeles and a weather station in New York and interpolate weather for the whole country. You have to have data – and it doesn't matter if you have large spatial density in, say, weather stations if the data collected is terrible. And you need not only current data over the last few years, but we need historical data, so we can look at trends and make predictions and projections based on it.

So some of the things I'm going to mention here that need to be in the public sector and need to be good quality and robust: harvested crop area and yields; major cropping systems, when they're planted, when they're harvested; crop calendar, but not just a coarse crop calendar—we need to know when farmers are planting, what decisions they make to plant, at a fine level of spatial desegregation; livestock species; soil properties. Did you know that, while we're making progress on getting soil data for Africa, there are no data on the effect of soil rooting zone in that database? And that determines how much, you can have a lot of rainfall, but if you have a constricted root zone, the plant can't use much of that rainfall. We need good public data on climate, water resources, weather—climate and weather are a little bit redundant, but okay.

And these data need to have a keen agronomic relevance because we're trying to use them to support agriculture in our move towards food security. We need data on human nutritional status, gender roles and technology. So these are examples for big, open public data.

I want to mention the seminal importance of weather data. At a time when we're all concerned about climate change, it is appalling how poor our available weather data are. And I think the danger is now that it will be privatized because it's so poor. And in fact the recent purchase of the Climate Corp. by Monsanto I think highlights how important climate data can be. And Monsanto has every right to add value to climate data and make lots of money, and that's good. But, if the public sector disinvests in collecting good-quality climate data at a reasonable density, then ultimately farmers, as well as everyone, will be dependent upon private provision of weather data. I think that's very dangerous. And it's deceiving how impoverished our weather data are, I'll give you the U.S.

So this is a slide that shows the harvested area of maize in the United States, the green shading, and the darker the green the denser the area. Fifteen percent of states account for 90% of maize production in the U.S. shown here. These are the weather stations; there's nearly 3,000 of them. Some are with NOAA, but they typically are located in cities or airports and have been covered up by urban development, and they only take daily temperature and precip, rainfall.

Another system, also shown in those points is Mesonet, specifically set up by states for agriculture. And these stations include all the data you would need to be able to simulate accurately crop growth development and yield—they're in blue there. These are the Mesonet stations, because quite frankly, the NOAA stations simply aren't robust enough to ask questions about future food production potentials that are there. These are the Mesonets; there's less than one fourth of those, about one fourth of those 3,000 total stations are Mesonet in agricultural areas. But many of these stations are no longer active, because these are run by states, and states have cut funding for them.

So these are the stations that have 15 years of weather data. Now if you want to ask questions about climate change, you need to have long-term data on weather in an agricultural area. We're down to 300 stations, and some states have one or a few—simply not enough to get a robust weather data picture of, for instance, how climate change may affect crop production.

Now, you could interpolate… Oh, and in the absence, of course, of public data, we're starting to see private companies provide it. And the problem here is it's sometimes simulated and sometimes it's—it's not transparent how it's derived, and there's intellectual property in doing it, so it's going to be hard to get.

Now, if you go to developing countries, I would call it even a black hole. So when we work on the Global Yield Gap Atlas [inaudible] and have tried to get, for four years now, actual weather data, with no more than 30 days of missing data, these are the stations we find. So in a world threatened by climate change, there is a critical need for good-quality, publicly available weather data, relevant for crop production. You need a daily time stamp, it has to be real time provided to farmers on a daily basis, or buyers and consumers as well as producers, as well as long term so you can ask questions about variability, stability and use those data then to project into the future.

And the reason it's so important—this is data that we've published in *Global Change Biology*, but the three quadrants, as you face it, upper right, lower left, lower right, are these gridded soil database. So in the absence of good, actual weather data, meteorologists, climatologists have come up with these gridded databases where they interpolate from existing data. But I've shown you the number of stations with long-term good quality weather data are relatively few and sparse, especially for agriculture.

And so when you use these gridded databases and then use them to simulate crop yields, they do a very poor job. You'd like to see in those three panels the points on the one-to-one line, because the X axis, the horizontal axis, is a good quality actual weather station data. So it's simulating yields with these gridded weather databases and then plotting it on the same simulated yield with good quality observed weather data. And there's a way to do that, and I won't get into it, in the upper left, that can get around some of the problems if you don't have the best data. But the point is, you've got to have good quality weather data, and most studies that have looked at climate change have used these gridded weather databases.

So what we're saying is that, whereas so many of the studies, because of lack of good data, have been top-down, using gridded databases. We need to have a similar level of investment in a bottom-up approach that finds a way to take actual, real data that can be validated and scale it up. And ultimately the real science to be had is to use both methods, so you can enrich the global, gridded weather data with validation and strengthening from bottom-up approaches.

We've tried to do that with the Global Yield Gap Atlas, and it's a collaboration between the University of Nebraska Water for Food Institute and Wageningen University in Holland, and I invite everyone to go to the website. But the point here is to do a bottom-up approach with real data as much as possible, transparent methods, so you can go to the method tab and see all of our methods and then published in peer-review literature. And basically a yield gap is the difference between what you could achieve (the red bar) with perfect management so that in irrigated systems, the only thing limiting yields is sunlight, the amount of sunlight, the temperature regime. And in rainfed systems, of course, it would be limited by temperature, solar radiation and rainfall. But that's the potential yield, and the actual yield is the green bar, and the difference between them is called the yield gap.

Now, I've heard some say—Oh, well, for places like Sub-Saharan Africa, we don't need to know the size of the yield gap because our farmers are way down there, and we can easily double yields with existing technology. And that's true, but here's the argument I would make: Doubling yields in Africa will not lift the small farmers I know out of poverty, especially when you're working on a hectare or less. And one can double yields with on-the-shelf technology, no question. And in fact, once it gets going and on track, as Dr. Nwanze has envisioned for us, it's not uncommon for average rates of gain of 150 to 200 kilograms per hectare per year. And so, within five to seven years, you could double production with existing technology. The point at which a yield gap analysis becomes important is how you double it at the next stage, because then it becomes critical to know what the probability is, how variable it is, because investing in the inputs and infrastructure costs money, and you need to have a much more detailed understanding of the magnitude of the yield gap and where farmers should be given their climate and soils. And that could come quickly in Africa and should.

So it leverages a lot of open data—we won't go into it. It upscales from climate zones, crop-specific harvest areas, weather station buffer zones, soil types and cropping systems. We use rigorously validated crop models, actual yields, and then we get the yield gap. I invite you to look. It's a powerful tool for delineating inference domains for new technologies, locating research work and do the best, most good, identifying regions for investment and upscaling, assessing impact, both ex-ante and ex-post, prioritizing research, and targeting policies.

So this is what it looks like. You can do different scales. These are yield gaps at the reference weather station level, based on actual yields at these sites, actual weather data, actual soils, actually cropping systems. We use climate zones then to scale up. Basically, we have a way of waking it, and then we can go to, of course, national estimates as well. That's upscaling.

So the seminal role of big data, to help farmers better manage and market, develop robust metrics—I haven't had time to talk with you about this—robust metrics for environmental performance, more effectively prioritize, adapt and mitigate the climate change, inform policies, and the bottom line, critical need to get going on required data. And the good news is that the actual cost is decreasing rapidly, thanks to technology innovation. So this is a vision for farming systems of the future. I would submit that we are not on track now. We could get there easily, and a key part of that is going to be big, open publicly available data, and we need to identify what those data are, where they will come from, who will invest—and get cracking.

Thank you very much.

Ambassador Quinn

Thank you, Dr. Cassman, for the great start. One of the very last things Norm Borlaug wrote, together at the World Food Prize, was two recommendations: How to build more roads and more infrastructure for information. So that map of Africa with roads and weather stations looks very similar.