SESSION IV. FUTURE SCIENCE AND POLICY CHALLENGES

October 19, 2007 – 10:00 – 11:30 a.m.
Moderator: **Margaret Catley-Carlson**
Speaker: **Cynthia Rosenzweig**

Margaret Catley-Carlson
Chair, Global Water Partnership
World Food Prize Council of Advisors

Now we've got somebody who has even more of a challenge, because she's looking on a daily basis, really, at the entire scene of climate change and climate impacts, from the standpoint of NASA's Goddard Institute for Space Studies. Cynthia Rosenzweig is a very distinguished scientist who leads the Climate Impacts Group in looking at interactions of climate systems and sectors important to ecological and human well-being. She leads, in particular, the Metropolitan East Coast Region for the U.S. National Assessment of Climate Variability.

Climate change and variability have been the kind of ghost at the banquet here. It keeps coming up, and this morning from our breakfast speaker we had an assertion that it is time to say – this is here, this is now, let's have a roadmap. So this is one of the people who has done the science on which you could build that roadmap.

Cynthia, we're very glad to have you with us.

Cynthia Rosenzweig
Senior Research Scientist, NASA Goddard Institute for Space Studies

Thank you, Margaret, and thank you to the organizers. I'm really honored to be part of the Norman Borlaug Symposium this year and the World Food Prize festivities. It's really great to be here.

So today I'm going to speak about challenges that climate change brings, in three areas:

First, the challenges of agriculture contributing to greenhouse gas emissions, the ultimate cause of climate change. Second, how climate change will affect agriculture and is affecting agriculture already. And finally, moving to the solutions. We're now, after about 20 years in the climate change issue, we're now in the solution phase. And as we know from the whole topic of this symposium on biofuels, people are jumping in, and the ag sector is jumping in, with solutions. So the third challenge is – how to work on those solutions in constructive ways.

First, agriculture's contribution to climate change. On the left you see the three graphs which show the greenhouse gas emission increases since – the large graphs show 10,000 years ago to the present; the little graphs show the rapid increases since 1850 for carbon dioxide, methane and nitrous oxide.

So in each one of these major greenhouse gas trajectories, agriculture plays a leading role. Of the primary source of increase, carbon dioxide, we all know is fossil fuel use. But land use change, as Margaret mentioned, provides a significant contribution, about 20 percent. In terms of methane, we all know that rice production and ruminants are major sources, dominant sources of methane.

And in terms of nitrous oxide more than a third are agricultural, predominantly from fertilizer. So we have agriculture as a major player – probably after the energy sector, agriculture is the major sector as one of the causes of greenhouse gas emissions contributors.

How are these greenhouse gas emission increases in our atmosphere projected to change the climate? I brought you from – I put in my talk – from the Intergovernmental Panel on Climate Change, Fourth Assessment Report, which came out this year, the current projections. So warming is expected to occur almost everywhere and to be greater over land areas. This is very important for agriculture.

On the left you see the probabilistic increases; the yellow lines are from the 2020s, and the red lines are from the 2090s. And in each of these three rows they are for different pathways of greenhouse gas concentrations in the atmosphere – basically low, middle and high – because there is still a lot of uncertainty in the future about climate change because we don't know what the global action will be on the emissions.

So when we do the science of the projections, we have to include all these different possibilities of whether we're going to be able to control greenhouse gas emissions or if we're going to continue with business as usual to the higher levels. So these are showing that the temperature increases are significant, even in the near decades, 2020s – that's not so far away anymore; 2090s warming ubiquitous on the planet.

A lot of times with climate change we focus on the mean changes alone; that's what these graphs show. But for agriculture one of the key parts of what really affects the agricultural sector is what happens to extremes. So with temperatures, hot extremes and heat waves will continue to become more frequent, and these will have major effects on our crops, creating increasing stresses as we go into the future.

What about precipitation, that very important other agricultural variable? Most often people don't think about temperature as a major agricultural variable, but it is because it has such a dominant effect on how and where plants grow.

In terms of precipitation, these are the projections from the IPCC for the 2090s, and we're starting now to be able to see what the future patterns will be like. So on the left we have December, January, February; on the right, June, July and August, for one of the greenhouse gas a mid-range of greenhouse gas emission scenarios.

So what we see is that precipitation is expected to rise at higher latitudes but decrease in lower latitudes. And every place where you see the crosshatches on these maps, the models are beginning to agree.

So this is very important in terms of agricultural zonation, and match up and need to be matched up, with the maps that David showed about where water in agricultural regions is stressed today.

Again, what will happen to extremes? So the total amount of precipitation is very important to see where our agricultural regions may shift. But at the same time those extreme events drive so much of what happens to farmers in the agricultural sector. So droughts and floods will continue to become more frequent. And again this is not something in the future. These droughts and floods are documented. This is documented in the IPCC report, that they are increasing already.

How will this affect agriculture? How will the changing climate affect agriculture? And here we see that, at the biophysical level, the effects are complex. Some of the effects are positive. There are possible benefits. If the only thing that we're changing were more CO_2, it would be positive for crops because CO_2 is a building block for photosynthesis and also helps to improve water-use efficiency through increasing the stomatal resistance, canopy resistance.

So that is a possible benefit that needs to be taken into account and is in the studies. Longer growing seasons in many regions, also where agriculture is limited by cold temperatures now – at high latitudes and also at high elevations. As these may expand, this may expand the potential for an expansion of agricultural land; however, we have to say soil resources permitting, of course. And we also have to say the effect that expansion of agriculture may have on the natural ecosystems.

Then I showed many places where precipitation will increase in the world, and there are places that have a deficit of precipitation for agricultural crops, that they may benefit as well.

But on the other hand, climate change is also going to bring drawbacks. I mentioned the more frequent droughts. There will be increases of pests, heat stress, and faster-growing periods. The high temperatures create a pressure on annual crops, speeding them through their growth stages, which is a strong negative pressure on yield.

Then, many places in the world do have agricultural areas near the seacoast, near the oceans; and there, because of sea-level rise, there will be increased flooding and salinization.

So in the models that we use to make projections, we take all these possibly beneficial and possible drawbacks into account and then put all of the studies together to see, in very general terms, what do we see about world production of agriculture, world food production potential with climate change.

And what this is showing is this is not for any one scenario; it's actually many, many scenarios. And what it's doing also is, it's giving a normative scale of from 0 to 10 of severity of climate change. You can also think of that as the time, as if we don't do anything about global warming, we are going to have increasing stress and high temperatures, as I showed you. So the 10 on this scale represents about a 5-degree sea warming and in terms of production in area extent, what happens.

And here we come to a very important part of what we've learned so far, but what we haven't learned yet enough is how crops will really respond to carbon dioxide – whether there will be high response, a positive response, as many of our agronomy colleagues and as many of the face experiments show that there's the potential for high response.

But on the other hand, out on farmers' fields it's hard to know how strongly those CO_2 effects will really take hold. But what we see for world production in general is that there will be perhaps a period with low amounts of climate change where actually world production could actually increase, then level off with warming, and then reach a point finally when the high temperature effects and the other climate stresses win out over the positive CO_2 beneficial – or sometimes called, the fertilization effects. But what we don't know, and this is very important and a very important research area, is where those inflection points may be. It may be much lower if the CO_2 response is lower.

So there's been a lot of funding on the climate system itself, how sensitive the climate is to the carbon dioxide and increasing greenhouse gases. What we still need is a lot of research attention on the sensitivity of our impact systems to the climate changes. And as we move into the solution phase, this will be, I believe, a very important area for work.

Following on from those productivity curves of possible increases leveling off, and then decreases, this is what happens with the real cereal prices, for the world prices with those projections. And what the economic studies (there are several that have been done) show that prices, world food prices with climate change (arrayed along the bottom) either fall, which is very optimistic, or hold steady until about 1 to 3° C warming.

But what we have to do is now deconstruct that global, those world production that I just showed you to look at the regions, temperate versus tropical. So what we see here is that in the temperate areas, which are on the left, temperate yields tend to thrive until about 3°, but the tropical yields tend to decline immediately. And what we also see is that adaptations can extend those positive responses to a higher level, but the tropical yields are much more vulnerable to the warming and changing climate, even with adaptation.

So what does this mean, this temperate versus tropical split? This brings me to what the IPCC probably, this is 2001 but also 2007, probably the strongest message from Working Group 1 on impacts of climate change is that the developed and developing countries diverge in vulnerability to climate change. This is both on the impact side and the adaptive capacity side. And this major result, major finding, depends on multitudes of global and regional studies, top down, bottom up, with rural groups and differing agricultural systems.

Two final points on how climate change will affect agriculture. Water resources are key. The increasing droughts and floods; increasing decadal variability, will be very dominant as we go through the decades. That's what we see as we work with the agricultural projections and the climate change scenarios. There will be changes in seasonality as well, both in the – The bottom right is showing some U.S. Corn Belt work, but also in the tropical regions with changes in dry seasons and wet seasons as well. And as we go into the future with this changing water situation, there will also be the stresses of competing demands from domestic users and the ecosystem's services, the water that's needed to keep the ecosystems going.

Finally, pests may surprise. It's not just the crops; I've been showing you the crop numbers. But it's the whole agro-ecosystem with the associated weeds, insects and diseases. And these are showing three examples, some that are actual that have actually happened in the past, how quickly crop pests can spread. Warmer temperatures, longer-growing seasons will allow more generations of pests to exist. So there will definitely be changes in agro-ecosystems.

And this is the final one on this part before I get to the solution part – that climate change is already here. What the map is showing is the annual temperature changes that have occurred around the world since 1973. Already in most places of the world you see yellows and oranges. Only blue is where it has not been warming over the last thirty years. And what the lines are pointing out is where there have been documented changes in agricultural systems already in terms of phenology, in yields, on effects on livestock, changes in management practices, and changes in pests and diseases.

So one thing that's very important about climate change is that it's not just in the future. It's no longer in the future. It is happening now. And this came out very strongly in IPCC Working Group 2 that had a whole chapter, Chapter 1, on effects that are happening now in all of the impact systems.

Let's turn to solutions, because that's really where we all and where you all are working. Farmers in the agricultural sector need to mitigate and adapt at the same time to reduce risk. As we are working as an agricultural sector to reduce agriculture's contribution to the greenhouse gas emissions, we are going to be living in and working with our agricultural systems in changing climate conditions. So it's not only mitigation, it's mitigation and adaptation at the same time.

In both cases there isn't just one solution. There are multiple pathways to both mitigation and adaptation – bioenergy, the topic of today, but others, improved efficiency and productivity in farm operations, carbon storage and agroforestry and soils, improved nitrogen fertilizer efficiency, methane emission reductions in rice and ruminants, and manure management. All of these are mitigation pathways for the agricultural sector to pursue.

This is also from the IPCC Working Group 3 that works on solutions, and they did an analysis, based on the literature, of the mitigation potential in million metric tons of CO_2 equivalent per year. And what the big red bars are showing – those are the CO_2 ones, and these are with the highest potential – is that improved efficiency of production in both crops and livestock and working with organic soils; these are the ones that offer a lot of potential. But at the same time, all the other ones including biofuels – and they actually felt that they couldn't evaluate the potential of the biofuels; they only looked at how it might affect soil carbon sequestration because of the many differing estimates of the mitigation potential.

But we see that agricultural efficiency continues to be such an important part of the solution, as well as all the other many pathways to mitigation that we have mentioned.

Just to very briefly speak on key points on bioenergy. I think the one I want to emphasize is that climate change will affect greenhouse gas emission calculations, productivity, crop types, etc. So as part of the long-term perspective that has been brought forward in the symposium, that the climate change has to be part of the thinking – it's making a calculation without taking the climate change into account – I think you will contribute to less than robust projections and calculations.

On the adaptation side, we also have to be studying and learning about and figuring out multiple adaptation options. So one of the ways we do this is with crop models, looking also at possible outcomes. There is still lots of uncertainty, so we now show things in terms of probabilities.

And everything is not, with climate change, all negative. It's very important to realize that. The biomass increase, under elevated CO_2, there can be cultivar selection in breeding to maximize yield there. Others of the negative effects, we will need to work on lots of adaptation strategies.

The final point on mitigation and adaptation is that they can be interactive and need to be brought together. They can be synergistic. What the graph is showing is that you need to – again, when you're looking at both the calculations, let's say, of soil carbon sequestration – adaptations such as increased fertilization or irrigation need to be taken into account to actually make estimates of what your carbon sequestration could be.

But also that carbon sequestration not only helps on mitigating greenhouse gases, but by having higher organic matter in our soils helps farmers to withstand both droughts and floods. So thinking about the interactions of mitigation and adaptation processes is also very important.

Here are the final thoughts. Agriculture has an important leadership role in both mitigation and adaption to climate change through a diverse mix of activities. Solving the climate change challenge requires strong continuing interactions between researchers and decision-makers, since climate, science and solutions continue to evolve.

The point here of this – I think it's shown so clearly by the symposium on biofuels this week – that we have to continue to work together. We have this early example of policies being made very, very quickly, and then look at all the issues that have arisen. So this is not something that policymakers can say to researchers and scientists, "Thank you very much. We have the idea. We'll take it from here." This clearly shows that we need to work together and find even better ways of working together.

And finally, despite posing tremendous challenges, climate change is a transformative pathway to sustainability. Thank you very much.