PRECISION AGRICULTURE & BIG DATA: TECHNOLOGIES FOR RESILIENCE

Panel Moderator: ***Reuben G. Echeverria***
October 15, 2015 –8:30 a.m.

Introduction:

Mashal Husain
Vice President – World Food Prize Foundation

Good morning, everyone, and welcome back to Day 2 of the 2015 Borlaug Dialogue. We're thrilled to see you all. We have a fantastic morning and afternoon of events planned, and we're going to jump right in here with a stellar first panel, as you can see. And to introduce that panel, I'm going to invite someone to the stage that we at the World Food Prize have tremendous admiration for and hold in the highest regard, and that is Margaret Zeigler, Executive Director of the Global Harvest Initiative. Margaret.

Margaret Ziegler
Executive Director, Global Harvest Initiative

All right, good morning, everyone, and welcome. Thank you for coming. I was so inspired last night by the words of Eric Pohlman of the One Acre Fund in Rwanda. During the Norman Borlaug Field Award Ceremony, he gave an example of the power of agriculture to transform and heal in Rwanda. Eric said, "From food insecure to food secure, today Rwanda is one of the only countries in the world with a positive rate of forestation, a feat only possible when farmers produce more food on less land."

Today the opening panel will dig a little bit more deeply into some of these issues that Eric raised, and we're going to explore how precision agriculture can be harnessed to help achieve the goals of producing more using less and wasting less and conserving resources—all while building farmer resilience.

It's my honor to now introduce the moderator and panelists for Precision Agriculture and Big Data: Technologies for Resilience and Productivity. I also want to mention that we're going to put up an infographic on the screen, and we would like you to feel free to join the conversation online on Twitter at #PrecisionAg. We want to generate conversation about how we can share the benefits of precision agriculture with more and more farmers, particularly women, and those farmers who are also at the forefront of agriculture production in countries as diverse as Bangladesh, Rwanda and Zambia, as well as explore the application in a developed country context.

So without further ado, I'm going to introduce the moderator and the panelists, and then we will begin the panel. We have our moderator today, the very distinguished Dr. Ruben Echeverría, the Director General of CIAT, the International Center for Tropical Agriculture. Dr.

Echeverría was appointed Director General of CIAT in 2009 and has worked on agriculture and rural development issues for over 30 years. Today he is a leader in helping to strengthen agriculture policy, research and extension for national agriculture systems across Asia, Africa and Latin America. He will help guide the panel discussion over the next hour.

Next to Ruben is Michael Stern, the President and Chief Operating Officer of the Climate Corporation, where he leads commercial implementation of the Climate Corporation's Systems and Solutions, as well as Global Coordination and Growth. Mike is also an officer at Monsanto and most recently led the Monsanto Row Crop business in the Americas for corn, soy, cotton, specialty crops and crop protection.

Next to Michael is Cory Reed, Vice President of the Intelligent Solutions Group at Deere & Company. He's been with Deere since 1998. Cory is an active supporter of agricultural education, and he serves on the board of trustees and is chair of the Sponsor's Board, also of the National FFA Foundation. Currently, he is the board chair of the Global Harvest Initiative.

Next we have Benjamin Pratt, the Vice President of Corporate Public Affairs at the Mosaic Company, the world's largest producer of phosphate and potash fertilizers. Ben leads the Internal Executive Investor Media and Communications and the company's sustainability reporting.

Dr. Jose Simas is the Senior Director of Global Market Access, Regulatory and Knowledge Solutions at Elanco. Jose joined Elanco in 2000 from Brazil. He's lived and worked in South America, Europe and North Africa and has led the U.S. beef business for Elanco and covers research and development operations.

Finally, we are excited to have with us a rising leader research, Ms. Yangxuan Liu, who is a PhD candidate at Purdue University. She concentrates on agricultural finance and agribusiness management issues, and, most importantly, she has a deep commitment to research to promote global food security, particularly for precision farming technology to help potato and tomato farmers.

Ruben, let's begin.

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Panel Moderator:

Ruben G. Echeverría
Director General, International Center for Tropical Agriculture (CIAT)

Panel Members:

Yangxuan Liu	PhD Candidate, Agricultural Economics, Purdue University
Benjamin Pratt	Vice President, Corporate Public Affairs, Mosaic Company
Cory J. Reed	Senior Vice President, Intelligent Solutions Group, Deere & Company
Jose Simas	Senior Director, Global Market Access, Regulatory & Elanco Knowledge Solutions
Michael K. Stern	President and Chief Operating Officer, The Climate Corporation

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Ruben G. Echeverría

This is a great panel, as you can see, and we have an hour, so I would try to be a moderate moderator for this session. Let me start by thanking for organizing this, Margaret. I think we have a big challenge ahead, and I would push all the speakers here to come up with concrete, tangible ideas and initiatives how we can adapt, adopt, translate all of these fantastic things that are going on with precision agriculture and big data in developed countries to developing country conditions. As we do research in the tropics, for us it is very important to try to assimilate and learn for all of these huge amount of farmers that you can see there in the screen for developing country conditions.

So I have just three comments to start very brief in my two minutes, and then I will let them go for about two or three minutes each. And then I have a very harsh question for each of you.

So my comments are, you know, in the 70s I studied agronomy in a little country called Uruguay, south of Brazil, Jose. And at the time, working on extension, the big issue there was how to translate all of this information in controlled trials to recommendation domains into technology packages? So it was quite linear and quite easy 30 years ago to say, well, researchers are telling me this. I have an extension agent; I can translate these for uniform conditions. This is in the 70s. I began actually doing part of my teachings at CIMMYT ten years later, and again a great work of CIMMYT working on recommendation domains, mega domains—how these new wheat lines can really be spread in uniform big places, big areas, big geographies...

So now, twenty years later, I'm getting old, and 30 years later I see these as fantastic, very precise, precision, site-specific type of agriculture, very sustainable intensification. I think that's great. So we at CIAT try to call site-specific agriculture—it's still precision—just to make a little difference. And we are working on it, starting. We think this new approach shows great promise for the modern agriculture on the path to sustainability. And adjusting this management practice to the reality of farming conditions across sites and over time in a given area.

So in the 70s CIAT started big data before big data had been around, and with a very famous dataset on climate, database all over weather stations across the tropics. It's been available for 30 years. It's called WorldClim, and this is much earlier than what Climate Corp is doing today and so on.

So from those origins, I just want to start by saying that site-specific agriculture and big data is really taking root in Colombia where I live. We started with a tropical fruits program. CIAT doesn't work in tropical fruits, but we have the conditions and the modeling and the research to provide support to that, and it went very well. The government now is almost close to sign a peace process, and they're looking at site-specific precision agriculture and these data, because there's a new agricultural development revolution, hopefully, starting soon in Colombia. So this is very real for the type of work that we do in the National Research Center.

So I would like to now go one by one, if you can make a short statement, two, three minutes each, and then I have a question. And then if we have time, you can think of great questions. We will have hopefully one or two questions from the floor. So, Mike, do you want to go first?

Michael K. Stern

All right, thank you. So good morning. The Climate Corporation's mission is to help all the world's growers more sustainably increase productivity through the use of digital tools. We accomplish this, and we continue to try to accomplish this, through using data science and software engineering to take large datasets and build sophisticated agricultural models that allow data to be upgraded to provide information and insights to growers to help them make more precise and real-time decisions in their fields and on their farms to help drive productivity.

This data comes from a whole, wide range of sources, through measurements that we might make in the field, in the soil, in the atmosphere. It will come from hardware running across that field. We'll use data that is publicly available on weather and crop yields and phenology. And, of course, we work closely with growers to understand the specific variability in their field to go ahead and provide some solutions and insights for them to make better decisions.

The world is digitized, and we're going to see the same digitization occurring on the farm. In fact, it's occurring on the farm dramatically right now. If you just think of what's going on around us, there's more cell phones on the planet than people. By 2017, there will be over 100 billion digital sensors deployed around the world, which I find just amazing. And the cost to move large datasets and store large datasets is dramatically decreasing; it has dramatically decreased over the decades.

So all this goes into what I call the digitization of the farm or digital agriculture, which will be an enabling technology as we become more precise, as we think about precision agriculture. And so, just like advances that occurred in breeding and biotechnology over the past decades, that have been, that drive tremendous inflection points in agricultural productivity, I firmly believe we are on the cusp of this next innovation wave, this innovation wave of digital agriculture. Digital ag will transform everything we do about farming—there's no doubt in my mind. And it will change and make more sustainable and more productive how the world goes ahead and takes natural resources and converts them into food.

So I look forward to the conversation this morning, and I turn it over to Cory.

Cory J. Reed

Thanks, Ruben, and thanks to the World Food Prize. And I thought I'd start by quoting a statistic from the Global Harvest Initiative GAP report, yesterday—some of the amazing work that's gone on in ag productivity so far. Now, I'll use a developing country. I'll use the U.S., because it was the focus of the report.

Over the last 70 years, agricultural output in this country has grown by almost 156% and largely on the same inputs going into the crop. So it's a tremendous accomplishment. But what the report also said is, not only in the U.S. but globally there's a lot more required for us to stay on course to feed the world going forward. And in fact, there's some regions of the world that aren't on track to supply their own needs and need a lot of tools going forward to do it.

I thought I'd talk from the perspective of how we've thought about quality in the industry and a few thoughts about how that can be translated around the world.

For Deere, and I think for most producers, we tend to think of quality starting with the products that we produce—tractors, combines, the individual units. And I think it's true for seeds and for fertilizer and for the individual components of this system over the last 70 years that led to that productivity. Going forward, what producers are asking us for—and this is everywhere around the world—is how those systems come together. And I think you've seen the product of that over the last 50 years of how those systems are coming together, between the quality seed, the quality fertilizer, and the ability to use the tools and mechanization in scaling of those tools to create better outcomes on the farm. The challenge is how do we do that everywhere around the world?

Innovation for us over the last 178 years has largely gone through a very similar scale. We normally go into markets and mechanize, and then we scale that equipment. And then we think about how we automate some of those opportunities where variability can occur. And then ultimately optimization of that through information and understanding of what's happening with the machine or on the farm. The opportunity we have in developing countries is to accelerate that. We don't have to go through that same learning curve we went through over the last 70 years. We can accelerate and use the tools available today and scale them into those new markets.

So we think about innovation not only from the perspective of our historical path—and we'll continue to build bigger, faster and stronger machines and introduce them into many markets—but increasingly it's about easier to use technology, smarter technology, more precise use of the inputs and the machines that are used in the operation, and we're focused on delivering those tools to do it.

I look forward to the panel today. It's a great opportunity to have a discussion about it. Thanks, Ruben.

Benjamin Pratt

Thank you, Cory and Ruben, and thanks to the World Food Prize for inviting Mosaic and me to participate on the panel. I'll acknowledge at the start that you might not expect someone who

works for a big fertilizer company to be on a precision ag panel, given that the last major advancement in fertilizer was about 110 years ago. Nevertheless, the need is enormous for us to make advancements in fertilizer and to contribute our part to precision agriculture. Obviously, fertilizer is a critical part of the calculus of precision ag, given the fertilizer accounts for about half of the food that's produced in the world.

But we also realize that, given the advancements that our colleagues in the seed business and chemicals and in the equipment business are making, fertilizer products need to adapt and improve along the way. This has been a fully commoditized business that we are just starting to see the need for real fertilizer innovation to help realize the full value of the seeds and other inputs that other people are making.

And I do want to address the need for access. I think this is a very complicated issue. We have the technology now; we have the technology to close the yield gaps that, as Cory mentioned, are highlighted in the Global Harvest Initiative GAP Report that we announced yesterday. But access is not an easy calculus; it's not an easy thing to solve. And if you take the example of fertilizer in Africa where African farmers pay about twice as much for fertilizer as farmers in more developed agricultural areas, that's an enormous hurdle for smallholder farmers to jump. And there's a lot of things that need to happen to improve that.

And if you look at it from the fertilizer perspective, the stuff we need is heavy, and it's big, and it requires good infrastructure to move it. And we don't have the infrastructure we need in a lot of the parts of the world to get the technology there and to really improve yields. So it's an area where Mosaic is, we are very much devoted to the product innovation and to process innovation. But there's a lot of sort of what I would call sort of blocking and tackling that has to happen with governments and with a lot of other elements of the ag supply chain to really get the promise of precision ag, which is enormous, to all the rest of the farmers of the world.

Jose Simas

Well, thank you, thank you to the World Food Prize for the opportunity.

Very similar to agriculture, animal agriculture, protein consumption, will significantly grow in the next 20, 30 years and the strategy to mitigate climate change impacts are very important for policymakers and therefore for producers.

Technology and innovation is the solution, is the solution for productivity; and productivity is the solution for sustainability. Technology in animal production systems, in a way, I believe it's very similar than crop reduction systems. You've got the process technology or management, and then you've got the input technology. So process technology—things such as the number of times a cow is milked per day, number of hours the light is on in a chicken house. And then inputs to technologies—things such as feed or the genetic semen or health, animal health products. The opportunity around big data—it's really to unleash the process technologies and the input technology, and it provides a significant step function change of the opportunity to maximize or optimize the use of those technologies within those production systems.

We have a group—we call it the Elanco Knowledge Solutions, and we issue roughly 3,000 reports a month to our customers based on their own data, and those reports really help them

make better health, feeding and commercialization decisions. And again there's a wide range of productivity amongst our customers. But irregardless of the base productivity level, big data really helps them with the step function change in terms of use of those resources and being more efficient.

Animal welfare is a key dimension of that component, so poor health is associated with higher mortality, and that is wasteful, decreases productivity, and is inhumane. So those technologies and big data also help improve the welfare of the animals, because you have the opportunity to intervene much earlier when you anticipate a health challenge or a problem within your herd.

So the technologies, management technologies and the input technologies are available, and then use of big data really maximizes or creates that step function opportunity to improve the outcomes and get more out of the animal production systems relative to the inputs.

Yangxuan Liu

Thank you, thank you for the invitation of the World Food Prize. It's a great honor for me to be here to talk with you guys. In my opinion about precision agriculture, transforming data into information and then putting information into useful knowledge is the biggest challenge faced for precision agriculture.

Usually, when we were discussing about precision agriculture, we have focused on corn, soybeans and other major cereal crops. Vegetable crops have received less attention. Here I would like to discuss more about high value crops. Unlike cereal crops, the high value crops, even the smallest problem can bring a big, significant, lasting impact on the yield and profitability for the farm. So farmers have to manage really carefully to mitigate the financial risks and production risks.

Here the precision farming technology, I will examine in my study, is related to new, potential application to late blight disease management for potatoes and tomatoes. This system, this new application is a new… it's a good example how precision farming technology transforms data in to information and then converts the information to useful knowledge to guide decision-making.

The technology I will discuss today is called Potato and Tomato Late Blight Decision Support System. It is developed by Dr. William Fry's lab at Cornell University. This system is an interactive computer-based tool, which helps the potato and tomato grower to use weather data to make informed decisions. Late blight disease is very sensitive to weather. However, individual growers have a difficult time in monitoring weather conditions and, more importantly, understand the relationship between weather and also disease. Without access to relevant information, it is very difficult for farmers to make informed decisions.

The Decision Support System can contribute significantly to transferring information to growers. The Decision Support System gave growers early warning signals pertaining to the development of late blight, helping them to schedule the next best fungicide application opportunities. Also, the Decision Support System helped growers to apply fungicides more precisely and timely, in accordance with weather conditions. This system reduced fungus applications for more disease-resistant cultivars. Our economic analysis found that adopting

this technology increased the average yield for the most commonly planted potato cultivars by 2% in the United States. And the value for potato growers to adopting this technology ranges from $30 to $544 per acre.

The Decision Support System has been designed for use by commercial potato and tomato growers as well as small gardeners in the U.S. So with proper support, bringing this technology to developing countries should not pose a major problem. And I will look forward to discussing more on the panel discussion.

To sum up, precision farming technology helps growers make informed decisions. This technology has improved decision and timeliness of the grower's decisions. In the process, precision farming technology has a potential to improve productivity and profitability of growers and at the same time mitigate environmental impacts.

Ruben Echeverría

Thank you, thank you very much. As you can see, this is a very well-behaved and precise panel on precision agriculture. So now we have time for a second round. And so I said this way. Mike, I had the pleasure of visiting Climate Corp a couple years ago when we were launching our big data platform. So I'm a little biased, because I was totally excited for what I saw there. So my question to you will be—as you mentioned in your opening statement, increasingly sophisticated tools are being developed that make it possible to project the long-term impacts of climate change with more certainty and in more detail than we ever had before. I remember your globe going around at the entrance of Climate Corp.

So we also seeing major advances in the development of seasonal forecasts, which you are working quite a bit in a national adaptation to climate programming in Colombia, that offer farmers better ways to cope with variable weather. So what more can be done to translate this beautiful, fantastic information into forms that are easy to use? How can we make such products being used today in the U.S. and Europe readily available to large numbers of growers in developing countries?

Stern So we are very, very focused on actually trying to solve that problem, and one of the first things we look for—you mentioned weather, and I think this is something where we think about infrastructure—is where does weather data exist? Weather explains an enormous amount of variability that occurs in the field in any season. And so weather data is very, very important.

And so what we see… of course, in the United States we're very fortunate—we have publicly available large datasets of weather and climate; we get over three million weather feeds a day to feed our models. And so one of the challenges is—where do we get great weather data and in particular as we begin to expand into other countries that might not have that infrastructure?

One of the things that we're working on and we're working on collaboratively, is how do you begin to get more localized weather measurements, even field-specific weather measurements, that can help us get better understanding of weather

occurring in the field and be able to go ahead and coordinate that with larger, maybe even satellite imagery and other forms of measurements to go ahead and get more information about weather in countries that do not have the infrastructure that exists in Europe or in the U.S.

So that's a big challenge, and I think it's a challenge that everyone's going to have to be thinking about in the precision ag area who are thinking about big data and modeling, because of, again, the variability that can be explained just through weather events. So we're working internally to develop some of those technologies. We're looking for partnerships, looking at startup companies that can go ahead and do more microweather analysis that will help in being able to expand the footprint that these digital tools can spread to, again, with that key input around weather.

Echeverría Good, thank you. Cory, mechanization is a big part of the solution. You had a great presentation yesterday in a complementary panel on what John Deere and others are doing. So we all agree it's a big part of the solution for better soil management in developed countries. When we think of precision ag, we naturally think about new technologies like variable rate seeders, sprayers and so forth, or crop yield monitors mounted on combines equipped with GPS, very detailed, you know, all of these dream technologies coming through. So what are the prospects for enabling agriculture in developing countries to benefit as much as possible from these extraordinary innovations in the north?

Reed I think the opportunity is fantastic. I'll share a couple of points. You mentioned site-specific agriculture. Much of the in-field extreme of site-specific comes from knowing where you are at any given time. So the ability to automate positioning, that technology, guidance technology, geopositioning, is something that started in high-value crops and vegetables, moved across the United States. Today, what most people don't know is it's from us available in 90 countries around the world. So the technology is now available in many of the developing markets.

The challenge is scaling solutions that are easy to adopt at all sizes of operations. So some of the focal points that we have are thinking about and understanding and meeting customers where they are in their operation. The challenge that we have as a globe is not going to be solved alone by the largest producers in the world. It's going to be focused on—how do you take everyone from where they are, one or two steps up continuously? So the focal point for us is to try to take some of these same technologies and learnings that we've had over generations and try to quickly scale them at sizes that we can move into each segment of the market.

Many cases, mechanization is one of the first moves, and we mentioned that progression, mechanization to scaling but often information. I think one of the tremendous opportunities we have in developing markets is the infrastructure that's gone in quickly on the communication side has allowed for dissemination of information in many cases as well as anywhere else in the world.

So the first thing we focus on is education of information. Countries like Ghana and Kenya and Zambia we've put mobile training in that talked about how the combination of mechanization, along with better farmers' practices and the use of the tools that these guys deliver allow you to go in and grow output. That alone doesn't solve it. You have to have an offtaker; you have to be able to market the product.

But ultimately it comes back to—how do you take what's available? How do you understand the local market condition and then tailor a solution that takes everyone from where they are and then moves them to the next step in their operation.

Echeverría Thank you, thank you very much. Ben, over the last several decades, most of the successes in ag research for development have resulted from widespread dissemination of seed. And we all know that seeds shouldn't go alone. We need the fertilizers, we need the good soils, we need the management and the rest. So documented cases of impact from research on natural resource management are very few and far between. We have all of these fantastic studies showing the rate of return on yields and specific crops but not on the natural resource management, which is in the area that your company operates. What is the potential for precision ag and big data analytics for turning this situation around? In the next decade or so, will these approaches make it far more common for large numbers of farmers to adopt even more fertilizer, as you mentioned is necessary?

Pratt Well, we don't think that a lot more fertilizer on existing land is the answer. We are big believers in conservation agriculture as the starting point. So this is a complicated question you ask, Ruben. The notion of resource scarcity, obviously, is real, but there is a vastly overstated belief around certain parts of the world that the minerals we mine and manufacture into fertilizers are in short supply. It's simply not the case. It doesn't mean we shouldn't be searching for ways to be conservative with those materials.

Technology can apply to fertilizer, and we can make better fertilizers that meet the needs of new seeds better and that stay on the ground better and have a smaller environmental impact. There needs to be more of that research, and there needs to be a bigger commitment from our competitors and from all of us to achieve that promise. We've made big progress in producing fertilizers that combine micronutrients with macronutrients to deliver more fertilizer to the plant. In developed agricultural systems, nutrient use efficiency has improved dramatically over the past several decades. We need to make sure that, as the technology that our colleagues like Deere disseminate around the world, as the technology moves and as farmers get access to good seed and good fertilizer, that they also sort of make that step change that Jose has referred to and skip over the time of inefficient nutrient use and protect the environment and make the most of their nutrients along the way.

Nutrient loss to the environment is a big concern for all of us in our industry and for growers. It's also… It might be an obvious statement, but it's certainly in no

one's best interest—right?—no grower wants to pay for his fertilizer and then lose it to the environment; they want it to be used in the plant. So we believe it's incumbent upon Mosaic and others in the fertilizer industry to continue to develop better products, better means of application to make sure that nutrient use efficiency in well-developed agricultural markets and in other parts of the world continues to improve.

Echeverría Jose, these days we hear plenty about advances in site-specific disease in management for a wide range of food crops. We keep thinking precision ag, site-specific, it's all about our crops. So through new applications to livestock for action in South America. How can we help with greenhouse gas emissions, while also making the action more resilient in the face of all this variability weather? To what extent is it possible for precision livestock farming to be applied across scales from smallholders to large scale production?

Simas So I'll probably use a couple of examples. Our most globalized, we say, platform—we call it Health Tracking System, which is a poultry health platform. And we use it with smallholder poultry producers in the Delta of the Nile in Egypt, 5,000 birds, to the largest global integrator companies with buildings of broilers. The platform is exactly the same, northern hemisphere, southern hemisphere. And that platform really helps integrate health, production and really going back to making better decisions and recovering as much as we put into the system into animal protein and minimizing the waste.

In the case of Latin America, one thing that we've been able to work with in terms of helping the smaller or the different size and scale livestock or cattle producers is really tools that are independent of actually having access to data. Those are more simulation-based tools that take away that constraint of having that systematic access to information, which is really one extreme of the constraint to the smallholder farm. How can you get a stream of consistent information flow? So we basically took more of a simulation modeled approach to create tools than we can with the smallholder producer, even without data, help them understand where they sit in the bigger scheme of data information that we have.

The other point I would like to make, maybe to counterbalance it—we talk about big data, but small data for smallholder farms is very, very important. And it's not uncommon, you know, going back to Latin America, in dairy production systems for you to have a tenfold difference in productivity from a thousand kilos of milk a year to 10,000 kilos of milk a year. The smallholder farm, the family-owned, they can benefit a lot from just writing down once a month how much milk that cow produced; and when that animal moves from pasture A to pasture B. And then with small data just registering it and treating the animal as an individual also creates a huge opportunity for improvement. So the concept of treating the animal as individual works for big data and small data.

Echeverría Thank you. That's a very good point. Liu, you had an earlier statement as a PhD candidate from Purdue, and I think for what we saw earlier from your summary presentation, you are going to be a five-star PhD pretty soon in Purdue. So my

question is—what is needed to help make your precision ag application for potatoes and tomatoes more useful in a developing country context? How will you translate that into a more developing country context?

Liu Okay. First of all, I want to say I'm only one part of the entire development of this precision farming technology. The development of the current potato and tomato late blight decision support system really evolved with years of hard work on researchers at Dr. William Fry's lab at Cornell University. And the way I continue improving this system, as with the question about how to adapt that into developing country. Because this system is designed for use by both commercial potato and tomato growers as well as small gardeners to the US, so it's very easy to suit to small farmers in a developing country. Issue will relate to tailor-based technology to suit the developing country growers, as well as adjust the parameter to suit local conditions. Weather information is a primary data for using the Decision Support System, so for the country without detailed weather information, to develop a weather forecasting system will be an essential first step, using the system.

Echeverría Thank you very much. So according to our instructions, we have about ten, fifteen minutes for questions and comments, and we have a full house. So priority setting—who has good ideas? What I would like to mention is that, instead of asking specific questions for each of the companies, or ideas here, for the North we can continue to focus on how we translate this into developing countries. Many people, even donors, we in the international centers are very connected to our partnerships and some of the donors are sitting here. They may think that this is too sophisticated, you know, this is great, but it's fantastic, it's moving on; but here in Iowa—but how about there? So that's another type of perhaps discussion that we can have if there are good ideas in the audience. So who wants to jump first? Okay, go ahead.

Q Go ahead. Wayne Fredericks. I'm a farmer in Northern Iowa, corn and soybeans, and also serve as president of Iowa Soybean Association. One of the things I've learned in my career of farming is that, like the gentleman from Elanco said, we have to somehow create manageable points in our operation for which we can make improvements. So you start off with enabling the farmer to track those manageable items—that's the number first step. The number two step is—how can you put him on a plane where he can start to benchmark with other farmers those manageable items? Because until you benchmark, you don't have real reality check to where you're good or bad. And if you get in a big enough database group, whether this be on crop production, animal production, financial management, any of those types, if you can standardize the type of information you collect, then you give the farmers the opportunity to benchmark against one another within that system, you find where your weak points are. And a weak point, many times when you discover it, that's kind of deflating, but it is your biggest opportunity to make improvement in your operation because you know you are doing below average of the group.

Echeverría Do you have a question for the panel?

Q My question is—How can you work together within those systems and really drive it, creating those manageable items for the farmers, because everyone kind of wants to go their every which way, but I think a lot of times when you can collaborate together, there's opportunities there for a win-win situation for everybody.

Echeverría Okay. Thank you, thank you very much. We are going to collect a few of these questions… Your memory is early in the morning, so I'm sure you can collect two or three questions and then we can see. Please go ahead.

Q Yeah, I was wondering what's happening in terms of using precision agriculture for soil sustainability. In terms of cover crops, are there ways to use cover crops with precision agriculture to conserve the soil?

Echeverría Thank you, thank you very much. Any other panel members want to tackle that one on soil? Ben, are you…

Pratt The cover crops and other conservation practices hold major promise for precision agriculture, and they are to me, and I think my colleagues would agree, that those kinds of practices are entirely complementary to the sort of big data-driven practices that also drive increased yields and the other promise of precision ag, which is reduced impact on the environment and reduced use of resources. Those kinds of practices clearly fall mostly on the environmental side, but they bring major benefits in the right locations.

Echeverría Do you have a comment on the first question, Cory?

Stern On the first and second, real quick. The first question about benchmarking, I think that's a very insightful and important topic about how can you go ahead and work and generate systems that allow growers to understand what the value is—what's the most…, what fields or elements of their operation have the most potential for improvement, so growers can focus on those, and then you can imagine you continue to find out, as you improve, what that next step might be.

So I think where we are today, first of all, there is data, and the data that's being generated from the farm, and getting back to the digitalization of the farm is going to allow for this. And there are… The Climate Corporation were developing these benchmarking technologies, and the good news is there's a variety of other companies in the marketplace today that are in fact doing the same, that are working on these benchmarking technologies. So I feel that, as growers and we organize data more—that's a big piece of this, having growers have organized data all in one place on a platform, you can begin to go ahead and anonymize that data so you're never using any one, specific grower information and sharing it, but you can anonymize that data and go ahead and begin to do these farm-to-farm, field-to-field benchmarks and be able to provide that type of insight. So I think that's

absolutely going to happen, and it's really important, and it's scalable. It doesn't just have to be in Iowa.

On the soil health piece, just real fast, we have a large program at Monsanto on microbials and soy health, and I think it's not… cover crops are going to be a piece of it, but I believe that this next wave of innovation, and again using genetics and sequencing and understanding microbes and soil health, are going to provide tremendous benefits to productivity going forward. It's the early days, but the technologies are there, and you can begin to see how, by understanding microbes, microbial health, you can begin to think more precisely how you can go ahead and address that in a field on a meter-by-meter basis, using equipment to go ahead and deliver microbes or other types of nutrients in the field. So I think there is a lot of work going on around soil health right now.

Echeverría Cory.

Reed I'd mention one thing on benchmarking, because I think what's changed in the last ten years is, you know, we had things like soil mapping, yield mapping and monitoring in the past. What's different today that allows for things like benchmarking, even on your own farm, before you think about who you're going to share with is it's now closed loops, so that the technology going out, the infrastructure going out in almost all manufacturers' vehicles now allow for you to collect that data in a higher-resolution way. One of the things we learn from the animal industry is, when you get down to the cow level, or in this case to the square meter level from the field averages, you've got a lot of benchmarking you can, do even inside your farm, to understand how your soils, your seed selection, how your choice of nutrients has allowed for variability in your farm and what you can do to improve that going forward.

The systems now are working to connect, so one of the major drives in the industry—and there's obviously no end to the number of offers you have out there for different types of things you can do. One of the tremendous enablers in the future will be how these systems start to interconnect and that you have the ability not only to control your dataset but to share it with who you want to, to get it in the hands of an advisor that you trust, to benchmark with the group that you choose. And a lot of those tools over the last four or five years has now been put in place, and these systems are starting to line up. The potential of this, to do exactly what the gentleman from Iowa said, if it exists, then it's going to explode in terms of how it goes over the next five or ten years. And you'll be able to choose your peer set. You'll be able to share that information with who you trust across… in fact, you can do that today. And that's what's changed that's going to propel this going forward. The ability to take that into developing markets is extremely important, too, to think about how those information sets get shared and connected.

Echeverría Thank you very much. Okay, I see an increasing line and a diminishing number of minutes, so we need to. Please go ahead.

Q Around the use of big data or analytics. Big data and analytics, our experience has shown, that doesn't replace the subject matter expert or the veterinary, or I would assume the agronomist or nutritionist, the PhD. Sometimes we tend to get excited, even in our own world, with data visualization, the cool app, the prediction optimization. We've also observed that weather explains most of the availability. But back to benchmarking, you know, practically speaking, benchmarking with a good technical resource really gives a big, big opportunity to identify and describe the best practices that can be replicated, either across neighbors or within the animal production system. Because you can actually identify which are the animals and what are you doing to them that allow them to be so much better than the other ones. And you need the subject matter expert with the biology and the knowledge to be able to identify those actionable items, because they can't really change the weather.

Liu I would like to have a quick comment about benchmarking. This is a very important topic for the welfare of farm and profit of the farm. And a lot of researchers at school are doing this type of research, to say which farm is good at what part and which part is not good at what part, and need improve. My advisor, Professor Michael Langemeier, together are collaborating with Kansas State University and also other universities around the world are doing research for benchmarking about finding efficiency on the farm. And they find that they can identify a certain area of inefficiency and telling the growers, "Here is what you need to improve to improve your profitability."

Echeverría We are all biased. We know that without agriculture research, we cannot survive. Thank you. Please go ahead.

Q I am Francis, so I'm working on water index insurance in Northern Ghana, so I guess big data for good, precise information. But is the main challenge to scale up this information to smallholder farmers? I think one of the big constraints can be education, infrastructure, and probably the language barrier. So, and again, who are the key players to scale up this information? Thank you.

Echeverría Should we take one more? Yes.

Q I'm Natalie Hahn. I worked with U.N. for many years, and I'm now a Nebraska farmer. My question relates to our partnerships at the field level. Are you working with colleges of agriculture? Are you providing in-service training? And the wonderful technologies that you describe are oftentimes with Western universities and primarily Western companies. A continuing constraint that we have is finding fellowships for African students, not only within countries but internationally. Do your companies provide fellowships? Could you provide more fellowships, whether it's Stellenbosch in South Africa, Egerton in Kenya, or Purdue or Iowa?

Echeverría Thank you. Keith, do you want to go ahead?

Q Okay, thank you. Keith Fuglie from the U.S. Department of Agriculture. My question is specifically for Mr. Pratt and Mosaic. When we look across

agribusiness, we've seen tremendous increases in investments and in research all over the world but especially if we look at the seed and chemical industry, they often spend 5, 10, sometimes even 20% of their revenues in research. Now, in the fertilizer industry, we really don't see that; we don't see that kind of level of investment in research and development. But nevertheless you talked about the commitment of your company to increase product development and fertilizer efficiency. So I was wondering if you could talk a little bit about the role of the fertilizer industry in innovation? Or, you know, where is the innovation going to come from in developing the new products that will raise efficiency, the new, you know, getting the real specific innovations necessary to address these issues? And what might be done, what could be done to strengthen incentives within the fertilizer industry to increase its research investment?

Echeverría Okay. Why don't we start with that one?

Pratt Thank you, Keith. I promise I didn't pay him to ask that question for us. You're exactly right, that the fertilizer industry has not been highly devoted to research and development and has not spent a lot of money on it. And we are firm believers at Mosaic that the next generation of farming has to include higher technology fertilizers. We have developed effective and efficient and economical higher-tech fertilizers. Now we have advanced micronutrient fertilizers in the market, and we're working on developing products that can also mitigate environmental impacts.

It's not an easy answer about why fertilizer hasn't spent the money or made the investment. And I think we can't really alter the genes of fertilizer, so the development of new fertilizer products has not – there hasn't been a lot of incentive for it in the market. I think we think that incentive is increasing rapidly as this demand for nutrient use efficiency for farmers losing less of their fertilizer and maximizing their investments and their yields is increasing. And we think it's a competitive advantage for us, frankly, because most of our competitors are still not heavily engaged.

And it's particularly important to point out, I think, there are plenty of people around the fertilizer industry who are thinking about advanced fertilizer products. Many of them are in the nitrogen realm, which is not our realm at Mosaic, so I'm not as well versed. But the real challenge is bringing to market an advanced fertilizer that can be produced at scale and economically. That's a much taller order than it may seem. Producing an advanced fertilizer that's too expensive for farmers is useless, and field testing of fertilizer that you can't produce in your plants and mines is also useless. And so there's an enormous amount of capital investment required once we have a product that we believe we can build a market for to get that product to market. Lots of disincentives along the way that I've just mentioned to producing new fertilizer but lots of incentives we see in the future to making big advancements.

Echeverría On the first question, the weather insurance, perhaps, or in the fellowship partnership?

Stern I have a comment on the first question, and I think it really went to infrastructure and how is that infrastructure developing? I think my comments on were about there's more cell phones on the planet than there are people. And, of course, we've seen developing countries, cell phone use is a major source of communication.

We actually have an example of a model of how we think we can get information, useful information to smallholder farmers. In India we have a program called, "Farmers First." It's cell phone based, has over three million smallholder farmers utilizing the system. It's a system where they can go ahead and get agronomic information either directly over their phone or through text messages. And it also gives them market information, so it gives them price discovery of the markets in their area, something that is not very common, to help them optimize where they can go and sell their crops.

So I think there are models out there. Cell phone use is going to be, in third world and developing countries, if you will, will be really the key to information transfer in the early days.

Reed I agree. I think the combination of both new technologies and improving technologies in that case. One of just simple extension—If you think of the university systems around the world and you understand what it means to take that technology out… We're partnering to take technology on the road, out into the village. You can take that technology and information out through the mobile networks. You can also just put boots on the ground—invest in universities, invest in the local… from a government perspective, in taking extension out across the rural countryside. There's no replacement for getting on the farm and on the field in addition to using the high-tech way that we can take information out. And I think the combination in all of these is the key.

Simas The comment I would make is on the other extreme. So infrastructure will get better and cell phones are everywhere. I would say a constraint that I believe we'll have is on the other extreme, which would be the extreme of data privacy. You know, in some countries of the world, they, the cow, calf, how much milk they gave it's a matter of national security. So, and data privacy is going to be a big social discussion that we will need to have.

Echeverría In the half a minute that we have left, in addition to thanking all of you for being so patient—on the second question on the partnerships, one thing that we are trying is we are supported by international donors at CIAT, and we have support in Colombia from the government of Colombia. But the real action is really with producer associations. All of the big data, site-specific agriculture, climate change, adaptation that we do in several countries where are we working is working with producer associations because they have the data, they have incentives, they have the interest of really getting applied solutions for their own farms. So I think, my own bias, since we have a lot of private sector representation here, and in the CGIAR sometimes you need the national centers. We've been a little reluctant in the past, now we are not, to do public/private collaborations. So one challenge for Margaret, who is the real engine behind this panel, Margaret Zeigler from Global

Harvest Initiative, will be to perhaps have our conversation in the future—how all of these ideas that we heard here in the last hour can be converted to reality, perhaps pondering with international centers and other partners in the audience. Thank you, Margaret, for organizing this. And thank you, everybody, for being here. Thank you.