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Keynote

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What I'm going to talk about in the 30 minutes that I have is to look at what are some of the key challenges for water and food security; I'm going to look at what evidence we have on the relationship between water resources and economic growth, which is surprisingly little as you'll see. I'm going to very briefly describe a scenario modeling methodology that we use at IFPRE to look at the longer run in terms of water resources, food security, and climate change, and other aspects. I'll present a few, sort of the baseline or business as usual results from that analysis. Then I'm going to introduce what we think are the key water policies, technologies, and investments that could really shift those kinds of trendlines and potentially make things better in the future. I'll describe those in just a bit of detail, then I'll put together an alternative scenario to that baseline in which we basically asked the question, can sort of plausible improvements in those policies, technologies, and investments actually make a difference for water and food security. Then I'll end with just a few conclusions.

So what's going to be influencing food security and water in the long run? We generally look out as far as 2050 on our own results, and this shows some results even further out. Look at the left side here, a couple things to note is that obviously population growth is still growing and it's almost all in developing countries which have a high propensity to consume more food. So given increase in income in Africa or Asia is going to require a lot more food demand then say in Europe or United States where there is very

* Please see the corresponding paper and/or presentation available at http://www.kansascityfed.org/publications/research/rscp/rscp-2016 for additional detail and referenced charts.

little growth.

So populations are also becoming much more urban as you can see in the green line of the urban population crossing the orange line of rural population already, and rapidly outpacing that. And that's going to shift demand a lot more to processed foods, and away from staple foods as we'll see in a moment. I think the graph on the right-hand side, I think, is kind of stunning. This looks out to 2100, and as you can see more than 70 percent of future population growth is going to be in Africa. And that's really going to be one of the key markets in the future, not only for U.S. agriculture but for agriculture in general, and getting incomes up enough to actually demand the food that's needed is going to be a huge challenge. Other than that, there is growth in Asia as you can see on the right-hand side, and then much less elsewhere in the world. GDP per capita, as you can see on the left-hand side, we average in the thousands of U.S. dollars per year, this is real terms, green for the world, and then orange in the developing countries, as you can see, the per capita demand is going to more than triple by 2030 in developing countries. And again, they are growing two to three times faster in terms of per capita income growth than in developed countries. So again, that's a huge part of the demand is going to come from that.

The trends that I've mentioned also are going to indicate as I said a considerable shift in the patterns of demand. Look at the right-hand side there, you get coarse grains, rice, and wheat in OECD in blue, and developing countries in orange. This is a shorter-term between 2010 and 2021, but you're already seeing how relatively slow demand in commodities like rice and wheat and much higher demand in livestock. You see beef, poultry, pork there, and then fish as well. And also very high demand for things like sugar and oil as you get that transformation of diets in the developing countries. Coarse grains hold up in demand better because of the huge demand for coarse grains for livestock. You can see a snapshot of how that happens. It's basically inevitable it seems that when incomes in countries increase, people want to eat more meat. This is a snapshot of one year, but it shows the per capita

consumption of meat on the vertical axis against GDP per capita or its national product per capita in 2011. As you can see, the developing world—India, Indonesia for example are shown there, and all the African countries and South Asian countries are clustered in that lower part—have very low demand for anywhere from four to five to 15 kg per capita, whereas US, China, and others are far out in 60 up to 120 kg per capita. One of the key things that determines food prices is to what extent the developing countries move out along that line, and it certainly looks like they're moving that way quickly, but probably we don't expect them to go all the way to North American style diet.

How about on the supply side? What is it on the supply side it's going to influence the ability to meet the demands that we see? Obviously one of the key supply drivers is climate change and climate variability. Work that we've done and other institutes show that by 2050 production of key staples could be 10 to 20 percent lower compared to what it would be without climate change in 2050. So there's going to be strong pressure on production from climate change, and then variability shocks have difficult long-term impacts as well. Water and land scarcity, waters what we'll be talking about more. Land scarcity is also a big issue now. There's not that much and left that can be economically exploited. Brazil and Argentina have a lot of it, and the rest of it is in Africa, and the ones in the land in Africa is very poor quality. In addition, expansion of land runs into driving up greenhouse gas emissions dramatically, so there's a lot of social pressure as well as economic costs to try to expand land. So we don't expect much from that. Competition of biofuels, as everyone knows, does put some pressure on the supply for food, but that seems to be a pressure that's waning a little bit now.

On the positive side, some of the key shifters, and I'll have a few more when I talk about water as well, obviously investment in agriculture research is one of the main areas that can drive productivity growth. Pretty much worldwide that slowed down dramatically over the past 20 years. Government public research isn't investing enough in agriculture

research, and the private sector has also slowed down pretty much. It's a bit cyclical, going up when you get high prices like in 2008 and 2011, but has slid off dramatically again since then. Science and technology policy is going to be one of the really key efforts in terms of how fast we can get new varieties for example, discovered, developed, and delivered. And here are some of the key turning points, could be in the area of intellectual property rights, regulatory systems, and extension. But one of the possibly really important changes that could happen this year is if the new gene editing, or so-called CRISPR technologies, can avoid the regulatory overload and huge opposition from NGOs and things, GMOs, so that could be a big turning point in terms of becoming more efficient and generating new yield growth. It's probably going to be determined over the next two or three years.

On the water policy side, I think we have here in the United States but also throughout the world, developing new water whether for irrigation or for water and sanitation is increasingly costly, seven times more than what it was say 30 years ago. So there's a lot of constraints to developing that and developing new systems. In addition, and perhaps even more important, is the incredibly wasteful use of already developed water supplies. Again, some in the United States, and other developed countries, even worse in the developing world, which is been driven by subsidies on water itself and energy that pumps groundwater as well, and end up resulting in way more water use than is necessary. That's contributed to depletion of groundwater, water pollution, and declining water quality and much of the world as well.

Then we have again climate change and extreme weather. What's the evidence? Is water outside of agriculture that important in terms of economic growth? Obviously it's important for many aspects outside of agriculture. The evidence on the impact of water on overall economic growth is pretty mixed. This was a comprehensive synthesis of what's been written and known about impacts precipitation variability, runoff, or water availability, drought, and flooding with respect to per capita GDP growth. And again, all the signs are in

the so-called right direction; variability in rainfall does tend to be correlated with slowing of economic growth; increased water availability through runoff has a strong positive impact; then droughts and floods also have negative impacts. But the amount of economic growth explained is fairly small, it strongest in the poorest countries and countries that already have high water stress or high dependence on agriculture. Economies like the United States, it's not that big of a deal; obviously it can have local or regional impacts when you have significant water scarcity but it doesn't overall influence economic growth that much.
A couple other recent studies, one done by the World Bank and the other using the GTAP model at Purdue University, looked at forward-looking evidence, at what would happen with water scarcity in the future. The World Bank, CJ Miles computed a general equilibrium model that shows again that there are economic consequences but they are heavily concentrated in the developing world and in the poorer countries, including the Middle East, the Saharan region in Africa, and Central and East Asia where water scarcity is the most damaging. The GTAP model I think also provided a lot of good insights. Again, they showed that there are negative impacts from future water shocks, that the economic feedback effects limits that substantiality. Obviously regents can take advantage of trade to adjust compensation of agriculture income and specialize in other commodities. So one of the important things that comes out of these kinds of studies is that we need to keep global trade open, and not give into the kinds of protectionist that we've been seeing. So these kinds of adjustment effects, including through markets, significantly dampen those effects.
But how about in the broader, or on the sense of food security and agriculture? Here we have, I don't want to go into details on this, it's described a little more in the model and I can always provide a lot of detail on this for others, this is the impact modeling suite that we've developed at IFPRI, it's a link system that includes not only economic partial equilibrium models which is the original model, but also hydrological models, water use and crop simulations, and linked to climate change outcomes.

So I think the key thing to note here is that there is a water supply and use model directly integrated with the food supply and demand model so that we simultaneously can assess what's happening in the water sector, and how that water sector is influencing food and agriculture sector. Again, we can talk about that in more detail at some point.

Let's look at some previous results, we call it BAU, or the business as usual baseline scenarios. Here's just a couple of examples of projections for the cereals and for meats out from 2010 to 2050. We are finding, and obviously we have a. Now where prices are down a bit, but I think it's worth noting that these lower prices are still significantly higher than they were in the early 2000's. I think some people have forgotten that we are still at higher prices than we've had for a while. But we project more increases in cereal prices under the baseline, or without climate change it's the bottom black line, and even their you can see about a 10 to 20 percent further increase in real cereal prices. With climate change, you get an average increase as much as 40 percent for cereals. So real prices going up which of course is a boon for American farmers, and others with aggressive expert markets, not so good for food security in the developing world. Meat prices, as you can see, also going up 10 to 20 percent depending on assumptions. Fruits and vegetables, again, 10 to 30 percent and pulses roots and tubers, it's up, that are very important in developing countries diets, and particularly also going up anywhere from 10 to 20 percent over time with significant impacts of climate change.

What does this do to hunger? And again, this is our baseline, the same baseline that I just showed you, if the so-called shared socioeconomic pathway to medium economic growth pathway that's in the IPCC scenarios under RCP 8.5 which is just the name for our relatively rapid climate change scenario. So here we do see real improvements in reducing hunger, and you can see East Asia specific, South Asia, and sub-Saharan Africa are the key areas where you have hunger in the world. So we are seeing progress from the blue line, the blue bars, which is 2010 out to 2050 without climate change in the orange, and then

with climate change in the gray. You see also the climate change does have that negative impact, increasing population risks of hunger relatively at 2050 without… And again some people say, "well that's pretty good, were really going after hunger," but most of the targets for hunger in the international community is to try to eliminate hunger by 2030. Yeah I've never thought those were very realistic targets, but this is as you can see here very poor performance relative to those kinds of targets. So we really have to do better on these kinds of indicators of hunger.

So what kinds of policies, investments might work to make things a little better off? Look particularly at the water sector, but also as it relates to land and food. One of the key areas, and again, this is one of the best things that we could do to increase water use efficiency, really is somewhat outside of the water sector per se. It's through plant breeding, that increases the plant biomass per unit of water to both more efficient transpiration, and the efficiency of biomass growth per unit of transpiration. In a sense, the poster child of this was the semi-semi dwarf rice varieties and wheat varieties that led the green revolution in Asia and Latin America which produced a lot more rain for the same amount of water, or less water. But there is still the potential to do this. I think there's various degrees of optimism or skepticism about what can still be done to get more productivity per unit of water. I think there is still quite a bit that can be done based on the science that I read, including effective breeding for drug tolerance and other traits to get more yield per unit of water. So the key things are availability of diverse genes, that it's unlikely that were going to do really well on this simply by traditional plant breeding techniques, but we are going to need biotechnology, including micro -assisted selection, cell and tissue culture, and again, coming back to the point that gene editing should come through in a big way. Transgenic breeding seems to be off the table and some of the developing world, but we keep working with governments to try to develop regulatory systems there that would make those credible for the developing countries. But many of these systems have unscientific and regulatory

system that basically rule out GMOs. Hence again, the potential importance of gene editing.

The other, of course, as you all know, is adoption of new irrigation technology and farming systems. Of course, farmers have many reasons to adopt advanced technologies, drip and sprinkler irrigation, precision farming, conservation agriculture. But all of these technologies are now starting to move outside the developed world as well, so we're seeing a spread of drip and precision farming also in some of the more rapidly growing parts of the developing country as well, plus they provide increased income, convenience, laborsaving, and lower pumping costs for the individual farmers. I think one thing we always have to take account of is that these kinds of improvements at the field level or irrigation system level, are not necessarily having great big real systemwide benefits. For any new technology that's adopted, whether it's drip for example or you can have several outcomes based on that one. Because the interconnectedness of water was in the basin. One, it can save water that would otherwise have evaporated unproductively or have gone to sinks, and that does provide the kind of net system benefits whereafter in terms of water saving and productivity. But then, they can easily just divert water that's otherwise used by farmers downstream where return flow gets diverted and that that just shifts the benefits from one farmer to another. The others that you see a lot in the United States, for example, it increases the water used by increasing the profitability of irrigation for the individual farmer, so that farmer actually uses more water rather than less. So again, that's why we don't see the kinds of benefits in the long term of water use efficiency that you might expect for water productivity from these technologies.

So what do we have to do to try to get those technologies and farming systems to generate broader benefits not just to the farmers. Obviously, the key is going to be to promote water allocations that recognizes the hydrological realities and this interconnectedness. To do that, well specified tradable water rights is likely to be the way to go in order to optimize economic value and the productivity of water. And at the high level,

were going to hear a lot more about this Mike Young who is speaking tomorrow morning. These are some of the high-level conditions that Mike has identified in his exciting work he's doing now, and for years, that you need to have perpetual rights for individual users of all allocations made in the river basin or systems, that you have to do a lot of homework to get the measurements right, actual allocations in any given season, that they be based again on solid evaluation of how much water is there, and you need a transparent process and accounting system that accounts for evaporative losses and environmental outcomes as well. Michael will tell you how we can make this kind of system work here in the United States as well as elsewhere.

Obviously, there's big constraints to set up this kind of water rights and trading system. Even in the United States, politics is very difficult, as many of you know better than I do; in developing countries, it becomes even harder, and this is where we need the greatest improvement in efficiency. Its high cost of monitoring and measuring water, because infrastructure there and institutions are very weak, so you may need to invest a lot just to get to where you can do that. You often also have these huge irrigation systems that service a lot of small farmers, so that makes it even tougher to measure and manage water rights and trading. You also run into long-standing practices and beliefs that water is supposed to be a free good, so it can't be charged for. That has powerful meaning in many developing countries. You also have entrenched interests, you know, the irrigation bureaucracies in many developing countries benefit from existing system of subsidies and administer water allocations where they can generate income from their cells in the way they allocate water. So a transparent system is a big threat. Because of that, the development of well-specified water rights and trading in developing countries in particular is likely to be a medium or even a long-term process, but something that really has to get a move on rapidly. The current system of inefficient, subsidy-driven water allocation is a huge problem.

The other area is in capital investment in irrigation water, and here that includes

of course new investments in irrigation water supply—I already noted that those are increasingly expensive— but substantial potential does exist for irrigation in many regions of the world, particularly Africa where work we've done has identified 16 million hectares, so some 32 or 33 million acres of profit of large-scale irrigation, and up to 50 million hectares as small-scale irrigation. So considerable potential there if policies can be put in place.

There's also a huge amount of investments that need to be done in water treatment and sewage. Estimates from the World Health Organization have shown $23 billion per year to get global access to improve water and sanitation, and up to $135 billion to actually have in-house pump water supplies. So there's a huge investment deficit as well.

Let me quickly run through a scenario to look at whether these water policies and technologies investments I just went through can actually make a difference in the longer run. Here we run an alternative scenario with the model I described earlier, where we put in place assumptions that we have higher water-use efficiency gains through improvements in industrial and residential water use, but also in agriculture as well. So the agriculture ones are due to drought resistant varieties and other advances in research, reduce non-beneficial evapotranspiration to better management, and reduce losses to sinks for that same reason.

That ends up with we've done an estimation of the 15 percent improvement in water use efficiency at the basin level in 2050 compared to the baseline. We regard that as a possible increase, but one that of course can be debated by hydrologists and so forth. We also estimate that the enhance research and development based on those investments increases the productivity of crops and livestock, and also through effects on the general economy, the overall economy, increases GDP growth per year from about 3.2 percent globally to about 3.6 percent because of the improve productivity in agriculture and water sectors.

So what happens under this scenario? First of all, we can get substantial

improvements in reducing irrigation and water consumption. So you're going to get it at the baseline level, if not just the farm level. A couple of interesting things here. In most countries, you're getting somewhere between 5 percent and 15 percent reduction when you combine the various scenarios. But an interesting alternative, outlier really, is South Asia and Central Asia, here you actually end up consuming more water and irrigation, and that's because of the efficiencies in the non-irrigation sector and urban and industrial sector are high enough that they actually release water back to agriculture in those sectors. So without those kinds of efficiencies, you're seeing a huge movement of water out of agriculture and into the urban areas. So we can reverse that.

What happens to the cereal prices? You saw earlier that the projections of increasing prices—here we can see under this scenario, you get a significant reduction in 2050 compared to those prices we showed. So we can almost wash out for rice, wheat, and maize or corn, those long-term increases we saw, but we have less improvement for other grains, millet and sorghum, which don't rely on irrigation much anyway. These changes in productivity growth and income growth, end up increasing per capita cereal consumption in the developing world as well, and the developed also, anywhere from 6 percent to 8 percent. So you do see important gains in food security through cereal consumption, and that's driven home by the reduction in risk of hunger that I showed you in 2050 compared to that baseline. So you get reductions of as much as 40 percent in sub- Saharan Africa, over 30 percent in East Asia and Pacific, Latin America, and South Asia. So those kinds of improvements, if we really get at them in terms of improving water-use efficiency and productivity, can make huge differences in the future.

So just to finally summarize a few points. Water scarcity is going to be increasing in much of the world, and together with climate change and other factors that I noted, will cause relatively slow growth in agriculture productivity and slow progress and reduction in hunger under the current business as usual situation.

Looking at a plausible scenario, we can all judge whether it is plausible or not since some of my colleagues here might have some thoughts about that, but a plausible scenario for water and crop productivity growth significantly improves those water and food security outcomes. The combination of policies that we implemented in the scenario with water include efficiency growth through, for example, water rights and trading, new water technologies and farming systems, investment in crop research to increased yields with respect to both water and land, and some increase in irrigation. Water policy and reforms such as I'm talking about, I've alluded to that earlier, has to be tailored to underlying conditions—levels of development, agro-climatic conditions relative to water scarcity, and levels of ag intensification and degree of water competition. Obviously, you're not going to have the same policies put in place anywhere, though the broad types of policies are as I've described earlier.

The other point is that solutions are difficult and take time, political commitment, and money, so observing a need to push forward rapidly in these areas to catch up with the evolving environment for water and agriculture. Thank you.

General Discussion
Moderator: Nathan Kauffman
Assistant Vice President and Omaha Branch Executive
Federal Reserve Bank of Kansas City

Nathan Kauffman: Mark, this has obviously been an issue you've spent a lot of time looking at through your career. You know, you showed some of the projections going out 2010 out to 2050. If you are looking at this and doing those kinds of projections say 20 years ago, can you give us some sense of where we stand today? Are you surprised? Is this something, are we better off or worse off? What kind of position are we in today relative to where we thought we might of been 20 years ago?

Mark Rosegrant: Yeah that's a great question. In fact, we've been doing some of these kinds of projections since 1995. It shows how long I've been hanging around. But you know, it was a simple model in those days, we've developed a lot more work along those lines. What we found is that in those days we were doing fairly simple your optimistic/pessimistic/medium scenarios. And what we're finding out is actually, where we are today is more like what we thought the pessimistic scenario would look like. I think the reasons for that is that productivity growth has slowed faster than we had anticipated in what we thought would be the baseline. GMOs have never come in the way people thought they would in those days; the collapse of the Soviet Union shut down or dropped agriculture production worldwide for many years. The biofuels, I think did contribute to a slowdown, not in the production, but in food security for a while, so that was a factor, although I think that's washing out pretty well now. But I think climate change has come on more strongly than people thought in those days, so I think that's also depressed progress relative to what we know now.

Nathan Kauffman: To that point about climate change, you know, you mentioned that a couple of times, and if we're putting together a symposium, you can have a symposium

on climate change and spend a week or more talking about some of the things in some of the assumptions built into that. Could you talk a little bit about what can be done to better understand the impact of climate change as it relates to water availability, and what's being done in that arena to think about being able to plan a little bit better and make some forecasts as it relates to climate change? I know as you looked at some of your bands with the gray shaded regions, there's some dramatic variations. So what kinds of things might be done to still get a better sense of what those impacts might look like?

Mark Rosegrant: Yeah, and it's interesting that the long-term projections that the general circulation models do are much more consistent for temperatures than they are for water. So water resource availability, rainfall has been much more difficult to project than temperatures. It's not clear that there's going to be… I mean, supposedly in the next round of these IPCC scenarios there is some improvements, and they are also trying to look at their ability as well. But I think were a bit trapped in to having much more uncertainty in the water sector than we've had in the past. Of course, that also makes it very difficult to invest, you know, you could argue generically it would be good to invest in more storage when you have more variability, but you don't know yet where that storage is going to be needed. So you're going to have to have very adaptive and short-term responses in the water sector.

Tom Rooney, Waterfind: We are from Australia, and also have a company here in California, specializing in water market development, and water software and accounting tools. They are very interested your paper and looking to do a little deep dive into the World Bank's forecast for the decreases in irrigation water consumption over the next 35 years. Fascinated about that, about just where that decrease is going to be coming from, because in the last 20 or 30 years, we've obviously seen quite a strong increase in demand for irrigation consumption. In your paper, you do say, which I think it's a great paper, that globally we are going to be reliant upon heavier or creating greater efficiency or production out of existing landmass. We see irrigation as being a great part of doing that, converting non-irrigated to

irrigated land, increasing production. Yet still, your slide here in trying to engineer irrigation is suggesting globally we're going to see a decline in irrigation water consumption. So I'm just wondering are you using the same World Bank data for that, or is that your own data?
Mark Rosegrant: So yeah, the graph that showed the decline in consumption is the one where we've implemented, we've published a number of improvements, so that when already has built in the kinds of recommendations that I made in terms of water efficiency and agriculture productivity efficiency. The long projections in the baseline, which unfortunately I didn't show here for water, are for increasing consumption of water over time, so increasing consumption use. But what we try to show there is that you can bring down, bend that curved back down a little bit with those kinds of efficiency gains from improved water trading and through water use efficiency.
Chris Hartley, United States Department of Agriculture: I enjoyed the paper as well. I guess my question is, I saw lots on production and on creating efficiencies of crops as well as irrigation management. I didn't see so much on behavioral changes, and those would either be consumer in the processing phase as were talking about things like food waste, which may be account for up to 30 percent current global production. If that really does equate to about 24 percent of global water, 24 percent of fertilizer use, and 24 percent of land, why don't we look for behavioral changes to try and match some of the shortfall that were seeing.
Mark Rosegrant: No, that's a great point, and you're right, I didn't get into that in this particular paper. But we have been looking at that also, and it's an extremely important question. The post-harvest losses, not my group but another group at IFPRI, is working with FAO to get better, improved estimates on those. I think some of the numbers you see are exaggerated, but there's still a lot of improvements that can be done. Grains, it could be more like 10 to 20 percent, and then maybe 25 percent or 30 percent for vegetables. That's still very important. The question is how much of that can be economically recovered, but I think you're right, something like 10 percent of the food supply could be recovered through better

policies, and anywhere from investment in better infrastructure in the developing world, set policies that allow the use of restaurant or cafeteria food that wasn't eaten— obviously, there's lots of issues for legal liability and things— but those kinds of policies could help a lot. Another area that's getting a lot of attention, particularly among climate change analysts, is substantial dietary change where you would have large reductions in meat consumption in the developed world, and we've done scenarios looking at what that would mean. It does help on food security. The issue there is, what is the policy lever? You can have educational programs, and school cafeteria programs. The question is, do we then start getting into meat taxes or fat taxes, and of course, that's a huge controversial issue. But I think looking at sort of noncoercive ways to change some of that behavior could be very helpful. So you're right, there's a whole group of climate change analysts who say the only way we can meet the targets, for example, that were set in Paris, is through massive changes in diets, and nothing you can do on the production side will succeed without that. So it's a very hot issue right now, and thanks for bringing that up.

Nathan Kauffman: Mark, could you talk about, you had showed a slide where one of your alternative scenarios relative to the business as usual suggested that the largest reduction in prices was going to be in corn. Could you talk about what are some of the drivers of that in your alternative scenarios?

Mark Rosegrant: Yeah, let's see, the corn. So that was partly because the alternative scenario slows meat consumption a little bit, it doesn't have a huge one there. Also because there's more potential for productivity growth in corn, so we got a little higher hit on corn there, not necessarily in the U.S., and Ken Cassman can tell us more about that later, but there's very substantial gap's and productivity on corn in the rest of the world that could be exploited more rapidly than some of the other crops.

Steve George, Fremont Farms: I have a question on one of the inputs you used. Since you're using the population projections for 2050, there was an article that came out last or that

said, it was an outlier article that said some people think those population projections are way too high in sub- Sahara Africa, that they looked at some of the population densities that you arrived at and they would rival Hong Kong and it was totally unrealistic when most people just use those carte blanche. Do you make any modifications to those? Have you had a chance to look at those on a country by country basis to see if they look realistic? And generally, what's your opinion on those populations projections because that has a big impact on certain areas that you're dealing with in your analysis.

Mark Rosegrant: Yeah, sort of the standard for population projections has usually been the United Nations projections, and I think those are the ones that are potentially too high in Africa. Were using the projections that were done by a group and it's in the IPCC the Intergovernmental Panel on Climate Change. They've had a group of demographers looking at them. So we ended up using theirs, and they do have a somewhat lower rate of growth in Africa, although African population growth still dominates, in total, other regions of the world. We also can do, and we haven't done recently, we can do scenarios where we do alternative population growth, and that's a huge factor obviously in determining the balance in the future. Thanks.

Steve George: So for the models that you're using, you think the sub-Saharan Africa is pretty realistic?

Mark Rosegrant: I think it's solid, but it's not low growth. I haven't seen that paper, I'll have to check it out.

Steve George: How far apart were those two projections roughly? Was that half 1 billion roughly between the one you're using and the World Bank projection?

Mark Rosegrant: Total, you have half a billion, and I think about 300 to 400 million and that was in Africa I think. I'll have to double check.

Steve George: And you're also obviously very close to the climate models. What is your opinion on some of the modifications made to the models recently to explain the pause in

the last 10 years and some of the warming statistics? Have you had a chance to comment on some of those?

Mark Rosegrant: I haven't looked at those, but where the hottest, I don't know if it's really going down. We've had like 10 years in a row of the hottest temperatures ever on average.

Steve Gabriel, Farm Credit Administration: You had mentioned that both public and private spending on agriculture research are slowing down or are down. I was wondering what would be, do you have any idea why the private sector is spending less on research? Is it push back there getting on GMO, acceptance of GMOs, and what thoughts you have on that.

Mark Rosegrant: Yeah, I think that is one of the key factors. Of course, they also really follow commodity price trends quite a bit, I mean, with some lags and so forth. So until about the early 2000's, as you all know, commodity prices have been going down for basically 30 years. And that really dampened investment. Then we had some increase in the early 2000's and the big spikes that really got people reinvesting again. Even the public sector tends to follow those. The donor agencies tend to follow those prices as well, surprisingly well. So that was important. But I think a lot of it is this politics around GMO has cost a lot of potentially important lines of research with strong value propositions, sort of private companies. That has dampened their enthusiasm for investment.

Ken Cassman, University of Nebraska-Lincoln: This question was sparked by the one about population. So in these models, have we elevated them yet to the level were population growth rates are sensitive to economic growth rates? Because your scenario showed 3.6 percent economic growth versus 3.2 percent; taken over 40 years or so, that's quite a bit. And we know that population growth rates are most sensitive to the age at which a woman has her first child. We know that that's very sensitive to education level, and we know that education level is highly sensitive to income level. So can we, are the models sufficiently robust to get that interaction, and would it be important to get better projections?

Mark Rosegrant: We haven't done that. I don't think any of these kinds of global models have that, partly because there are so many intervening variables that you mentioned about education, fertility. But obviously economics is very important for that. I think that something actually that we ought to put on the list to look at more carefully. A quick point would be that that would further make these reforms even more effective, because in addition to the direct impacts through the ag and water sectors, you'd be pushing down a population growth, so you'd get even more favorable results from those kinds of scenarios. So that's a great point too.