

THE WORLD FOOD PRIZE
2008 NORMAN E. BORLAUG INTERNATIONAL SYMPOSIUM
Confronting Crisis: Agriculture and Global Development in the Next Fifty Years
October 15-17, 2008 - Des Moines, Iowa

BIODIVERSITY AND AGRICULTURAL SECURITY

October 16, 2008 – 8:30 to 10:00 a.m.

Moderator: Margaret Catley-Carlson

Speaker: Cary Fowler – Executive Director, the Global Crop Diversity Trust

Participants: Pamela Anderson – Director-General, International Potato Center

Emile Frison – Director-General, Bioversity International

Rosamund Naylor – Director, Stanford University Program on Food Security and the Environment

Ed Rege – Director of Biotechnology, International Livestock Research Institute

Ravi Singh – Director of Bread Wheat Breeding, International Maize and Wheat Improvement Center

Margaret Catley-Carlson

Chair, World Economic Forum Advisory Council on Water

I'm Margaret Catley-Carlson. I am going to be the moderator for the next session. I work in a number of – I'm now reading Ken's introduction of me... I work at a number of organizations that have to do with water and with agriculture, and I'm very pleased and proud to be on the Council of Advisors of the World Food Prize. So that is why I am here this morning.

And we are going to have to compliment this excellent beginning that Rita has given us, with another presentation speech to get us going, to going to us thinking about the broader issues, followed by a first-class panel. So I'm quite looking forward to this. I know you will be, too.

Our first, next speaker, after Rita, this morning is Cary Fowler and he – I think some of you will know of him. I'm very proud of the fact that he just, in Vancouver three days ago, received a new, honorary degree from one of the universities in Vancouver and was all over the newspapers and television there. So, congratulations, Cary. This is well-deserved. So it's very nice to follow you here.

His career in conservation and the use of crop diversity is more than 30 years. Before he joined the Crop Diversity Trust, where he is now the Executive Director, he was professor and Director of Research in the Department for International Environment and Development Studies in the Norwegian University of Life Sciences.

He headed the International Conference on the Program of Plant Genetic Resources at the FAO. And that produced the first-ever global assessment of the state of the world's plant genetic resources. And then he drafted and supervised negotiations of the FAO Global Plan of Action on Plant Genetic Resources, which has been adopted by 150 countries in 1996. And the same year he served as special assistant to the Secretary-General of the World Food Summit.

So now we're going to start opening the door on something which is as complex and very much related as the things that Rita was talking about, which is – How do we protect, how do we

know about the need for the dimensions, of the scope of the need to promote and protect diversity? So that's the window that we're going to be opening now. Cary, do come up. Where are you? And please enlighten us with your very special perspectives. This is Dr. Dr. Cary Fowler.

Cary Fowler

Executive Director, the Global Crop Diversity Trust

Thank you, Maggie, and good morning, Iowa. No PowerPoint presentation today, just some conversation.

About 20 years ago, something quite unique historically began to unfold, something unique in the history of agriculture, even if you go back to the very beginnings in the Neolithic Period, 10,000 or 12,000 years ago. About 20 years ago for the first time in history we made a transition.

Prior to that, the chief source of increased food supplies for a growing world population had been derived simply from cutting down trees and expanding cropland, expanding agriculture. But about 20 years ago the transition started to be made so that the largest incremental amount of food being produced was coming not from expanding cropland but by intensifying production.

Now, there are a number of ways in which food availability can be increased. You can reduce post-harvest losses, you can double-crop, you can substitute one low-yielding crop for another. But historically the main source of additional food has been to increase cropland, and now that's no longer the case. This means that the use of crop diversity in breeding new varieties, new high-yielding varieties was, of course, quite pivotal to this historic transformation. It was essential, obviously, to Norman Borlaug's efforts in Mexico, essential to the efforts of Pioneer Hi-Bred here in Iowa and around the United States, and it was the reason for the first collections of crop diversity even being made. So now, more than at any point in history, crop diversity, or genetic resources, has become the quintessential and necessary resource for moving agriculture forward and for increasing productivity and food security.

Now, yesterday Sir Gordon Conway outlined a number of challenges that agriculture is facing. I know you remember some of those. This is a historically unprecedented group of challenges, any one of which would be enough, but the combination of which is really quite something.

So we have climate change, and the situation which Roz Naylor on our panel from Stanford will talk about, where we can expect the future climates to be totally unlike the past climates, just a little bit farther into this century. In other words, we have agricultural systems today, which are based upon thousands of years of evolution in one climate, and which in this century are about to face a completely different climate to which they are not adapted.

We have water problems, where 70 percent of the freshwater supplies on earth are used by agriculture, and there is of course more and more competition for those water supplies; energy problems, which Sir Gordon spoke about yesterday, higher energy and fertilizer prices; chronic underinvestment in agricultural research; low stockpiles, etc., etc.

These crises seem to come back to back, and they don't go away when the next one comes; they simply get added to the list. This year we've had the food crisis, but that seems to have been

pushed to the back pages by the financial crisis. So I suppose one of the most important questions we could ask ourselves today or tomorrow is this question – it's a simple one.

The question is – Is agriculture ready? Ready not just to produce the same amount of food, given all these new crises and challenges, but actually to produce more food, despite the fact that we're about to experience a different climate and less water and less or higher energy.

Well, if we're not ready, and I suspect most of us in this room would agree we're really not ready to meet these challenges, then the first thing we have to do is assess what our tools are and what our resources are to get ready.

And here the news is actually rather good. We have a tremendous amount of crop diversity upon which to draw, crop diversity in the form of different traits and characteristics, many of which are unexplored and untapped. Let me give you some examples.

There are about 200,000 different varieties of wheat. To put that in perspective, there are 400 breeds of dogs, but 200,000 varieties of wheat; 200,000 to 400,000 different varieties of rice; 35,000 different varieties of beans; on and on. These aren't just pretty and interesting. These are not stamp collections. These are essential raw materials and resources for the future of agriculture.

And so in many ways – and let's not be embarrassed about saying this – these are the most important natural resources on earth. Tomorrow's Norman Borlaugs are not going to be grabbing higher protein content, drought tolerance, disease resistance out of the sky. They're going to be grabbing these traits out of gene banks. But this assumes that the gene banks are there and the resources have been well cared for; and this is an assumption, I'm sorry to say, we shouldn't be making.

Is the current system working? I don't think anyone on the panel today is going to tell you that it really is. Now, we have experienced dramatic losses in crop diversity in the past. You just have to look at the United States. In the 1800s, about 7,100 named varieties of apples were being grown in this country. Today 6,800 of those varieties are extinct. And any unique trait or characteristic that they may have had is gone. These are apple varieties which, I dare say, bear the names of many of you in the audience today because your ancestors gave them the greatest honor they could give them – they gave them their name. But these are lost varieties.

Now, we might have considered this a luxury in the past. After all, we're replacing old varieties with new varieties. But we know too much now. We know that the old varieties are really the biological foundation of the new.

We're losing, however, varieties now and unique diversity even in institutions that bear names that would indicate that they're safe – gene banks. There are about 1,300 gene banks in the world today, but there are not 1,300 good gene-bank managers, and there are not 1,300 good systems for conserving this diversity. I know of not a single gene bank in the world that operates on a secure multiyear budget.

So we've lost, we continue to lose their diversity – a sort of drip, drip, drip of extinction – because of equipment failures and poor management and accidents. And then sometimes gene banks, just because they're in buildings, get in the way. And they get in the way of wars, so recently we've lost gene banks in Iraq and Afghanistan (you can take a guess why), in the Solomon Islands,

and then there are natural disasters that come along. So we had a big disaster in the Philippines in September 2006 – a typhoon came through and put over a meter of water in the gene bank there.

We lose a lot of diversity, and frankly we lack a system for caring for it. And this, ladies and gentlemen, is simply a crime. It's a crime in the context of challenges when we know that we're going to need the diversity to meet the challenges in the future.

We know, however, how to solve this problem. It's not rocket science. It's actually fairly simple. We know how to conserve diversity, and we know how to distribute and manage it.

We can construct a system where we have all of the unique diversity in one gene bank and backed up safely in the facility that Gordon Conway showed you yesterday up in Svalbard, with which we are associated.

The time has come, therefore, I think, to put on the table some fairly bold proposals that are not simply a list of Christmas wishes but a list of things that we must do and can do. Let me give you a couple of examples, and I'll end with those.

Within two years, can we not endow wheat or rice or corn or potatoes? We endow chairs at the university, even chairs in plant breeding. We endow art museums. We endow a number of things in society, and all of which are great. But if we really want to ensure the future of our own crops, can we not think in terms of endowing the crops themselves?

For somewhere between \$350 million and \$400 million, one-off, we can conserve, understand, distribute, and ensure the use of crop diversity for every major crop in the world, forever. In the scope of the kind of things that you're reading on the front page of the newspaper in the last couple of weeks, \$350 to \$400 million dollars, one-off, to secure the biological foundation of agriculture seems like a pittance.

Within five years, could we not collect all of the remaining biological diversity that's out there, in the form of wild relatives of our agricultural crops, which we know that the new technology which we're using today will make more and more valuable in the future to combat climate change and the other challenges that agriculture faces? I think we could do that. That's where the real diversity exists that's not already been collected.

Could we make a major initiative on root and tuber crops – crops which sometimes don't get the attention they deserve? We can call them “orphan crops,” because we haven't invested in them sufficiently to the importance that they have and yet which are so important to food security for the poor.

And within five or ten years, could we not screen the existing collections? We have a wonderful library of life here, but in many cases the books in this library haven't been opened or read, and we don't have a card catalog. This is simply unacceptable for an agricultural system facing the challenges that we do face.

We can do all of these things. The cost-benefit ratio is absolutely enormous, and it's within our capacity – not involving Star Wars technology but simple tried-and-proven methodologies using existing institutions, which you're going to hear about from panel members.

Let me close by saying this. I'm not saying that conserving and making available crop diversity is a panacea. It's not going to solve all the world's problems, but it's a prerequisite for solving them.

Can I ask you to consider whether you can imagine an effective, reliable, efficient or sustainable solution to climate change, or to water problems, or to energy constraints, or to food security that does not involve the conservation and use of crop diversity? I can't come up with any such solution.

We know how to do the job, and we can do it. The interesting thing, of course, is that food crises tend to trump other crises, but they get moved to the back page all too often, as we've seen this year. One of the reasons that they do is that there's a long lag period. So we'll never really have a crop-diversity crisis. Why? Because by the time the real crisis hits and moves to the front page – the big food crisis – we'll have lost sight of the fact that it was really a crop-diversity crisis.

That seems to be a ubiquitous problem in society of how we deal with crises without having a crisis. And yet we know in this case, I believe, that we must; because if we wait, frankly, the cost will become too high and perhaps we won't even be able to pay it, no matter what kind of financial resources we mobilize.

Thank you.

CONVERSATION

Margaret Catley-Carlson

Thank you, Cary. A very fascinating and sobering presentation, particularly the end – that by the time we're actually experiencing the crisis we'll be calling it something else, because the needs that we would have to deal well with it is something we may have dropped along the way.

So we've got a panel this morning, and we're going to ask them some of these rather sobering questions to see if this is indeed the ultimate and inescapable reality in this particularly important area. Would the panel like to come up, please, one at a time as I'm introducing them, please. This is just so you can each have a moment here. Pamela Anderson has been the DG of the International Potato Center in Peru where she was previously the DDG of research and the senior environmentalist at the [International Center for Tropical Agriculture] in Cali.

CIP is a major partner with UN FAO, and this lady hasn't been home for a whole year, because it's the International Year of the Potato, and she has been running around as Madame le Pomme de Terre. And she has been everywhere talking about the importance of potatoes.

She is a leading expert on emerging plant diseases with research including extensive work in plant-virus epidemiology related to food security and income generation for resource-poor populations. She has been in Latin America for 30 years and has spent two decades working with agricultural research centers. So, Pamela, you're very welcome.

Our next panelist is Emile Frison. And as head of Bioversity International, which used to be IPGRI, he's worked to highlight the role of agricultural biodiversity in nutrition, hunger and poverty and sustainable development. He also leads the CGIAR system-wide genetic resources policy

program. And you heard in the introduction of Cary the work that's gone on in that treaty and to forge the international consensus that would actually start to answer some of these problems. For the last couple of years he's been chairing the Alliance Executive of the CGIAR where he's been spending a great deal of time on the future form of the CG system. He's a plant pathologist by training, started his career at the International Center for Tropical Agriculture in Nigeria, a leader in establishing the Global Consortium on *Musa* Genomics, a 27-member group from 14 countries. Emile, you're very welcome.

Roz Naylor – there she is – directs both the program on Food Security and Environment and the Goldman Honors Program in Environmental Science and Technology and Policy at Stanford. Her research focuses on the environment and equity dimensions of intensive food production – so we're back to some of Rita's themes – with emphasis on high-input agricultural development, aquaculture and livestock production, biotechnology, climate impacts on agriculture, and food security. A big mouthful. Among her projects are long-term studies in Sonora, Mexico, where Dr. Borlaug launched the Green Revolution. Welcome, Roz.

Ed Rege is the director of biotechnology at the International Livestock Research Institute, ILRI, in Kenya, where he oversees research that included the development of vaccines and diagnostic tools for tropical livestock diseases, characterization, and conservation of animal genetic resources and genetic diversity, development of breeding strategies for low-input smallholder production systems. He initiated and headed ILRI's Animal Genetic Resources Program and coordinated global activities on characterization and conservation. And if you want to hear a heartbreaking about the loss of genetic resources, get the ILRI annual report for this year.

Finally, Ravi Singh. Ravi is a leading expert on wheat breeding, wheat improvement and disease resistance, especially in most crucially wheat rust. He's contributed to the development of over 168 wheat varieties in his career. Working at CIMMYT since 1983. He's been heading programs, including wheat development for durable rust resistance, rust resistant research and irrigated red wheat improvement. He also coordinated CIMMYT's Global Project on Wheat Resistance to Diseases and Pests from 1998 to 2003. He's recently been involved in the formalizing of the Borlaug Global Rust Initiative. So he, I think is going to tell us a little bit about the importance of biodiversity to being able to fight both the biotic and the abiotic stresses.

Well, panel, Cary has given us a good opening against the background of Rita setting out how this looks from one country. This is so important that protecting plant diversity must be uppermost in the minds of all of the governments that you work with. Right?

Pam, it's the International Year of the Potato. I'm sure, given all the varieties of potato in the world, there must be a real concern to protect the plant diversity in potatoes – right?

Pamela Anderson

Director-General, International Potato Center

Thank you, Maggie. Good morning, and Happy International Year of the Potato to everyone.

The discussion this year has been about the importance of potato in particular, roots and tubers more generally. Cary's point this morning – and it's a sad commentary, but often we do feel like the orphan crops. Roots and tubers have tremendous potential. Potato, what we're seeing, is exploding in the developing world.

We see in China – one of the first countries to meet the Millennium Development Goal on poverty – still having 24 million people in extreme poverty. In their poverty belt, they have explicitly included potatoes in their Eleventh Five-Year Plan as a pathway out of poverty. So we're negotiating a large center with them.

India has said they're going to double potato production in the next 5-10 years. Africa sees potatoes expanding more rapidly than any other major staple at this point. And so all of the nations are looking at potatoes. In 2005 we had an historic moment – more potatoes planted in the developing world than in the industrialized world for the first time in recent history.

So it's really a potential for food security, which is Dr. Norman Borlaug's legacy. His legacy is not about rice, wheat, and maize. His legacy is about feeding people. And potatoes in specific, roots and tubers in general, have a real role to play in this.

Your question is, What about the basis for realizing that potential? And that's the discussion that we don't have outside of Latin America. It *is* a discussion in Latin America because that's where the diversity lies. We have a very special relationship with the potato producers in the High Andes. The domestication of potato, I'm sure you all know, was in the Lake Titicaca region around Peru and Bolivia.

As the potatoes moved north and south, they evolved to the estimated 5,000 varieties of native potatoes that we have today; 4,200 of those are in the CIP gene bank, so we have the bulk of the native potatoes that do exist. Cary's right; we need to finish that job, and there are political and legislative reasons why we haven't been able to.

The discussions we do have locally, the Latin Americans are extremely concerned with preserving the potato diversity. But we don't have that same concern outside of the region.

What we see is high vulnerability. If you have political unrest, if you have natural disasters, potato farmers will lose their seed, because they plant the potatoes for the next crop. In the last five years we have repatriated 25 percent of the CIP gene bank back to more than 40 communities in the highlands to help them maintain their diversity. So we have a very interesting working relationship that we sometimes call “dynamic conservation” between the *in situ* and *ex situ* collections.

Margaret Catley-Carlson

Are you losing potatoes?

Pamela Anderson

Yes, yes.

Margaret Catley-Carlson

You are.

Pamela Anderson

Urbanization is one of the problems, and basically, you know, we can't keep repatriating at the rate that we're losing, so it is a problem. And we have to protect the gene bank – Cary's right: we don't have more than one year of funding at a time, which is true for all of our gene banks.

So the other biggest concern is climate change. We are talking about potatoes in the High Andes, diversity in the High Andes. And basically the way of dealing with climate change has been to keep moving up; there's no place to go anymore.

And so there's tremendous concern as late-blight, the diseases and pests, catch up with the rising temperature that we are going to have severe loss. So collecting the rest of what's out there becomes even more important.

Margaret Catley-Carlson

Ravi, the situation must be much easier in wheat – right? I mean, we've been growing wheat for a long, long time, and there's, as Cary said, either a hundred thousand or more accessions of wheat, and we have depended on this ever since it came out of the Middle East. So the situation must be much better, enabling us to fight with things like rust disease, right?

Ravi Singh

Director of Bread Wheat Breeding, International Maize and Wheat Improvement Center

Well, good morning, first of all. Yes and no.

Margaret Catley-Carlson

I somehow thought that might be the answer.

Ravi Singh

Well, there is plenty of genetic diversity you can draw upon to tackle the problem. But let me just mention, taking the example of the stem-rust situation, the race of the stem rust, which we mentioned yesterday – the Ug99 race, which appeared in Uganda first, or that's where they were first detected and slowly started to move, and in 2003 started to affect fields in Kenya, and all of a sudden it started to migrate faster, crossing to Yemen in 2006 and a year later was picked up in Iran.

Okay. So this is just one race, which you may think, "Well, there are many races of biotypes of a stem-rust pathogen over time." But when you look at the germplasm of varieties developed by breeding programs – not just CIMMYT, but U.S., Canada, Australia, India, Pakistan, many different countries – this particular race somehow evolved to overcome whatever resistance genes people

used for over 40 years. For 40 years this disease was under control through the use of genetic resistance. But pathogen could overcome all that resistance. So between 80 to 90 percent of the wheat area currently sown worldwide is vulnerable. That's why Dr. Borlaug got so alarmed, and he raised the alarm.

Now, you can imagine – about 230 million hectares of wheat is grown. So it's a huge area, and wheat is a very important staple crop among cereals; wheat, rice, maize, these three are so important for many of us, especially the poor in many countries.

So I said “No,” because the problem is there; you have largely susceptible wheat varieties. And I said “Yes,” because there are some resistant wheat materials in the breeding programs and some, a few cultivars have been identified.

So you can kind of manage this crisis in the short term. But you have to look for longer-term approaches, as has been mentioned by Cary. I mean, it's a huge area you are talking about. You can mitigate the problem in the short run, but we have to continue looking for new diversity – a constant research and breeding effort, which can continue to feed new diversity into breeding programs, into farmers' fields – and also look for ways where the more diverse wheat varieties are grown in farmers' fields.

Margaret Catley-Carlson

Why aren't we in better shape? We have known about rust. It's one of the plagues that's listed in the Christian Bible; it's in the historical texts. Why are we not in better shape to fight what is an old-time enemy of this important crop to human beings?

Ravi Singh

It's quite simple. Sir Gordon mentioned many crises, you know. So when you look at the crop, you'll find we are facing not just wheat stem rust; it is one of the three rusts which affect wheat. So when Dr. Borlaug went to Mexico to work with stem rust, there was major cooperation in those days between the countries of North and South. They all worked together, shared germplasm information, tested each other's material, and came up with this stem-rust resistant wheat, which remained resistant to such an extent that most of us, the younger-generation people, we started to forget that that disease ever existed.

So when you look in your research agenda or the donors who put money, or your own bosses in your own institution, they have many other situations, many other priorities which need funding. So there was neglect for a long time; there was lack of funding. Researchers stopped quit working on a stem rust. We can name just four or five people who currently work on stem rust worldwide. That's about it. So capacity is another issue coming up.

Margaret Catley-Carlson

Wow. Ed, take us to how this fits the world of animals. I think everybody in this room has some glimmer of this happening in the plant world, but when you start seeing the faces of cows, goats, and sheep species that are no longer with us and that used to cover an appreciable part of the farmyards of the world, I guess, because it's an animal and we're animals, too, it brings home in a

very real way what the loss of biodiversity is about. Tell us a little bit about how this also applies in the world of animals, because we're not just talking about plant diversity.

Ed Rege

Director of Biotechnology, International Livestock Research Institute

Thanks. First, I would like to really appreciate the introductory speech by Cary, because I think you have set the theme. You have identified the challenges as well as the opportunities. The only difference is that the challenges are greater in livestock, and opportunities are much fewer. And I'll talk to that in a minute.

It's amazing that whenever we talk about biodiversity or whenever we talk about agriculture, that livestock seems to be the last to be spoken about. And this was exemplified by the introductory speech by Cary this morning. He was talking about some very genetic things, but all his examples were coming from the plant side. And that's because, basically, because of the fact that he has been working on the plant side, and the plant has gotten much more attention to date, and for good reason as well.

Ladies and gentlemen, I would like just to start by saying that livestock are feeding 1.2 billion people. Their livelihoods often depend on livestock. Out of that, 600 million actually could not do if there wasn't any livestock. About 400 million of these people live in crop-livestock systems where livestock is not just used as livestock, a product, [but as] what livestock does in agriculture. Indeed, livestock is critical in those systems because without livestock, there's no crop. Livestock pull the plow, and livestock provide the manure that provides the nutrient cycling that provides sustainability in those systems.

In the pastoral systems, 200 million people depend on livestock. Period. There's nothing else. Livestock is critical in those systems for another reason, that it provides the only quality protein on which women and children depend.

Some facts and figures for those not familiar with livestock: Livestock is not synonymous with cows. Cows are livestock, but we have 40 species of livestock that are used for food and agriculture. So the situation contrasts quite significantly from the plant side, because in the plant side we talk about hundreds of thousands of varieties and so on. In livestock we are talking about a very small, narrow genetic base.

So the 40 species I'm talking about range from the yak of the Himalayas through the Bactrian camels in Asia, the dromedary camel in Africa, the lamas and alpacas, the rabbits that are used in domestic production, and so on – only 40 species we have. And within the 40 species, Madame Chair, within the 40 species we have only somewhere between 8,000 and 14,000 breeds, varieties, or strains that are available for food and agriculture. Now, note that range. The range is so wide because we know so little about what we have. We haven't characterized them enough to be concrete about the number of subpopulations that we've got. So there's a lot of work still needed to understand what we've got.

We do not have, in livestock, wild relatives, so that's another big difference.

Another difference is the fact that whereas in crops, particularly when you talk to people from developing countries, there are concerns about loss of diversity as a result of what they're

calling a movement to the North. In the animal world, the problem is exactly the opposite – that the biggest cause of loss is movement of so-called “turbo-type” or high-productive breeds from the North to the South, which are being used in cross-breeding as well as replacement, but on the basis of very little information. In many cases, these have ended up actually destroying the very basis and integrity of the national populations that are adapted in those systems.

So these are some of the problems that we are facing. Now, the current drivers, as I’ve said, is movement of material from the North to the South, but also the tendency, I mean, under pressure to increase productivity, to actually assume that monoculture in livestock is going to be the solution.

So the same situation that we have in crops attain with regard to livestock in that sense.

The challenges, Madam Chair, as we look to the future, include at least three, but there are many more. One is the livestock revolution. The livestock revolution simply says this: That by the year 2030, we will have double the demand for livestock products, particularly milk and meat. To meet this demand, people are moving very quickly to find the highest-producing breeds, but not necessarily thinking through what that is doing to the resilience of the systems, which actually depend on the low-producing but yield-sustainable breeds that we’ve always had, particularly in the smallholder systems in the tropical world. Now that’s a big challenge, but it’s also an opportunity.

Margaret Catley-Carlson

And the other two?

Ed Rege

The two are climate change, Madam Chair, as well as emerging infections diseases. Now, climate change...as an example that was given yesterday, was the fact that southern Africa is going to be a hotspot. And when South Africa loses 100 days of growing season, you will not just adjust the production system of today to hopefully meet the livestock production need. You will actually have to change species from cotton, probably, to camels – so you can imagine what kind of challenges.

If you look at infectious diseases that are emerging and re-emerging, I would give one example only, Madam Chair, and that is avian influenza. With that avian influenza, countries are moving towards basically what they’re calling “mass kill.” “Mass kill” means getting rid of all the chicken you have in your pathway, and that means clearing away the entire genetic diversity in the native systems.

Margaret Catley-Carlson

What a picture you paint for us. And thank you for getting so much information into a short time. Roz, we take the three challenges there, and then we turn to you and we see that you’re trying to look at high-input agricultural development, aquaculture, and livestock production. How do you do that kind of high-input, and very intensive, agricultural production in order to achieve your equity and environmental goals, when you’re faced with exactly these issues – that it’s the intensification of some of these systems that has indeed led to the situation, particularly, that Ed is describing?

Roz Naylor

Thank you, Maggie, and it's an honor to be here with all of you here today. In looking at the intensification of systems, I've really been looking at both of the environmental implications of high-intensive agricultural systems and the equity – who wins and loses in the development of these systems. And obviously, in the intensification process itself, a whole host of pests and diseases have become much more complex and have required all sorts of new controls.

And as we look to the future, one of the issues – if you don't mind that I touch upon it – is the second challenge on climate change here: How will these systems really fare now that we've put all our eggs into the more-intensification basket, because there's really no other choice? How will these systems fare in the future?

And this is a topic that Cary and I, with the Global Crop Diversity Trust and the Program on Food Security and the Environment at Stanford, had a conference at Bellagio last year really to look at the types of systems you just mentioned in a world of climate change. So where are we heading with this? Characterizing these systems and where we're heading in the future is the first step, but then really figuring out what the solutions are is the second step.

And as we look at the roughly 20 global climate-change models that have contributed to the recent IPCC AR4 report, the one that won the Nobel Peace Prize recently; taking the full range of uncertainty out there in the projections, what we find is three very overwhelming agreements among all the models all around the world. One of those is obviously rising temperatures, so the sorts of threats on livestock, whether it's very extensive livestock or more intensive livestock in agriculture, is that we are going to face rising temperature throughout the globe.

The second major conclusion is the decline in soil moisture that's going to occur, particularly with rising temperatures in the subtropics. And that will lead to more droughts in some areas and the inability to intensify, and flooding in other areas where you have rain, but it just falls on hardpan soils and floods areas.

And the third is the sea-level rise and the flooding of massive areas, particularly of South Asia, for example.

But when we look at these systems and we combine our crop models on intensive systems and more extensive rain-fed systems, what we find is in southern Africa, which was just mentioned here, on average, the projection is – even within this very short-run breeding cycle that we're looking out to 2025 or 2030; not even looking to the end of the century – the mean projection is a 30 percent drop in maize production in these systems by 2030, for example, just by climate change alone. So not even with all the other complications that go along with intensification, like where the water is going to come from, the pests and diseases, and so forth.

That's a massive fall for a population that obviously doesn't have a lot of security mechanisms to fall back on, as maize is the major crop in those systems.

South Asia, as was discussed earlier today, is another unanimous area where there's going to be problems not only in sea-level rise but in very predictable falls and yields across all of the crops.

And livestock, which I'm really glad was mentioned, is so vulnerable in all of these systems. It's the one security net in terms of assets in a lot of these systems, and it itself is intensifying in very important ways.

So the industrialization of livestock has been really overwhelming. Some of the highest growths in any of the food-production sectors has been in poultry and hogs and providing a protein source in developing countries. That's been very important.

And, in fact, some of the industrialization process and the vertical integration in that process has been good in terms of confining some of those diseases that you see emerging in the more household chicken systems, for example. But they're really threatened by massive types of pests and diseases, and by climate change.

For example, you know, in all of these systems there is an upper tolerance to heat for all of the animals – particularly in more humid systems where the animals can't sweat. Hogs don't sweat anyway, so they're very much threatened. As was just mentioned, finding new breeds where they're already bred for the hottest areas is going to be unbelievably challenging. But even in the very industrial systems, it's going to be very challenging because there's not the genetic diversity in these systems to rely on.

When we look further to the future, I think the really scary thing, as Cary mentioned earlier in his talk, is that we're really moving towards an out-of-bounds situation where, by 2050 or slightly beyond, in virtually any country you look at, when you take the global models and go down to the country level – in virtually every single country, the mean temperature for the growing season is going to be equivalent to or hotter than the very hottest, extreme season we've seen in the past hundred years. So the mean is going to be at that hottest extreme.

And in very large – if you look almost throughout the tropics or parts of the subtropics, the mean temperature in the future is going to in fact be way above that. And even the coldest seasons are going to be hotter than the hottest seasons we've seen in the past hundred years.

So how you deal with the genetic diversity in plants on that issue is going to be challenging. Animals are going to be eminently more challenging in that context.

Margaret Catley-Carlson

Okay. I think you've given us a lot to think about there, an awful lot, thank you. This room doesn't seem to know about global warming; I think our mean temperature keeps going down, maybe it's to keep us all awake.

Emile, so many complex and really difficult and dangerous things have been brought up. Roz is talking about heading towards an out-of-bounds situation. I guess the treaty that you've worked on for so long handles all of this well, and people are rushing under the umbrella of the treaty to do the right thing. Is this what we ought to conclude from all of you and your colleagues' very hard work on the treaty? And if not, what is the situation?

Emile Frison

Director-General, Bioversity International

Exactly. But, no. I think what we've lived through in the last 15-20 years has been a drastic change regarding the way people look at genetic resources, after the Convention on Biological Diversity brought in a new dimension or notion of national sovereignty over natural resources, including genetic resources.

What was the basis of progress in agricultural breeding has been really jeopardized. And if you look in the last 12 years or so, in some continents, Latin America is an example, virtually nothing has moved from one country to another in terms of genetic resources.

And while we know that this is the basis of progress, of increasing productivity, this is really problematic. And therefore, the negotiations that led to the international treaty have been extremely important to reopen the exchanges.

Now, that has been achieved at the international level in theory. We still have to translate that into a reality, and that means applying the openness that is foreseen in the international treaty at the national level and translating it in a restarting of the exchanges of genetic-resource flows.

Margaret Catley-Carlson

What will it take, Emile? What will it take? In your common-sense knowledge, after your long experience, what will it take to get this started?

Emile Frison

Well, I think we are receiving a lot of questions from countries that say, "While we have ratified the treaty" – there are now more than 100 countries that have ratified the treaty, and it's expected to become a universal treaty like the CBD – but at the national level, the people that are dealing with the exchange of germplasm say, "We don't know how to do it. Who is in charge in my country? Who has to authorize things?" etc.

So we are receiving a lot of questions on, How can we put in place at the national level the necessary policies, the necessary arrangements – legislation, in some cases – where there are incompatibilities between national or regional legislation and the treaty that has been ratified? So a lot of efforts have to go into making and helping countries, in a way, to develop those policies and legislation to allow this to happen again.

Margaret Catley-Carlson

Cary, do you see recognition that treaties could actually make this happen in the work that you're doing, in trying to mobilize the international community to be more responsible about genetic resources, plant genetic resources?

Cary Fowler

Well, I think that the treaty is a prerequisite for progress. We do need a legal framework. But I think we also need to be better on our side in articulating a vision of where we need to go and what we can be doing.

Maggie, I wouldn't want anyone here to go home feeling hopeless or helpless. I think that in fact a number of very important things are being done. At the Trust we're actually working in partnership with every one of the institutions up here, the leading institutions in the world.

And I'll give you one or two examples. In the next three years we will rescue from extinction, literally from extinction, a 100,000 unique crop varieties that are in substandard conditions, primarily in developing countries' gene banks. That's probably the biggest biological rescue program in history.

We are working with Emile's institute, Bioversity International, in partnership to develop essentially an Amazon.com for plant breeders. We're facing huge challenges, as we've all been talking about, and yet plant breeders have no way of accessing the entire gene pool with their crop to find the kind of materials that they require. We can find a used book at Amazon.com, but can we find disease resistance or drought tolerance, or something like that, with our major crops? Not today – but in a couple years we can.

So this is one of those wonderful fields where we don't have to sit up here and talk about “Woe is us,” and “The problem is overwhelming and great.” We can actually map out where we need to go. We can start doing that work. And we can tick off the boxes, and we can get there.

Margaret Catley-Carlson

Good. I like one of Cary's expressions, that “plants just can't pack up their roots and move.” It has a lovely resonance when you start talking about climate change, and, “Oh, it's warmer up there – I'll just pack up my roots and we'll go and move up there.” It doesn't quite happen that way.

Ravi, is this true? Can we actually get away from the – Cary says, “Look, we've got better information exchange, we've got the possibility of sharing information better among a wider community of people.” Is this going to help with plant rust?

Ravi Singh

Definitely, especially if germplasm, which he has, has the knowledge to go with it. And that's what Cary is mentioning. If we are looking for a gene or genes for resistance, diverse sources, if we know which germplasm to access, it will greatly help the breeding program.

And disease is one example. There are many other traits which people are basically looking for new genes, new alleles of genes. Heat tolerance, we have been [hearing], for wheat crops; it's very important to start right now breeding and incorporating genes which will give heat tolerance.

Take, I mean, if you take the Dr. Borlaug's shuttle-breeding strategy where you grow two crop seasons per year – you need six years at least to build up this kind of self-pollinated wheat varieties, from the time you make a cross. And some wild relatives, if you want to transfer genes, it may take even longer.

So, yes, Margaret, the initiative is very important, and I think the other aspect is the characterization of germplasm, which the initiative is looking at. That's equally important in restoring the germplasm for the breeding programs.

Margaret Catley-Carlson

Pam, I'm going to turn to you because of something Cary said. Your CV says you've been working in Latin America for 30 years, and Cary has characterized the Latin America region as one of the ones that's had particular difficulty in sharing germplasm material.

I'm not asking you to represent Latin America governments, but can you reflect a little bit on the kinds of concerns that governments have which actually get in the way of increased international collaboration in these areas? And as I say, I don't expect you to be an apologist, but I do expect that by now you probably understand this quite well.

Pamela Anderson

Yes, Cary is absolutely right. The CBD came into effect in 1992, and we have essentially not seen a new acquisition of potatoes, so it's very extreme – the chart just drops. Latin America has been particularly interesting, because what we are sitting on is the crossroads of international, regional, and national legislation, which are often contradictory. And so part of what we've been doing, in terms of the legal/political framework, is working with our partner organizations to really sort through those different scales of legislation. It's been very challenging.

And, yes, I've been in the room with a lot of those meetings. We've been working literally with a legal organization giving legal advice with our partners. But there is another fundamental issue which sometimes we are shy about talking on – and that's trust. Part of what's really behind all of this is the trust in terms of the genetic resources.

Latin America is very, very proud. If you take a look at the crops that the world depends upon, this is the legacy of Latin America to the rest of the world. We didn't have written language, and so sometimes this doesn't come across quite as much as some of the other legacies. But Latin America gave more domesticated crops to the world than any other region, and they know that, and they've very proud of that. I live in a country where genetic resources are letters to the editor and front-page news.

And so there's a particular sense of ownership of these crops, and a problem with trust: "We have turned over our genetic resources to you, the international world; what have you done with them, and what have you done for us?" There's a paradox. The people who were the breeders of a lot of these crops that we rely on and become rich on, including potatoes, are some of the poorest people on our continent.

And so there is really an issue of rebuilding the trust. And we're working on that, and we're very, very close to having the breakthroughs and moving the germplasm again, helping people understand this is mutual benefit; that we all need this, we will all benefit. But there's been a real job of rearticulating and rebuilding trust so that we could move these very precious treasures around again.

Margaret Catley-Carlson

Ed, what's the animal equivalent of all of this? You've got the Treaty on Plant Genetic Resources, but I've never heard of a treaty on animal genetic resources (which could be my

deficiency), but what's the international equivalent of this? How are we going to protect and promote that kind of genetic variety?

Ed Rege

Thanks, Margaret. I think that, under the CBD, there have been a lot of discussions, quite similar to what's happening on the plant side, on the animal side – which is, wouldn't it be nice if we had an animal genetic-resources treaty in the same way that we have a plant one? And in fact the NGOs, particularly pastoral-group NGOs, are really pushing for a treaty like the one we have on the plant side for livestock.

But I think there's also a lot of people saying, "Wait a minute. We already are experiencing problems on the Plant Genetics Resources Treaty. Wouldn't it be better if we understood what those problems are, and learn from what the plant people are experiencing? So that whatever treaty – if one is ever needed – whatever treaty they would come up with is one that reflects the truism on the livestock but also the lessons that have been derived from the plant side."

So, yeah, there are many, many workshops and meetings and conferences just discussing this issue. I would say that it is fortunate that there isn't a treaty that has been rushed to be concluded because I think the experience on the plant side is a great experience.

But let me just add one more thing, Margaret. I think in terms of presenting the real issues on the animal side, I think I would have failed if I didn't tell you that we are losing on the animal side one breed a month. And I said the genetic diversity and the window is very small. We are losing a breed a month, and we don't have *ex situ* conservation programs on the animal side.

So I think the situation is much more serious on the animal side than it is on the plant side. And the climate-change impact on the animal side will also be much bigger, as has been explained.

So I think we need to really be thinking about this one point – 2 billion people whose lives and livelihoods depend 100 percent on livestock.

QUESTION AND ANSWER SESSION

Catley-Carlson I want to give each of the panelists two minutes at the very end to get out any messages they didn't get out. But in the meantime, let's have some questions. What does all of this raise in the minds of people? Adel, is that you? You have to go to a microphone, please, and introduce yourself.

Question Adel El-Beltagy; I am the chair of the Global Forum for Agricultural Research, GFAR. I would like just to share with you three points. Let me first talk a little bit about Dr. Borlaug, a visionary who has seen with his work in Africa the danger of Ug99. And he picked up the phone, and he used the phone as a lethal weapon. At that time I was the director-general of ICARDA. He talked to Timothy Reeves as well, the director-general CIMMYT, and he was shouting. He said, "How on Earth that these two centers, international centers dealing with wheat, they are not aware

about the danger of the Ug99?” And he said we should come, we should have an initiative, global initiative, to get rid of this and have genetic makeup which be resistant to the stem rust.

Anyhow, he launched a meeting in Kenya, with the presence of ICARDA and CIMMYT, whereby the majority of the genetic resources, ICARDA being the center of diversity for wheat and CIMMYT working on wheat, as well as universities such as Cornell, as well as U.S. aid funding. And then he invited the aid countries, which will be the first cycle of being won over to this. I’m just – God bless him. He has a vision and leadership to see the danger and move everybody into this direction. Now this initiative is taking off and has several meetings and a lot of countries becoming interested and know about the danger and trying to identify a genetic resistance, a gene which could avoid this terrible disease.

Anyhow, let me go from this – it’s a recognition for him, and God bless him. Let me go very quickly and say what I missed in the presentation of the colleagues is the impact of climate change on the biota and the fauna. Climate change, when we have an increase in temperature, will affect insects and diseases as well as the microbiology microbes in the soil, which is a living organism, and it will affect, as well, plant production.

Moving from this, I would like to admit to what Cary has said. We are just scratching the surface in identifying genetic resources. We need to have a campaign, and we need in every gene bank not only to have a description of the phenotypes which exist, but a molecular passport which will give us what is the character of these genetic resource which you are putting in the gene banks; therefore, it could be utilized easily, and the same for animal genetic resources.

Thank you, Madam Chair.

Catley-Carlson *Shukbram*. Thank you, and thank you for reminding us about a recent contribution of Dr. Borlaug in this area. Anybody want to take on the etymology? I remember Tom Odhiambo used to say that the real history of Africa is written in its bugs, and I remember hearing that years ago and thinking, “What an amazing comment.”

Who wants to talk bugs? I’ve got two volunteers – Pam, and then Roz.

Anderson Quickly. We did a publication a couple years ago. One of the areas I worked on is emerging diseases and pests. And the examples this morning, avian flu and wheat rust, are pandemic, dramatic events. There are dozens and dozens and dozens of these events happening in our major crops around the world at a smaller scale. And it is a huge threat we’re not paying attention to. We are totally unprepared.

And in our analysis, Emile, in terms of drivers, 57 percent of the new, emerging diseases we saw as introductions and 25 percent as a result of climate change or weather events related to climate change. So it’s significant. Vector-change ranges, all kinds of impacts. It’s something we really seriously need to put a foundation under us on.

Catley-Carlson Roz?

Naylor Yeah. I'll just add that when we had our Bellagio conference, the impacts of climate on the pests and pathogens was the one area that it seemed the scientific community was least well-equipped to deal with in terms of really understanding the broad framework. And there are some specific, very complex examples.

But since that time a group from Cornell, the University of Washington, and Stanford has come together to form a research project that really looks at both the ecological range shifts are likely to affect, obviously, the competition of pests and pathogens, vis-à-vis the crop, but also the evolutionary competition.

And when you think about how quickly pests and pathogens can evolve to changes in climate – whereas crops have been bred for so many other qualities and are somewhat constrained in how quickly they can evolve just to the ambient environment – it's going to be startling.

And I think one of the areas with Rebecca Nelson at Cornell that we're picking up is on the aflatoxin issue, which by all indications looks in sort of a complementary way, with other carriers and vectors, to be a major problem with the warming of the climate and particularly in tropical areas. So it's going to be quality of food, not just quantity of food.

So anyway, the point is that this whole field is emerging.

Catley-Carlson Very much so. Ravi, briefly.

Singh Yeah, very briefly, I'd like to just mention that because of climate-change issues, what we see on wheat, the resurgence of aphids, aphid problem – everyone knows aphid, but in many areas of the world you can see the increased use of insecticide just to control aphids.

One more disease like the wheat crop in Brazil, where temperatures were a bit warmer; in the '80s Brazilian scientists reported another disease, which we know in rice very well, called rice blast. And there we started to find a blast disease on wheat, which is unheard of in other parts of the world where you see rice and wheat rotation.

Okay. This disease started in Brazil in the '80s, and it also is spreading to nearby countries like in Paraguay and Bolivia. So people should be aware of this. And this is a disease where the wheat crop was not exposed in the past. And you have to look for – I don't know, I mean, there's very little diversity so far found in wheat for resistance to this disease.

Catley-Carlson Well, Adel, you certainly got a broad degree of agreement with your main thesis there. And if you think it's difficult to find support for collections of seeds, you should try finding support for collections of molds, fungi, and rusts. I chaired the CABI board for a while. And you can't see them; you can't even hold out a paper

bag and say, “they’re in there.” It’s extremely difficult to get support for those collections. So, yes, next. I can’t quite see you.

Question My name is Dean Kleckner. I’m an Iowa farmer, and I grow corn and soybeans and hogs on my farm, or as much of the world says, pigs. And we’re number one in all three of those in this state, incidentally.

Let me say that I’m concerned about weather, not climate change. I may lose some sleep on my farm – because I produce the food – I may lose some sleep over weather; I don’t lose any sleep over climate. And isn’t it odd that we’re hearing about climate change, and we’ve eliminated global warming? Margaret, you’re the only one that’s mentioned that, I think, today. Now, climate change, which covers us both ways, whether it’s hot or cold, it seems to me.

It also seems to me that weather averages make climate. My first question, and I have two, and the next one will be less ahead of it. My question: How many years of weather averages does it take to make up climate? [laughter] A serious question, not funny; I’m wondering what you all think about that.

Next one. Our present climate is different from a millennium ago. I think we have history of the world that says that. Now my question: Isn’t it rather elitist to think that our present climate is the ideal, and maybe some true climate change might not be better?

Catley-Carlson Thank you. No. Thoughtful question. Roz, it seems to me that you would be a good starter there, followed by Emile.

Naylor In terms of how many weather seasons – you’re right; obviously, farmers care about weather, but the collection of the Global Crop Diversity Trust cares about climate and the perpetuity of these genetic resources, is why I mentioned climate.

But basically, the question is, at what point are we out of the natural climate-variability bounds? Because we’ve seen a lot of variability, and as you go further up in latitude, the variability is higher. So on your farm, for example, you’d see much more year-to-year variability or decadal variability than you might see in the tropics.

And what we’re seeing now is emerging out of that variability in a statistical sense. I mean, taking whatever data which exists – which are, on the climate side, hundreds of years or a little over a century, I would say, of climate data that are accurate enough to do something with – we’re starting to emerge out of the natural bounds of, for example, temperature variability.

In terms of climate-versus-global warming, global warming is one element, but changes in precipitation patterns, extreme events, sea level rise and so forth – they’re all encompassed, and that’s why climate change is kind of the term that is used more frequently now.

Whether we’re in an elitist state now versus before, I think the main differentiation is that the current changes that we’re seeing in the climate are attributed to human

causes: the putting of greenhouse gases into the atmosphere and the changing of atmospheric circulation patterns and conditions due to human behavior itself.

And I think that's the critical thing people are worrying about, because we're fundamentally changing how the global atmosphere and ocean-circulation systems work now, because of our addition of greenhouse gases.

Catley-Carlson Thank you. Emile?

Frison The last two speakers have asked questions relating to climate change, and I think it would be really a pity to have a session on biodiversity and agricultural security and focusing like we've done essentially on the use of genetic resources in breeding programs.

I think we have to look at: What is the function of diversity in the production system? And this is particularly relevant to climate change. We know that agriculture intensification in the last 30-40 years has been based on the availability of cheap energy, on the principles of economy of scale, and on simplification of the production system in terms of number of species, the number of varieties of each species, that are being grown.

I think in Gordon Conway's presentation, one of the last slides he showed, was about the importance of resilience, building in resilience in the production system. And one of the characteristics of climate change, and that is of interest – I think that's what the farmers live through, also, every year – about the weather, the greater fluctuation, the extremes, the unpredictability, the greater unpredictability of what the climate will be this particular year means that we have to mitigate risks of crop failures or production failures in a different way than we have been doing in the past.

And that I think can be done relying on diversity, a greater use of diversity. We've seen these nice gardens that were shown in Gordon Conway's presentation, but too little attention is still paid. And I think we can really combine a diversification from an economic point of view, bringing greater income, and making more, better use of the scarce water resources, by having a better deployment of diversity in production systems.

And that will also look at some of the other dimensions that were mentioned in Gordon's presentation about combining different land uses. Instead of opposing intensive agriculture and conservation areas, we can have much more of a diverse agricultural ecosystem that also provides for the other ecosystem services that we haven't talked about, which are essential for our survival.

Catley-Carlson I don't know whether it's elitist to want to hang onto the current world, but extinct is an awfully long time.

Question How many years of weather does it take to make up climate? That was my first question.

Catley-Carlson Does anybody know the answer to that? How many years of weather does it take to make up climate? I think you're into a Wikipedia question here. If somebody thinks up an answer, they're welcome to give it, but I'm going to go to the final two questions, just to keep it going here.

Question Thank you for your talks. Biodiversity is certainly very important –

Catley-Carlson Could you identify yourself, please?

Question Mamadou Chetima, PhD candidate at Cornell University and Borlaug LEAP fellow. I think one of the issues with biodiversity is, certainly within the scientist community, it's more or less understood, the importance and implications. But how to actually advocate and gather resources for attracting attention to conserving biodiversity? What lacks, I think, is the direct connection of biodiversity with livelihoods.

So I'm thinking right now, like, okay, we're talking of how many animals? One animal, one breed is lost every month. How many plant species are gone? But – how many types of human livelihoods are lost directly as a result of change in biodiversity?

If we stress enough the connection between change in biodiversity and change of livelihood, probably more attention will be brought to biodiversity – as it took some time to call attention to global warming. So the reason I mention that, because the biodiversity helped people diversify the risk in areas where, for example, in drought and everything, when you have different breeds, different varieties, people try to adapt, have in their plots different varieties and everything.

But now because of the change in climate, which is – actually, climatic adversity is not very new, for example, where I come from in the Sahel – but because of the changes in the last few years, people are orienting themselves toward short-term plants, drought tolerance, animals that are resistant toward certain diseases and all that. So we're seeing a shift in, or a specialization on, very specific species. And when those people specialize in those areas, they are leaving alone some other areas.

So how is any one of you, or your institution, working toward really stretching the emphasis between change and livelihood? Because the problem is, today, biodiversity, we wonder how important it's going to be, losing some of the species. But tomorrow, too, because we're specializing in some areas, what is it that we're losing in terms of livelihood, direct impact to people and human life?

Catley-Carlson Thank you very much. That was a very excellent statement. I'm going to take it as a statement, and if people want to comment in their final presentation on that, they certainly can. But thank you for bringing that very much home.

Yes, our final question.

Question I'm Tim Williams, University of Georgia. It seems to me that gene-for-gene theory would tell you, and gene-for-environment theory perhaps would tell you, that, with the changes in environment that were projected for, say, corn, that the coolest

environments in the future are going to be greater than the hottest environment now. One has to sort of think that the biodiversity that we're preserving might not be the right stuff.

We might need to actually look at a much wider range of species and use the genetic options of moving materials out of the camel into perhaps the chicken, or something like that; you know, I use that as an example. But think of this biodiversity as going out and looking for, not in wheat and not in maize, because that might not be where the solutions to the new environments might be.

Catley-Carlson Thank you. I remember the first time I heard about somebody using the trout tolerance for cold as a possible means of increasing cereal resistance to cold, I was absolutely fascinated. There would be a lot of people in the world who would have the hair rising on the backs of their necks about this.

But I'm going to give the panel now just a minute and a half. If you'd like to reflect on either of the final two suggestions – the second one, go across the species when you're looking at extending biodiversity, and the other one, more emphasis on livelihood – or anything that you wish to conclude with.

Pam, I'll start with you, and then just work right down towards me, and you've each got about a minute and 30 seconds.

Anderson Thank you. We need a paradigm shift. We were asked yesterday morning to think about the long term. What we've been talking a lot about is: How do we improve productivity of our basic food crops? This is critical. But we need to go beyond commodity thinking to food-systems thinking. And that means a paradigm shift.

For example, we are working actively to increase the productivity of potatoes and protect the biodiversity. But we have begun to work on what we call potato-based systems. What does that mean?

In the High Andes, we are now also working with barley, quinoa, oca, ulluco, cañihua, and trying to really look at that as a portfolio – how do we study, understand, and engineer resilient systems? It's a portfolio for food security and adding value to each one of those options for the poor.

So it really means we've got to start thinking completely different and take a systems approach, and that is really going to make a lot of difference in terms of how we go forward.

One final point. What's missing from our conversations is still gender. It's a sound bite. We're not getting to it in a serious or systematic way. In agro-biodiversity we need to understand that in many cultures and crops, women are the keepers of the seed. If we don't understand their role in collecting, conserving, and managing the agro-biodiversity and the information assets that go along with those physical assets, we're not taking full advantage of the knowledge that's out there in situ.

Catley-Carlson Thank you. Much wisdom.

Frison

I'd like to follow up on what Pamela said, looking at things in a much more integrated way and how we can use the diversity that is there to address the real problems.

And I'd like to bring up a point that we haven't had a chance to talk about in the discussion here, and that is the issue of nutritional quality. The hunger problem is still too often talked about only in terms of quantity of food and calories of maybe protein. But what really matters to people is to have a healthy diet, much more than just the quantity of food.

And this is an area that has been very much neglected. The availability of cheap food that is energy-rich but nutrient-poor is having devastating impacts now in developing countries. Diseases that were known as disease of affluence – like cardiovascular disease, Type II diabetes, cancers and obesity – are expanding at exponential rates in developing countries and among the poorest people; because the available food that they have now is energy-rich and nutrient-poor.

And I think we have to restore a much greater diversity in these diets if we want to have healthy people and not have people that are stunted or handicapped also in their intellectual development and basically having an impact on the whole capacity of a nation to fulfill its capabilities.

And therefore, again, we must make much broader use of the available diversity, also looking at it from a nutritional point of view, in order to have the kind of health and livelihood outcomes that we all wish for.

Catley-Carlson Oh, thanks for bringing in that really important cross-guiding element. Thank you. Roz.

Naylor

Yes, I'll take on those two questions, because they both deal with adaptation to future scenarios. We have adaptation that's more autonomous, what farmers and households are doing now, just in response to things, and then planned adaptation.

The *Economist* had an article recently that surveyed a number of organizations, including some represented here, that said adaptation is really going to require about \$50 billion a year to solve some of the broad problems beyond agriculture that we're going to see in the future – declining genetic diversity and climate change.

In terms of the crops and identifying new crops, I think it's a really important point. At our meeting in Bellagio, we identified the need to look at extreme areas in terms of genetic-resource collections. And I'll just put the idea on the table that we thought pre-breeding as a public good was very important, because breeders don't want to touch this stuff that's outside of the core collection, typically, but it's important.

We also identified the need to look at these alternative crops and use the tools of..., for example, to understand where their characteristics might exist, in sorghum and quinoa or teff, that could be used in some of the more major crops as well.

And so this is all part of how we're looking at sort of analogues to think about the future.

Catley-Carlson Thank you, and thanks for addressing the last two questions. Ed.

Rege Thank you. In summing up, I think I would like to raise a specific issue – in regard to thinking beyond what will happen to us to what we will do about it.

What will happen to us from the perspective of climate change, I think there's a lot of people working on that, a lot of data being generated. I think what we are not doing enough about is what, therefore, should be done. And I want to take the southern African situation and say the following.

As when weather changes, farmers have the ability to adjust their production methods to deal with that, including planting time and so on. When weather changes a little bit more severely on the livestock side, farmers start thinking, "Perhaps I should find another breed." When weather changes so much more dramatically that it is basically climate change, then farmers start saying, "Well, maybe cattle cannot do here; I need to find camels."

Now, it means we have to be thinking, How will we be retooling farmers over time to be able to adjust to things they have never before had to deal with? So that's one comment.

The second comment is the whole issue of balance between improving productivity, which we must address, because population is increasing, incomes are increasing, and urbanization is happening. We need to create opportunity for productivity improvement.

How then can we be insisting that the very poor farmers should be the ones that are conserving our very exciting, exotic breeds of animals and plants which have low productivity? I think we need to be thinking about this.

Thank you very much, Madam Chair.

Catley-Carlson Thank you. Ravi, you have the last word.

Singh I think when we look at the plant-breeding side, the only thing I'd like to say is that we are going through a really exciting period. We heard yesterday there are quite a few new technological advances which can be used. You can move some genes around from one species to other more easily than it was done in the past, even perhaps from one crop to other crops.

And we should be really positive that if we prepare a good, scientific base of people in the North, in the South; good partnerships between private, public, international centers – we should be able to manage genetic diversity much better and be able to produce what will be needed to feed the world.

Thank you.

Catley-Carlson Thank you. Well, we answered one question on what's the difference between weather and climate. It's when shedding coats of the cows is not enough, and you have to start thinking of camels. So if that happens here, you'll know that you've moved from weather change to climate change.

I think we've had a very rich discussion, which I won't attempt to summarize. On one side you have Roz, who is saying the situation is really heading out of bounds; on the other you have Cary saying, "We have all the tools, and we're beginning to be able to use them more." And that's the note that Ravi chose to end on.

And I think that everybody in this room is here because they believe that they can try and work hard along that spectrum to make sure which way we head. It's a pretty daunting challenge.

Would you join with me in thanking very much this panel for adding their expertise?