2013 THE "BORLAUG DIALOGUE"
October 18, 2013 – 8:50 a.m.
Panel: *Mark Cackler, Moderator*

PANEL:

RESILIENCE AND REALITY: THE FUTURE OF A CLIMATE VOLATILE PLANET

Introduction:

Ambassador Kenneth M. Quinn
President - World Food Prize Foundation

This is a terrific morning program. We're going to hit the three key topics in our symposium. We're going to start with climate volatility and sustainability, then biotechnology.

And we have a wonderful array of speakers. And we have Mark Cackler is here, who's going to be moderating this, from the World Bank, and Juergen Voegele was going to be here, but thank you, Mark. Now you're from Illinois, from Moline as well. So you see this Illinois theme is running throughout. I used to live in Normal, Illinois, just so my biases are clear. But, Mark, thank you so very, very much for being here.

My dear friend, Professor Rattan Lal, is here, a Nobel Prize Certificate recipient. But you know I'm a political science guy, and when I was working on our agricultural exhibits in our Hall of Laureates, I said I've got to have somebody who really knows things who could advise me on this. And he was the principal advisor. So I'd call up, and I'd be saying, "Here's what I was thinking about saying about what was going on in the 13th century in Great Britain." And he was very kind as a mentor and would say, "Well, no. Maybe you don't want to say quite that." But to the extent that we are successful, it is with his guidance.

Ren Wang is here, now at Rome and the FAO. And please give my warmest wishes to the Director General. He was here I guess in the next chair, but here in 2011 right before he was going to take over in the position. And I'm just so impressed with his dynamism. And the concept of zero hunger is now proliferating everywhere, but when Dr. Ren Wang was working at the bank and the CGIAR system, we got to know each other and him here. So, welcome back.

And now Hermann Lotze-Campen, the co-chair of Research Domain II - Climate Impacts and Vulnerabilities from Potsdam Institute for Climate Impact Research. And I read all of that because this is his first time here, and we're getting to know each other. But let me tell you, the things that we've heard about him and how in his precision of his thinking and his insights are extraordinary.

So, Mark, over to you – I'm getting out of the way.

PANEL:

RESILIENCE AND REALITY: THE FUTURE OF A CLIMATE VOLATILE PLANET

Panel Moderator:

Mark Cackler
Manager - Agriculture and Rural Development Department, World Bank

Panel members:

Ren Wang	Assistant Director-General, Agriculture and Consumer Protection Department, UN Food and Agriculture Organization
Hermann Lotze-Campen	Co-Chair Research Domain II - Climate Impacts and Vulnerabilities, Potsdam Institute for Climate Impact Research (PIK)
Rattan Lal	Distinguished University Professor and Director Carbon Management and Sequestration Center, The Ohio State University, Columbus, OH

Mark Cackler

Good morning, everybody. It's a great personal and professional pleasure to be with you this morning and to serve with this panel.

Today we're going to be exploring in particular how to build resilience in a climate volatile world. And I'd like to thank the World Food Prize Foundation for providing this platform. Because how we feed the planet sustainably in a world that's going to be more and more volatile is the key question for our generation.

You've already heard the brief introductions of our panelists, and I'm looking forward to hearing from these very distinguished gentlemen their observations on building resilience. I might say at the outset, we could have done with a little better gender balance, perhaps, on this session. And I mention that not just because women produce most of the food in poor countries, but it is women who are the most vulnerable when it comes to climate change and other shocks and lack of resilience. So maybe we can keep the gender perspective in mind this morning.

And before turning to Dr. Lotze-Campen for his observations, it has been noted that climate change is actually giving agriculture a lot more prominence. So that's good for us. We have agriculture more on the world's agenda because of the effects of climate change. And we keep hearing over and over again that we're going to have to produce a lot more food, at least 50% more food. Some estimates, we'll have to double food production in developing countries by 2050.

But we've also heard estimates that, because of climate change, one degree increase will reduce productivity by 5%. We're on track for a 2-degree world, which means, if we do nothing, we're not going to increase food production by 50%; we're going to reduce food production by 10%. This is a very scary world we live in.

Panel Discussion

Mark Cackler — So Dr. Lotze-Campen, how much trouble are we in? I mean, what are the vulnerabilities that agriculture has to climate change? And what does that mean for resilience?

Hermann Lotze-Campen — Thanks for inviting me here. Just a personal remark to start with. I mean, I'm the first time here at the World Food Prize event, but I personally have a longstanding relationship with the Midwest. I'm coming from a farm myself, and I don't know what Norman Borlaug was up to in 1962-63, but my father was actually, as a young farmer on a farm in Minnesota, Southern Minnesota, and since then we always kept a friendly relationship with his farming family. And later I went to the University of Minnesota for one year of PhD study. So I have a long-term relationship with the area here.

So that you don't confuse me with a climatologist coming from this institute, I actually have a deep background in agriculture. And I'm dealing there with all relationships between climate and agriculture, actually two ways – climate impacts on the agriculture sector, I guess which we'll focus on today; but also the contribution of agriculture to greenhouse gas emissions. And as we all know, agriculture is quite a significant contributing sector to overall emissions. And I think we have to see these things together.

As you know from various reports, and very recently the latest report by the IPCC came out, confirming and pronouncing a lot of things which were well known. We are certainly heading for a warmer world, so temperatures will be rising; there's no doubt about that. And if we talk about global mean average temperatures of two, three or four degrees more, then this means on the land area the temperature increase will even be more than that. And the further you go to the poles, to the temperate and boreal zones, it will be even higher. So if we talk about a four-degree warmer world, which is where we are heading at with the current emission trajectories, then we are talking probably about six, seven degrees warmer average temperatures in the temperate zones and a little less than that in the tropical zones. But if you know that you may already have 45 degrees in certain times of the year in the Sahel area, two, three degrees more is already quite damaging. So temperatures will rise; there, all the climate models agree very well. Precipitation patterns will change.

And as you probably know, in some areas of the world, the planet models agree very well on the direction of change; in some other regions, they don't.

But the overall effect, if you look at the modeling results, and we are strongly involved in the AgMIP, the Agriculture Model Intercomparison Project, which has been started by U.S. colleagues two years ago, the modeling results show on average around the globe that yields will be quite strongly reduced over these scenarios on average in the long-term trend. And this will lead to rising food prices. While that's good for farmers, it's of course potentially damaging.

Mark Cackler Some farmers, because of course most farmers are net consumers of food.

Hermann Lotze-Campen Right, so on the consumption side, of course you have these potential negative effects. So that's the gradual changes, and we understand those quite well.

The more problematic fact is actually the climate volatility, because for one, we don't have very good scenarios on how these extremes will change. It's very likely, from the underlying physics, that extreme temperatures, prolonged drought, extreme precipitation events, will increase because that's underlying in the system. But we don't have enough records to train the models to have good projections on how this frequency exactly will change. But the things we have seen, for example… I don't have to tell you about the 2012 drought here in the U.S., but if you think about the heat wave 2010 in Russia or extreme rains and floods in Pakistan in the same year, so it's very likely that these kind of events become more frequent; and then, if they occur simultaneously in various big producing regions, then of course that will contribute to more price spikes. Of course, that's not the only reason that has been investigated heavily – there were other reasons for the recent price spikes – but this is very likely to contribute.

And this increase in these extremes, we don't have to wait another 20, 30 years; I mean, they will build up and we can be hit by these events tomorrow. And of course it adds to the problem that the global North, the temperate zones, are relatively less affected than many tropical zones where also the adaptive capacity is much lower. So this adds to this global injustice in the whole climate issue that the rich countries have contributed most of the causes of the problem, and the poorer regions, the currently poorer regions are very likely to be affected more than proportionately by that.

Yeah, I think that's for my introductory statement.

Mark Cackler

Thank you. Professor Rattan Lal, these are very profound effects on agriculture, being caused by global warming, being caused by greenhouse gas emissions and of course agriculture and associated deforestation is the largest contributor of greenhouse gas emissions. So in one sense we're the biggest part of the problem. But it's also said that agriculture is the only sector that can actually suck carbon out of the atmosphere, suggesting that there could be a mitigation potential. Is there a big mitigation potential of agriculture? Can agriculture become part of the solution as well as part of the problem.

Rattan Lal

Thank you. First of all, it's a great honor to be here and been invited to this very important panel. I might take your question that agriculture is the biggest contributor. Agriculture is the second-biggest contributor. Fossil fuel, of course, is the biggest, 10 gigaton every year fossil fuel based emissions of carbon. In comparison, deforestation and land use conversion emit about 1.6 gigaton per year. But until the 1940s, land-use conversion, drainage of agriculture land, peat land cultivation, tillage, were the biggest contributor until the use of fossil fuel increased especially after the 2nd World War. So if you go back to the beginning of agriculture that Ambassador Quinn mentioned, 10,000 years ago until today, then land-use conversion, soil cultivation and agricultural activities have contributed more total emissions than those by fossil fuel. Thus, to date, emissions from land use conversion and soil management, etc. are more than 500 gigaton. Fossil fuel is not quite that amount yet; global cumulative fossil fuel emissions to date are estimated at about 300 gigaton, but the annual rate of emission is much more rapid now.

The difference between emissions from fossil fuel and land-use and soil is that the carbon pool depleted from soils and biota can be restored.. World soils to one meter depth contain about 1550 billion metric tons of organic carbon (1550 Pg C). The topsoil contains much more organic carbon than does the subsoil. And if you estimate the C pool to three-meter depth, including the Cryosols, or the frozen soils, that Arctic region as President Grimsson mentioned yesterday- then the soils of the world contain about 4,000 gigaton of carbon, compared with trees and all vegetation about 600 Pg, and the atmosphere at present (in 2013) contains about 800 Pg of C. Thus, soil is the largest pool in the terrestrial biosphere. Even small changes in the soil C pool can have large impact on the atmospheric pool.

And agricultural soils, because of the historic land use when we did not manage the land properly, especially due to soil erosion, and extractive farming practices, taking away the crop residue and not returning the manure back to the land, most soils in the developing countries – Africa, South Asia, and so forth – ,may have lost 70 to 75, 80% of their original organic carbon pool. Most soils of the tropics,

especially those managed by small land holders and resource-poor farmers, are severely depleted of their organic carbon reserves.

Soils of the Midwestern region in the U.S., Ohio, Iowa etc, may have lost about 25 to 30% of the original organic carbon pool. So most agricultural soils have a carbon deficit. It is because of this deficit that the quality of soils has been degraded. There is a critical level of soil organic matter content that a soil should have to support terrestrial life, crop growth and numerous ecosystem functions and services. In most soil, that level is about 2%, 1½% of soil organic carbon in the root zone (top 20 to 30 cm). Soils of Asia, West Africa and those of Punjab and Haryana that I am familiar with, may have soil organic carbon content of as low as 0 .05%. As a result, these soils have lost the capacity to hold nutrients, fertilizers, pesticides and water. These pollutants can be leached into the ground water and can be a major health risk to the population.

So it's not just a question of mitigating the climate change and reducing the volatility, restoring soil organic carbon is important also to advancing food security and improving the environment. The l efficiency of inputs, soil productivity, and resiliency against climate volatility also depend on the fact that the organic matter content which has been depleted is restored – that's the way to increase and sustain food production. And the potential of carbon sequestration in soils of agroecosystems is about a gigaton (billon ton or a Pg) per year. Harnessing this potential of mitigating climate change and reducing climate volatility is also the low-hanging fruit because it is the most cost–effective option. That is what we must do, compared with, for example, the geologic sequestration – we call it here in this country the clean coal technology. The cost of geologic sequestration is $600 to $800 per ton of CO_2 for capturing, scrubbing, compressing, transporting, and injecting. In comparison, the cost of putting carbon back in soil can be negative. It is negative because of many other co-benefits (such as improvement in water quality, increase in biodiversity, etc).

So if I were to make a recommendation, the first priority – not only to address climate volatility or change, but even more important to advance food security – we have no choice but to put the carbon back in the terrestrial biosphere that we have lost due to historic land use and management.

Mark Cackler — Thank you very much. Dr. Wang, Professor Rattan Lal mentioned the difference in the soils being more degraded in developing countries than in more temperate, richer countries. From your perspective at the Food and Agriculture Organization, how do you see the issues of

climate change and resilience, particularly in the context of the challenges of developing countries?

Ren Wang

Well, thank you, Mark for the question. But first of all let me also take this opportunity to thank the Foundation and also particularly Ambassador Quinn for inviting me back. I was telling him, this is, as I remember, probably the fourth time that I have been here at the Prize. And I am very pleased to see that the World Food Prize ceremony and those involved and the dialogue is becoming such an increasingly important forum internationally and so influential.

Now, I very vividly recall that it was in 1996 or so - 1995 or 1996 - I was accompanying Dr. Norman Borlaug in China visiting a number of field sites on quality maize – QPM. And that time I do not recall really the governance, the local governance or people, or all the research organizations in China talking very much about the impact of climate change. And then during the past two years or so I went back to China as I finished my term, or not finished but after my service at the World Bank as the director of the CGIAR system. I traveled to more than 24 or 25 provinces in China in two years, and almost everywhere I went, now the research organizations and the local governments now are talking about the impact of climate change. And now also recall that when I was working in the International Rice Research Institute – now I see Dr. Khush and Ron Phillips and my mentors, and Dr. Swaminathan with the IRRI connections are sitting here – now we are talking about rice.

And I recall that during those years when I went to visit Thailand and India, Bangladesh, and of course we were talking about the impact of climate change, particularly in terms of increased temperature, for instance, especially when temperature, high temperature comes to the grain filling stage of rice, or there's more unpredictable sort of a flash flood in the eastern rice area of Thailand or Bangladesh where farmers had no choice but growing rice, because that's the only crop sort of available for their livelihood is to grow rice sort of in anticipation of the seasonal flood. But when there's sort of an unpredictable, long, sustaining flood, then farmers don't know whether they will have a crop.

And then let me just mention particularly that this year, 2013, the early crop rice in China was hit by high temperature during the grain filling stage. And that was really probably for the first time that high temperature impact has caused a concern to ordinary people, because it is affecting ordinary people, everyone's livelihood.

So as a result of these, what I want to quickly bring to a message is that I truly appreciate now that the impact of this increased temperature, the climate change, is not just something of alert to the

government, it is now to very ordinary people, and it is affecting especially farmers, smallholder farmers in developing countries not only in China but particularly Bangladesh, India and Sub-Saharan Africa, where drought is a serious problem.

So it is an impact on everybody, and also more importantly, I think, is that we need to realize that it is posing a responsibility issue. It is not just the responsibility of the governments, it is also the responsibility of ordinary people and industries, the private sector, that we need to take this issue seriously.

Mark Cackler — Professor Rattan Lal, in your first set of comments you were talking about, not only can we use agriculture as a mitigator, we must use agriculture as a mitigator. But Ren is talking about why we have to adapt today and in our problems today. What is your take on the adaptation issue?

Rattan Lal — Agriculture has a capacity to adapt. In fact, I should go back to the history of agriculture when it began 10,000 years ago. All of a sudden there was an increase in temperature, about 5 degrees centigrade, 10,000… 12,000 years ago, the so-called long summer. Not only did the temperatures increase and stabilize, but the concentration of carbon dioxide in the atmosphere also increased from 180 parts per million to 280 parts per million. And that stabilization in temperature and increase in concentration of carbon dioxide made agriculture, as we know it now, possible. Therefore, modern agriculture according to the recommended management practices has the capacity to adapt to high CO_2 concentrations and to high temperatures. The question is how.

The climate-resilient agriculture is something that can buffer big fluctuations that can conserve water in the root zones during the drought, such as we had in the U.S. during 2012 and even some states experienced it during 2013. The impact of such drought can be reduced through adoption of recommended management practices. The temperature moderation, soil temperature in the summertime can get up to 30, 35 degrees centigrade here in the Midwest. But soil temperature in the surface (1-5 cm layer) can reach up to 45, 50 degrees Celsius in South Asia and West Africa. So if we can moderate the temperature by increasing the protection of the soil with some kind of cover, increase soil's water holding capacity, improve soil biological activity, the microorganism, the earthworm, the termite, centipedes, etc. – these are the biological processes – then soil can have a resilience against extreme events. Resilience does not mean it does not react; it means that soil can rebound back and restore ecosystem services.

Among several practices which increase resilience are those that mimic nature: Maintaining continuous ground cover; not taking away the crop residue; recycling as much biomass as possible, such as compost, dung, manures, city sludge, whatever organic material is available and can be returned to the soil. It is because of these needs of returning biomass to the soil that I'm concerned about making about 1,000 billion tons of residues available for converting into cellulosic ethanol. If all the biomass is taken away, something will give, and what will suffer or give is the quality of the soil. Using perennial systems, agroforestry, establishing perennial culture, anything that encourages biomass production and enhances activity of soil biota, is important to enhancing soil's resilience against climate volatility.

It is also important to make sure that soils are not taken for granted. Soil is like a bank account. You can take out of the soil what you put into it. If you take more out of it than what you put into it, that's what leads to degradation, depletion; and that is what we don't want to do. Soils have an adaptive capacity if we replace what we remove and maintain a positive carbon and elemental budget.

I must also mention that mostly we hear about the negative impacts of climate change .Yes, it is likely that –the corn yield may decrease worldwide by 10, 11, 13%. Rice yield may decrease even more; wheat is certainly more vulnerable to increase in temperatures at the grain filling stage. But nature does not always give us bad things. There will be opportunities, just as there were 10,000, 12,000 years ago when agriculture started because of the warming and melting of glaciers Thus, to be prudent is to identify opportunities and explore and avail them while minimizing the risks.

So adaptation has two sides: minimize the risk and avail opportunities, be on the lookout for both.

Mark Cackler Dr. Lotze-Campen, my Midwest cousin, where we've of course engaged in low-till and no-till type practices, where are you on the adaptation, mitigation? If you were king, where would you put our resources when it comes to trying to increase resilience to climate change?

Hermann Lotze-Campen First of all, I think it's important to note it's not either/or. It's not either, let's wait and see and adapt, or mitigate climate change. I mean, in general we already know that we are bound to at least one and a half or two degrees of global warming, to which we have to adapt in all sectors but of course also in agriculture. And already a two degrees warming, tropical areas may be already quite heavily hit. But Professor Lal has nicely shown that there are options which serve both purposes. Improving soils will store carbon, at the same time

increase water holding capacity and improve yield capacity. But I think we have to do more.

And I think about it in like three regions. If people think about adaptation, they immediately think about productivity, production technology and so on. And I think in addition to good soil management, of course we need new varieties, better-adapted varieties to the new conditions. And that's of course at the heart of this dialogue, and I'm pretty sure that biotechnology will play a role in that in the whole set of options we need. We need improved irrigation systems to deal with water shortage. We need improved tillage systems to increase water-holding capacity. So there's a whole set of technology packages which need to be developed. And of course they are locally specific. I mean, it's different whether you are on a heavy soil or on a light soil. There's no one solution which fits everything, of course.

But that's the production technology part. Apart from that, I think it's very important to keep trade in mind. I mean, open trading systems, in my view, act as a buffering system to alleviate production shortfalls in some areas because, as we see with more volatile conditions, these production shortfalls may shift from region to region. And it's interregional trade within countries from surplus areas to deficit areas where we have to keep systems flexible. But of course it's also international trade. That's the element at the market level.

And then the third aspect is insurance schemes and safety nets. I mean, we have to adapt. And there are options: micro-insurance schemes already well adapted to providing farmers with risk management options for these more volatile conditions. And I think these three dimensions together can provide a good option space; but from what we expect, the challenges will be huge enough that we cannot preclude any of these options. And there will be no silver bullets; I mean, we need to look at these packages of solutions.

Mark Cackler — Ren, Dr. Lotze-Campen had brought up trade policy, and this opens a door. I mean, we talked about science earlier, but policies are hugely important. And the Food and Agriculture Organization as an inter-governmental body, obviously, very much involved in the policy dimension. You earlier said that Chinese farmers "get it" in a way that they perhaps did not get it a generation ago when it comes to climate change and resilience. But what about policymakers? What can we do that policymakers "get it," whether it's adaptation or mitigation or both at the same time?

Ren Wang — Well, it is quite a complicated question, I think. But I would start by emphasizing the need of really putting agriculture more prominently on the global climate change agenda. So far we really haven't seen

sort of, I would say, a concerted effort or much-coordinated effort in doing so, especially influencing policies at a national level. And that's why I like perhaps to mention here that FAO in 2009 tried to advocate a concept of a climate-smart agriculture, and two years ago we developed this sort of a definition that now is gaining momentum, that the World Bank, the United States, particularly the USDA, the government of the Netherlands and those of South Africa now are sort of working together as in sort of a core group of countries and organizations to promote particularly the idea of then a global alliance on climate-smart agriculture. But put that aside, just as a concept of kind of an alignment of policymakers but also research efforts as well as all walks of life, basically – the industries, the private sector, research organizations, the international organizations, and the farmers and so on – in working on promotion of this idea of a climate-smart agriculture, as also prioritized by the World Bank President Jim Kim on his agenda.

But what are we talking about here in terms of climate-smart agriculture? There are three pillars basically that we are advocating.

Number 1 is to sustainability increase the productivity of your production systems, agriculture systems; so that's the number 1 pillar really – sustainable increase of productivity. And secondly is to improve or increase the resilience of production systems, and the third - really adamant - is to reduce emissions of greenhouse gas wherever possible in the production systems. So to achieve these three outcomes is the main goal.

Now, we heard from Professor Lal and also Dr. Campen about the science behind possible solutions. And as friends and colleagues know, I am kind of notoriously optimistic. I would like to look at, in a constructive way, opportunities of really dealing with climate change impact on agriculture through such a framework of climate-smart agriculture.

So I will not repeat those sort of possible solutions and the science that the two experts have mentioned, but I'd just like to mention that, what we have been advocating, especially I think the USDA made a strong point in a meeting last week at the Hague to further conceptualize this idea of an alliance on climate-smart agriculture was to achieve or implement climate-smart agriculture at landscape level. But I say that that is really addressing the opportunities that are really as kind of a horizontal way, on a landscape level, to scaling up the application or the implementation of some of these technological solutions, such as conservation agriculture, such as introduction of certain heat-tolerant rice varieties or drought-tolerant maize.

But we also need to look at vertically along the value chains to identify point of entry for policies, conducive policies that promote climate-smart agriculture, such as in the area of… The best example is really in the livestock sector. I brought with me this new book published by FAO – I'm an advocate – it's called, *Tackling Climate Change Through Livestock.* FAO launched it last week. And it is talking about opportunities of reducing up to 30% of the emissions of greenhouse gas in the livestock through improvement of the feed and the improvement of manure management and so on and so forth.

So really to sort of wrapping up my comment, I think we need to look at a landscape-level implementation, and that has implications to policymakers. It is really the opportunities for the governments and organizations, but if you look at the value chain vertically, and then that really comes upon individuals and the private sector and the industries also. And more importantly, I think, is to continue to increase, let's say, not only maintenance but increase of investment in agricultural research, in identifying and understanding the mechanisms of climate-smart agriculture, of mitigations and so on. So that is really important.

Mark Cackler — Thanks, Ren. Before we turn to the audience for their comments, Dr. Lotze-Campen, Ren has been talking about a climate-smart agriculture that delivers a triple win of better productivity, better resilience and reducing greenhouse gases. From your perspective, I mean, what should we be focusing on? I mean, anything you'd like to leave the audience with before we turn to them for their comments?

Ren Wang — To follow up on one remark, what one was saying – It's all good to have these options on the table, but I'm not a big believer in voluntary behavioral change. I think we have to set the incentives right. I mean, the old slogan by the economist was, "Get the prices right." I mean, greenhouse gas emissions are just a big externality to the environment, like any other type of pollution, and we have to provide the right price incentives like is done through either emission taxes or like emission trading schemes. Because only then will there be enough incentives for consumers, of course, but more importantly for industry to invest and to look for new technologies. I mean, induced innovation, by Vern Ruttan from University of Minnesota was a big thing, and that's in connection with what we are talking about here with biotechnology. So we need to set the right price signals for economic agents to look for new solutions. Because without that, look at the shale gas revolution and all these new coal reserves. The problem will not go away by itself. If we don't limit emissions and then find market-compatible solutions to solve the problem, it will not go away; and then we are heading for a four-, five-degrees warmer

world because the scarcity of fossil resources will not help. It's just not there.

Mark Cackler — Professor Rattan Lal, before we turn it to the audience, final thoughts that you'd like to stimulate the discussion.

Rattan Lal — Thank you. I think, whether it's climate-resilient agriculture or climate-smart agriculture, we are coming down to a series of options while keeping in mind that there's no one silver bullet. There are many options – conservation agriculture, mulch farming, cover-cropping, agroforestry, perennial culture, nutrient recycling, and improved varieties. The idea is: keep the crop residue, biomass, everything, back on the soil. To sequester a hundred, let's say, grams of carbon, or a hundred molecules of carbon, you need ten of nitrogen, one of phosphorus, perhaps half of sulfur. It's not just putting the carbon alone in the soil, you also need input of nitrogen, phosphorus, sulfur and others. All of these elements and inputs have a price. And unless farmers are compensated for the price of these inputs, such as crop residues, these will not going to put back on the land. Similarly, dung is not going to be used as manure if there is no viable cooking fuel.

So the payment for ecosystems services to small landholders, whose income is very small, is absolutely necessary to promote the adoption of recommended management practices. Otherwise, why should conservation agriculture be adopted which requires that the crop residues are returned? I started experimenting on no-till farming in 1970 in Nigeria. But, there has been little adoption of no-till farming, because the crop residues and other biomass are needed for other competing uses.

So the payments to small landholders for ecosystems services, at a fair and just price – the price of carbon sequestration, biogeologic sequestration, $600 to $800 a ton, which is the cost for geological sequestration, is a fair strategy. Chicago Climate Exchange crashed at ten cents a ton of CO_2. So fair pricing is very important to avoid tragedy of the commons. One kilogram of humus has enough nitrogen, phosphorus, potassium and water retention capacity equivalent to 30 or 40 cents at the present market value. So a fair pricing of the ecosystem services, not as a subsidy, not as a handout, not as a gift, but as payment for global services provided is an important option.

Mark Cackler — Thank you very much. We're going to open it now to the floor for your comments and observations and recommendations. But I do find it fascinating that we started with three scientists and have ended with three comments on the policy environment. If I could ask people to introduce themselves, and, please, sir.

Alan Koslow

Dr. Alan Koslow from here in Des Moines. I'm very interested with the last comment and the comments several of the commentators have made early on about the soil being the largest carbon sync and that the soil could be the chance of mitigating the excess carbon in the atmosphere. But in regards to the very last comment, you know, is there enough nitrogen and phosphorus in the world? You know, even if you have the money to pay for it, is there actually enough to accomplish what we need to on a global scale, not just on the local scale?

Rattan Lal

Reduce, reuse and recycle. The nitrogen use efficiency at the moment under the best conditions scenario is often 25, 30%. So improving the efficiency is very important. Right now urban centers, home to more than 50% of the world population, bring a lot of food from outside, rich in nutrients, especially phosphorus, which are not getting back to the land where these nutrients came from. Somehow a system of collection of urban waste, so that it can be returned back to the land, is very critical. It is not merely a question of not having enough of those resources, there is also a problem of not using them efficiently and properly. Low resource use efficiency (water, nutrients, energy) is a major problem. In addition to carbon and nutrients, the same argument applies to water. Resource availability depends on how efficiently and objectively and wisely we use the limited resources. And that is really what climate-smart agriculture is all about. It must be defined in terms of producing more from less – more from less land, less nitrogen, less phosphorus, not by adding indiscriminately but by applying through the concepts of precision farming and by conserving it and not wasting the limited resources and not polluting the environment. It's increasing the use and efficiency – that's the key concept.

Mark Cackler

Thanks, and let's try to keep both questions and responses relatively brief so we can have a number of interventions. Sir.

Larry Dreiling

Thank you. Good morning, gentleman. My name is Larry Dreiling. I'm a field editor with *High Plains Journal* – it's a farm magazine based in Kansas in the United States, and I cover a lot of different issues related to farm policy. But one of the things that's been really dear to my heart over the years is covering the issue of climate change and also how agriculture particularly, as Dr. Lotze says, prescription agriculture, and the issue of using limited tillage or no-till and how that can work to mitigate climate change.

My question for the group, and probably Dr. Lal, who we had a wonderful conversation last night… I'm trying to figure out – We've got in Kansas sort of a push/pull situation. We have a lot of people now using no-till, leaving as they would say "trash" on the ground,

but at the same time we have a lot of people promoting the idea of the use of cellulosic ethanol, which would meaning picking that loose cellulose off the ground and taking it up and putting it into the production of cellulosic ethanol, which could be a reduction in greenhouse gas as well and would also be a domestic source of energy. I'd like to get your guys' views on this push/pull situation that farmers are having and where we could direction that sort of push/pull in what direction that should go. Should it go towards cellulosic, or should it go toward keeping that material on the ground and using it as pure cover? Where should we go?

Mark Cackler — Actually, what I'm going to suggest is let's get a couple of interventions, and then you all can respond as appropriate.

Sarah Delaney — Sarah Delaney with Episcopal Relief and Development in New York. And I was wondering – we have a number of programs working with farmers on adding carbon back into the soil, and I'm sure a lot of others here do as well. And I was wondering if you knew if we have any way of measuring that carbon capture yet at the small farm level in order to be able to be more specific about that kind of benefit for advocating for payment for environmental services and policy change.

Mark Cackler — Thank you. Dr. Hillel, please.

Dr. Hillel — I'm an ex-practicing professor and a current farmer. I practice farming in Israel. I planted an orchard of avocadoes and grapefruit trees and mangos on a sandy soil that was devoid, practically devoid, of organic matter. And about 40 years ago I began to enrich the soil by a process of no-till, absolutely no-till, and drip irrigation, which doesn't disturb the soil at all, merely drips the water with injected nutrients at the base of the trees. And over the past 40 years this soil has been enriched with organic matter. Zero erosion because of this accumulation of residues of plants, and the drip irrigation involves no disturbance of the soil, and consequently the soil has been enriched in organic matter by applying less and less fertilizer and nutrients; it sort of sustains itself. And I've surprised myself by the efficacy of the practices that my good colleague, Rattan Lal, so ably promotes. And so I invite everyone to come to Israel and see my orchards and partake of the fruit thereof.

Mark Cackler — An invitation we would all gladly accept. It's clear to see why you won, were awarded the World Food Prize, sir. One last intervention, and then I'll turn to our panelists.

Ron Tigner — Ron Tigner, I'm a return student at Iowa State University, working on another degree. My question is – For many years we've seen a push and a pull towards large-scale livestock operations, large-scale

farming operations, and specialization has been a major trend. Should we return back to the days like my grandfather's farm where he had crops and livestock and fruits and vegetables and orchard and diversity of cropping systems and was a smaller scale? Which would be better for the climate mitigation?

Mark Cackler Those were very rich questions and comments. I have no idea how you all are going to respond, but that was Dr. Lotze-Campen, would you like to start?

Hermann Lotze-Campen I think talking about specific technologies, whether it's corn, ethanol or specific soil management techniques, it's always difficult to compare, and it brings me back to this price issue. I mean, if enriching soil organic matter is so effective, you could certainly ask why it's not happening. So either people, farmers don't know about it, or the price relationship is that it doesn't pay off and the farmer of course has to trade off between the cost of labor, the cost of other inputs, the prices they can erase on the market. So it's hard to say. And the ethanol question is even more specific, because let's face it – in Europe as well the U.S., the whole ethanol market, that's driven by policy subsidies, and we don't even know whether that in the long run… We are pretty sure that in the long run that will not make a very big contribution to overall energy supply.

So I'm coming back to this issue of getting the price signals right. On the energy side, the different kinds of energy production, be it renewables, be it fossils, have to compete on a level ground; and that means you have to price the emissions, and then we'll see which one is the cheapest one. And I think farmers then know very well how to work their soil, how much residues to retain in the soil to keep it healthy, and how much straw or other residues are then available as a surplus to maybe use for energy production.

And then another issue with pricing is relating to nitrogen. I fully agree. I mean, there's no shortage of nitrogen – it's all over in the air – it's the question of the cost of energy, because producing nitrogen fertilizer is very energy intensive. And imagine that we have effective carbon prices or certificate prices. I am very sure that the price for nitrogen fertilizer will go up heavily as we have seen with the oil price rises. And that may actually change the price relationship for production systems. Maybe for some situations it will then pay off to go away from the very specialized crop rotations we have now, which are very much labor saving, but you only grow two crops anymore because that's the most effective way. And with very high nitrogen fertilizer prices, maybe we'll get a higher share of legumes back into the rotations, because under those conditions that's the more cost-efficient way to do it. So I think the relative prices of inputs and

outputs and the pricing of these externalities, that's a key thing; because we don't know for which situation, which technology is the best one. The farmers themselves know it very well, supported by proper extension services, of course.

Mark Cackler — Thank you very much. Ren, how would you respond to those interventions?

Ren Wang — Perhaps I could quickly pick up the question regarding larger-scale livestock production versus small scale, or the question – should we all return to small scale? Well, the answer first of all is actually, at least from FAO's point of view – no, we are not really saying that everyone or the largest-scale industrial size production of livestock should all return to small scale. What we are trying to say here is actually there are ample opportunities for improving the efficiency of production, livestock production, hence, reduce emission in both the small-scale and the large-scale productions, and that really the key is that we need to advocate and really to implement these best practices. And of course industrial size livestock production already has a much-reduced sort of intensity of emissions in terms of climate change, and the small scale, let's say smallholder farmers and livestock producers actually do need to probably adopt more sort of environmentally friendly practices. But that relates to help from the government and so on.

What I would like also to add here is again the importance of research. From FAO's point of view, we really feel that increasing support, especially from the public sector, in researching, understanding the mechanisms, developing the technologies, especially in strengthening the extension, so that these technologies can reach farmers – that is really critically important. As far as exploring new options, like last month's there was an international meeting held in FAO to discuss the status and the potential of perennial crops. I mean, I thought that was very fascinating. Thank you.

Mark Cackler — Professor Rattan Lal.

Rattan Lal — First of all, the cellulosic ethanol, I think biofuels are very important. Biofuels have been a source of energy for humans ever since we discovered fire. We are talking about modern biofuels so we can put those in our cars and other utilities. My slogan in my class is always, "Grains are for people; residues are for the land." That equality must be maintained.

That means if you want to have cellulosic ethanol rather than the grain-based ethanol, there will be some impact on soil quality and the environment. Ethanol from sugarcane is a different story; grain-based

has lower energy production efficiency than sugarcane-based. If we want to have a cellulosic ethanol, it is important to grow switchgrass, miscanthus, sweet sorghum, guinea grass, etc. If you're in Africa, elephant grass, and guinea grass or whatever, on land which is not suitable for agriculture. Taking away even 25% of the crop residues on sloping and highly erodible lands can degrade soil quality…. Last year was a very good example with our experiment at Coshocton, Ohio. In treatments where we left the crop residue on the surface, in the drought conditions of 2012, we harvested 60% more grain and stover yields than when we did not. So for buffering against the climate change and volatility, you need to return the residues to the land. Produce the residues somewhere else on non-agricultural lands, but don't steal it from the cropland. I think that is the message I want to give.

Measuring soil carbon is a very important question; it always comes up in international forums (such as IPCC). For monitoring soil carbon, the first paper was published in 1856 from France. It is a very easy method. You can burn the soil in an oven (at 900 C) and measure the loss in weight, and account for carbonates. Another method is wet combustion by using chemicals. That is the traditional method. Today we have CHN analyzer. In my lab we analyze 80 samples overnight with an automatic CHN analyzer. Two years ago we published an article with Brookhaven National Lab, in cooperation with Dr. Lucian Wielopolski, who is a nuclear physicist, and the technique is called "INS – Inelastic Nutrients Scattering. The device is mounted on the back of a tractor, and you calibrate the device at the speed of 5 miles per hour or 3 miles per hour. It monitors the carbon in the land where it drives in terms of tons per hectare to a depth of 30 to 50 cm. When he will get the device operationalized for commercial use, I have no idea. But what I am trying to say – there are many techniques available including the one developed by LANL called LIBS. Furthermore, you do not have to monitor soil carbon everywhere on the land or even every year. There is a system by which you can extrapolate the results. There is an experiment station in Ames, Iowa. The results from there are obviously applicable to the regions within Iowa. There are many, many ways to monitor soil carbon.

I just want to come back to Dr. Hillel's comments. I think he is very right that we can improve soil quality provided you have commitment to improve it.

Mark Cackler — Thank you. Unfortunately, we're out of time, but for me this has been a fascinating session here. It is worth remembering: 75% of the world's poor are rural, and actually most are farmers. And we cannot eliminate poverty and create shared prosperity without more and better investment in agriculture. And increasingly that's a climate-

smart agriculture and a climate-smart agriculture that is not adaptation versus mitigation but actually has the triple win of increased productivity in food security, increased resilience, especially for the most vulnerable, and reducing greenhouse gas emissions.

Please join me in thanking the panelists. It's been a terrific session.