BUILDING SOIL HEALTH FOR SMALLHOLDER RESILIENCE

AUDIO TRANSCRIPT

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PRESENTERS

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PRESENTATION

Jerry Glover: Good morning or good afternoon everyone, depending on where you are in the world. And as Julie pointed out, happy international year of the soil. The UN highlighted this topic for two reasons. One is of course the importance of soil in our lives, but also the fragile nature of soils around the world, and the challenges farmers face in producing enough food for all of us. So it's appropriate we bring in two of the great experts on the topic, who have many years of experience working with smallholder farmers around the world.

Now, land degradation or soil degradation is an incredibly big challenge. Particularly now, as we're expanding our global human population. Recent International Food Policy Research Institute book shows that global land degradation is now costing hundreds of billions of dollars. That includes lost productivity and less efficient use of the inputs farmers purchase to grow their crops. So right at the time that populations in these especially vulnerable regions, such as Sub-Saharan Africa, are needing to increase productivity to feed a growing population.

These farmers also have to raise their yield significantly, their crop yield. And of course they're doing this on some of the most nutrient depleted – some of the thinnest soil farmers have worked with in human history. Now, on the bright side, the investments made to improving soil health, restoring soil fertility, the returns on those investments are quite large. Recent studies have found that $1.00 investment in soil rehabilitation returns $5.00, in returns to greater productivity, more efficient use of inputs, and so on.

So there are many bright spots out there in terms of reversing some of the damage done, improving the soil conditions, and of course improving the livelihoods of the farmers that feed the rest of us. To highlight some of the bright spots, and also some challenges faced around the world, we have two great scientists, soil scientists, that have worked for decades in some of these more vulnerable regions of the world.

First, I'd like to introduce Dr. Geoff Heinrich. He's a senior technical advisor for Catholic Relief Services. He's worked for over 25 years directly with farmers in both Africa and Asia. So has a great understanding, a deep understanding of the issues faced by farmers, what drives their decision making within their households, and how soil degradation directly affects them. Geoff has a PhD in crop and soil science, and he's worked with a range of institutions on this issue.

Then, after Geoff speaks on the topic, we'll have Dr. Sieglinde Snapp from Michigan State University speaking on her specific work in Africa. Sieg has won many awards. Most recently, the American Society of Agronomy recognized her as a fellow for her contributions both in the United States and internationally. She's had many, many journal articles, extension bulletins. She specializes really

in participatory action research, and has really pioneered some of the research design and how best to work with farmers, including the mother and baby child design, for which she's possibly best known.

I should say she's a soils and cropping systems ecologist at Michigan State University, and the associate director of the Center for Global Change in Earth Observations. Sieg really works with many, many different partners. So she has firsthand direct interactions with farmers, but also many of the development agencies and research institutions that do this work. So with that, I'd like to turn it over to Geoff, who is speaking to us from Malawi.

Geoffrey Heinrich: Thanks very much, Jerry. That was a really nice introduction on the soils issue. Thank you for that. And good morning or good afternoon everyone, as Jerry noted, depending on where you are in the world. I'm going to talk today about restoring soil health for smallholder resilience in Africa, and looking at critical issues and options. Jerry has started this conversation well, but I'd like to add my own with some…and photos just to outline the magnitude of that problem.

So the first one – this quote from the Dust Bowl days in the US. Humankind, despite its artistic pretensions, its sophistication, and many accomplishments, owes its existence to a six inch layer of topsoil and the fact that it rains. And that might be a slight oversimplification, but essentially it's true. It depends so much on soil.

This picture is from Central Malawi. And this land has been prepared for planting. Doesn't take a lot of imagination to predict what's going to happen when you get the first heavy rain. In fact, the end result can be sort of seen up near the crest of the hill, where it's basically turning to stone. Here's another quote and photo. The rainfall runoff takes about 40 percent of the nutrients applied to the soil in Africa through organic and mineral resources. It's part of the loss that Jerry referred to.

And you can imagine in this picture how it might be true. This picture was taken by a person named Peter Aargaard. But this phenomenon is common in traditional systems, and you can see the massive loss of water, of soil, of seed, and any fertilizer and manure that's been applied in the field. The question is how long can this be sustained without major impacts on yield and food security. Obviously having important impacts even from this current season.

So here's a quote from FAO. In Africa, the most conspicuous symptoms of the negative impacts on land degradation on food production are stagnating and declining yields, and increasing levels of poverty. Actually this picture is cheating slightly, because it's from Bolivia, but it illustrates the point. The impacts of land degradation are devastating. If you notice down in the bottom of the hill, along that pathway, there are two homesteads, and one can imagine life for them is difficult and somewhat precarious.

If you would notice also the big gullies on the hillside. We're going to go back and talk a bit about those later. But I guess the point here is that it's very difficult to increase household food security and incomes in rural areas unless we really take care of the soil resource. Okay. One final slide with quotes and some statistics.

In Africa, land degradation has already gone very far. In terms of land already damaged, it's already two thirds of the arable land, 30 percent of the grazing land, and 20 percent of forest. Another observation is Africa is already food short, and it imports $40 billion worth of food annually. Soil is a cornerstone of food security, and its conservation should become a major global priority. And there certainly is a crisis of land degradation and soil management.

So these final quotes are actually from a Montpellier Panel in 2014. It was composed of some pretty eminent persons. Btu the takeaway really from these pictures and quotes is – okay, so food is already in short supply in Africa if it's importing $40 billion annually. Yields are stagnant or declining. The population is doubling every 20 years. The potential for major food crisis is very high. Going well beyond the food price crisis we saw in 2008, which, if I remember correctly, there were riots in over 10 capital cities across the continent.

So the key to avoiding disaster in the medium term really is restoring the soil and increasing the productivity and incomes of rural households and communities. And actually restoring the soil and regenerating its productive capacity has to be done before other technologies like improved seed and fertilizer can really be effective. And there's some evidence that shows that fertilizer efficiency in Africa is very directly related to the soil organic matter, which is very low and generally declining.

So that's a bunch of bad news. We'll switch over to some good news. The good news is we can reverse soil degradation processes and restore productivity with known technology. We don't need any new information. And we can do it quite quickly. In a relatively short time span. If we just focus our resources and energy on that. To do that we need to work at both the landscape level and the farm level, and I'm going to talk about those separately. We'll start with the landscape level.

Management at the landscape level is really vital, because a number of important ecosystem services can only really be managed effectively at that level. And water is probably the best example. The photo here is from a food for piece project in Southern Malawi. If you remember those big gullies we saw on the hillside – so there were some of these gullies here. And as part of the overall watershed restoration process, check dams were built in those gullies. And you can see those people are standing on one of the check dams.

But within two years, the soil filled in behind the check dams, and people were able to cultivate there again. At the end of the project, we went back. There were 32 different watersheds that were rehabilitated. At the end of the project we went back and talked to communities in a number of watersheds. They reported very consistently increases in stream flows, sometimes quite dramatic. Rising water tables in their wells. And people also reported that with watershed management they started to get better yields even in dry years than they used to get when there was good rain. And if you can imagine all the water that was pouring off the hillside in that second slide, you can understand why.

If you capture that, and it goes into the soil, that really gives you much higher potential. So the watershed management work really stabilized the soil, but it also did great things for the water resource. So looking at some of the options for landscape level management, there are a lot of them. Just put a couple here. I put community based natural resource management right at the top, because communities need to be engaged if we're going to have effective landscape level management. The communities are the custodians of their areas. Without their support, effective intervention are not really possible.

Once the communities are engaged, then there are a lot of things that can be done. CRS has done a lot of good work, I think very effective work, on watershed management, mostly through food for peace projects. One of the few kinds of projects in which this work can be effectively done. But we've also done quite a bit in Latin America with support from the Howard Buffett Foundation.

The farmer managed natural regeneration is also really another very good intervention. I saw Doug Brown was on the line. World Vision had a lot to do with the development of that. But it's been used effectively in West Africa to re-green over 5 million hectares and really stop desertification. It's a really low cost effective technology. Maybe doesn't have an immediate massive effect on crop yields, but it certainly is very good at protecting the landscape. The issues of don't burn and don't deforest are basic tenets, but they're so common and devastating across Africa, I think they really need to be emphasized.

There's lots of things that can be done. I've only touched on a few at the landscape level. Just in the interest of time, I want to move to farm level approaches for soil regeneration. Before we look at specific technical approaches, there are two things I think we need to consider very carefully. First is that farmers have very serious constraints in terms of adopting new technology, and if we want technologies to be adopted quickly and at scale, we have to take these things into consideration. And there are lot of technologies that have failed not because they're bad technologies, but because they didn't meet some of these criteria.

Four key ones are that technology needs to not cost any extra money or labor, at least very little. The second thing is it has not to have big opportunity costs. And there I note for example if you want farmers to start doing rotations, it means they have to not plant maize on part of their field in any given year. For example, in Eastern Zambia, 65 percent of farmers are net maize buyers. They don't produce enough already to feed their household. So convincing them to not plant on some of their land is quite difficult.

So the issue of opportunity cost is there. There has to be immediate benefits. Doesn't help to say, okay, do this, then five years from now everything will be fine. Because farmers have also to live in the short term. So it needs to really have both short and long term benefits. And last but not least, it needs to be feasible and accessible, which means really easy to apply. They need not to have to go to the capital city to get some sort of…It needs to be available and easy to find in their local area.

So the farmers have those technology adoption constraints. And then the second thing is that at the macro level, the right policies and incentives have to be in place to promote regenerative forms of agriculture. And in that regard, a lot of governments are still promoting sort of sole maize and commercial fertilizer, which are not bad in themselves, but they don't solve the soil problem.

Some governments are also promoting conservation agriculture, which, again, is a good thing, but it has three main components, which are minimum soil disturbance, maximum soil cover, and rotations. So quite often they can't do the rotations, and because of other things, they don't get as much mulch on the soil as they need, and so the impacts are relatively low and we are seeing fairly slow adoptions. Conservation agriculture by itself is good, but it's not really enough.

So what I'm trying to say here – we need practical, obtainable options that farmers can easily and profitably adopt, and we need to have the right policies and incentives in place. Okay. So then what can we do?

So really at the farm level, rebuilding the soil organic matter is a key issue. We need to rebuild the organic matter for a number of reasons. First is it increases the water holding capacity of the soil. If you imagine a cement slab, and you pour water on the cement slab, what happens? It all just runs away, right? So but if you imagine now laying a big thick sponge layer over the cement and pouring water on it, what happens? The water stays there, right? That's what organic matter does for the soil, essentially.

The other thing it does is increase the nutrients in the soil as well as increase nutrient availability to plants. And because of that then it can really be effective at increasing the fertilizer use efficiency. So overall the soil organic matter is really crucial to improving soil health and improving the fundamental productivity of the soil.

The best thing I've seen so far is really green manure cover crops. So green manure cover crops are different from traditional rotations or when we think of traditional green manure processes. I won't go into detail, what really we should do is get Roland Bunch on here for an hour to talk about that. He could really explain it very well. But and I will say a few things about it in a minute. But I'd note it's a really good option. It's often accompanied by minimum tillage. CRS is working with Roland Bunch on these options, has been the last couple of years.

Sorry, I think I got ahead of myself. I did. So I do want to say something about this picture, though. So this is not Roland Bunch in this picture, but it is a green manure cover crop system. So this picture was taken this past year in Zambia. This is a maize and velvet bean intercrop. It has had no commercial fertilizer for the last six years. It has had some cattle manure, but that's all. They were expecting a six ton maize yield this year, which is pretty good.

As I mentioned the green manure cover crops are different from traditional rotations and green manures. Mainly what they are, are cereal and legume intercropping systems, or cereal tree crop intercropping systems that improve soil fertility and reduce weeds. And the legume also often has a food or income benefit. And I think they're the best option because they usually don't require any extra costs or labor or external inputs, and they often produce additional food income from the legume crop as a benefit. The last point to consider is when you use them to increase soil organic matter, they can sequester large amounts of carbon.

So this picture also shows a potential of a green manure cover crop system. These pictures are from this past rainy season in the Luangwa Valley in Zambia. And they're from a project that was being run by an organization called Comaco. So the picture on the left is what most of the maize fields in the area look like. This is sole maize with or without small amounts of commercial fertilizer. They were undergoing quite severe moisture stress, and the yield expectations were also quite low.

The picture on the right, which is only a couple hundred meters from – shows a field of a smallholder farmer that's been using maize intercropped with gliricidia for the last six years. Again, they don't use commercial fertilizer. They were just using some small amount of cattle manure. You can see one of the stumps of the gliricidia trees in the foreground. So in this system, the gliricidia branches are cut, pruned from the tree stock before planting, and laid on the ground of the mulch. And that increases rain volume penetration. It prevents evaporation. And soil erosion. It reduces weed growth and allows – adds a lot of organic matter and nitrogen to the soil.

So there were quite a number of plots where farmers were using the gliricidia in that area, and they were basically unaffected by below normal rainfall season. I mean the difference is quite stark. And I think it has important implications for food security and resilience. This is a big issue. I want to touch on it briefly. Increasing soil organic matter and nitrogen availability usually requires intercropping with legumes or tree species, or legume rotations.

So to date the commercial seed sector has shown very little interest in food legumes or tree species. So it can be a really big problem to get seeds. And CRS faces this every year in Southern Africa. This year we have major seed relief programs in Malawi and in Madagascar, and we've had them recently in Zimbabwe and Zambia. It's very difficult to find commercial supplies of food legumes. Even sometimes ground nuts. We also for our green manure cover crops are promoting in all of those countries – we want to do on farm demonstrations.

We sometimes struggle to get even enough seeds to do the demonstrations, which is pretty bad. So we're going to need new systems for seeds if we want to go to scale. Right. So some of the systems we might consider include working with the smaller seed companies on niche markets. Working with farmer based systems. Even working with the informal sector, like with this woman in this market in Southern Malawi in this picture here who is clearly very well organized.

Anyway. The seed issue is a big issue. I don't want to – you can't explain it in one slide, but I wanted to flag it and note my colleague, Louise Sperling, is working with – she's one of the world's leading experts on that. She's working with a number of people to start some initiatives to really try and address that. But it's going to be a critical issue as we try to go to scale in rehabilitating and rebuilding soil organic matter.

Okay. So to just wrap up, I would note it is really crucial to invest in restoring the soil, both at the farm level, and at the landscape level. At the farm level in particular, the soil organic matter is crucial, but if we can improve soil health, we will improve everything else. This needs to be a priority for governments, for donors, and for the private sector, as well as farmers, and to encourage adoption at scale, we need the right policies and incentives, and we're going to have to address the seed issue.

I have not said much about the private sector in this presentation. But I would just note they have a really important role to play, both in increasing the soil productivity, and in the seeds issue. If we have time at the end, we can maybe discuss that a big more. But the good news from all this is there is a lot that can be done, impacts that can be achieved quite rapidly. But as we do that we need to remember new technologies must address and fit within farmers' real needs and constraints. And in that regard, I like to remember the saying that it's only bad technology that requires really good extension systems.

Anyway. Thank you very much. I'll leave it there for now. Thank you for your attention. I'll turn it over to my colleague and friend, Sieglinde Snapp.

Sieglinde Snapp: So today I'll be talking about work that comes out of that work from the early '90s, and work on many connections, which I will get back to, but I just want to acknowledge, right up front, my coauthors here, supported by IITA, Africa Rising, which is a project of USAID. And we couldn't do it without this interdisciplinary team of ag economists, soil scientists, budding next generation of agronomists, and our support from IITA.

So I hope you're all seeing the challenges up here. So we've been hearing a bit about how degraded soil seems to be a driver of food insecurity and environmental insecurity, and in fact it goes both directions. Poverty has been certainly something to be correlated with some areas with degraded soil. So I think we're all here to try and figure out how to break those links and support increases in soil rehabilitation to support food security, ultimately.

Now, we hear a lot about degraded soil from conversion of marginal lands that shouldn't be in agriculture, but I want to talk about the other problem, which is continuous production without enough investment. So this is a way that soil degraded, shown here in Zimbabwe. Imagine you were in their shoes, of these farmers and extension officers, trying to see how we can turn this around. But one of the underlying factors I think is short, very – only four months of a year that a crop is grown.

So maize is grown for maybe four months, and then we have this long dry season. Again, this is from Malawi, showing lands ready for planting. You can imagine how vulnerable this soil is to water and wind erosion.

Now we've seen recent evidence from my student Placid Mpeketula who just became a PhD yesterday, will be going back to teach, at the University of Malawi. And very exciting but disturbing news: when the Food and Agriculture Organization went around to different parts in Malawi and dug pits and most of the soil maps that we be use today comes from that effort in the last '80s, early '90s, around Africa, to document soil. Bringing that back to these locations so over these 25 years, we found that in areas where there was continuous production, the redder areas, this is where there's also we're seeing reduction in soil carbon.

Not just where forests have been converted to agriculture, which certainly there's a loss in organic matter then, but just continuous production is leading to a small but significant decline. So we seem not to be at a new plateau, but at a continuous decline, in soil carbon at least in Malawi, and this is quite worrying.

So many of us here in this virtual room are all in this project together, and we heard about some of the options. Community level. But when we talk just about farmer decision making at household plot level, in terms of legumes to address both nitrogen and organic matter at once, and also human health, because legumes provide protein rich beans, farmers -- we give them options. Like in the mid '90s working with…College of Agriculture, Rockefeller Support, and…Institute of Agriculture, we were able to try a whole bunch of annual legumes.

And we continue to work on improved varieties of beans, peanuts, so called ground nuts, soy beans, cow peas. But in order to really improve soil fertility, these don't do that, because the nutrients all go into – we eat them or we sell them, right? Perennials, such as agroforestry we heard about…which is apparently easy to establish for an agroforestry system just from seed, you can see its green leaves between the maize, supporting very productive maize.

Certainly this works. And I'm a big promoter of green manures, as we heard about, in agroforestry. However, decades of work later, actual research around these best bet options for legumes, we found that in fact rarely *(0:30:47)* could the poorest farmers adopt these. Probably the opportunity cost. Even though we try and develop technologies that can build on farmers' technologies that are really low cost. But still, we just don't see a lot of traction. And so more and more we've focused on a middle way, a type of legume, a shrub, like pigeon pea, which is eaten, but also produces particularly when it's ratooning run for two years produces maximum amounts of purely…seed and also soil fertility regeneration.

Climbing bean is another kind of in the sweet spot in between something that grows for at least a year. Macuna or velvet bean, also called velvet bean, is eaten some places, but most places just used as a forage. So we really see shrubby pigeon pea and climbing bean in cold areas where they can be grown as kind of as unique middle way, a long duration legume, in these pulse systems.

So if you want to see how this works, we try to test for different soil types, different climate conditions, which requires models. There's the APSIM model, which is one of the few crop models that are calibrated for Southeastern Africa, and that allow you to look at intercrops. And you see on the top right here that the three systems that have pigeon pea in them are the only ones where you see an increase in soil nitrogen over time. So that's modeling data. And it's encouraging. But what do we see in the field?

Well, we see farmers adopting varieties, such as…type of pigeon pea, that have – that leave multiple benefits. Pigeon pea gives you grain but also brings fuel wood. This is from Malawi, where farmers' new variety is spreading like wildfire. I can say that. And it is providing increased food security as well as environmental security in that they can grow their own fuel wood. So it's quite

encouraging. But we wanted to see if it could fit into new places in Malawi beyond Southern Malawi, where there's markets currently.

And also what are the impacts on soil fertility? Could it be a three way pull? A pigeon pea – another way it recommends itself to farmers is that it can be grown as an intercrop. Particularly the traditional varieties and some of the farmers' tested…varieties, like…that I just mentioned, are good intercrops. In fact, that's how they're grown. You can plant them at the same time as maize for a very small initially. So they don't interfere with the maize crop. So you can get two crops for the same amount of labor. And, in fact, they can suppress weeds, which is an ever encouraging effect aspect of them.

However, one of the challenges is this doesn't rest the soil from continuous maize production. Maize, we found, doesn't actually increase soil fertility, even soil organic matter, despite all the residues, unless we can somehow break all that maize, and it's very difficult for – you can imagine. If you only have an acre of land, how can you dedicate part of it to soil rehabilitation that doesn't give you food?

So this is a system that is the sweet spot that I think was really encouraging, because it – there were two legumes, so two crops. Here's ground nut is shown, but also can grow soy bean or common bean. Cow pea is a bit more challenging. It's very competitive. You can grow these in the understory in pigeon pea. You can see pigeon pea here. Can see how thick the stems get even in just one year. And we can cut them off and ratoon them and get a second year of growth. And then in the third year, we have like a pure maize crop in some cases, or sometimes maize beans.

So farmers are experimenting in different options with this, but we through support from Africa Rising are looking at different ways that more pigeon pea can be deployed because you wouldn't to disseminate it in areas where it took up too much water. For all these benefits, you have to look carefully at risks, and particularly with a changing climate. And with the variable climates, as we know, that Southern Africa faces, and much of Africa.

So we found that although pigeon peas grown here in the south, there's markets, in fact then optimal area is in the middle, and so need to see where it can be tried out, and new varieties can provide these new options for farmers that provide immediate returns as well as the long term soil rehabilitation. Up here, near Mzuzu in the north, actually, is in area where now over 100 villages and tens of thousands of farmers have adopted this double up legume with pigeon pea. And there's actually been changes in child health, which is very exciting, and should be more carefully studied, because it shows how this can have transformative effects when you address these underlying issues.

So let's talk about Central Malawi, where Africa Rising has now been working since 2012. And we have chosen four different sites that represent different agro-ecology, from the hot dry Golomoti in the lakeshore, to the most high potential mesic area closer to…Linthipe. So we have 1,400 farmers now engaged in mother-baby trials. And in fact farmers are experimenting with these different options. We provide technical support and seeds initially for access to the latest varieties, and incubating approaches, including integration into livestock, value chain…

But, other farmers – it depends on the different types of households and their socioeconomic – what the aspects of these legume options they might adopt. But we're trying to explore them both through this on farm experimentation, through mother-baby trials, but also through modeling to see where things might be best disseminated. So this is intensive action research with this thousand some farmers, and many partners, including Bunda College Luanar, and also IITA and CIAT.

But and extension is very integral to this work. Malawi Extension. Couldn't do that without them. But what we're learning – we're not just trying to do direct development. We're trying to do research to understand where and how these technologies might have the best impact. So this just shows you a few pictures from on farm experimentation. With pigeon pea. Here's pigeon pea and ground nuts again, doubled up legumes, different pigeon pea varieties.

And to point out again we're not just supplying certain technologies, we're trying to support farmer experimentation. And this – you can see that after two years, farmers have expanded areas, and we have female and male farmers here. Women in particular seem to be looking at the legume technologies. Here are some of the double up legumes being tried out. And then the legumes.

And then many are trying small amounts of manure, compost, different integrated approaches, which don't have time to go into, but it's very interesting to sort of learn from which technologies farmers continue to experiment with, and then we're trying to see, what are the impacts then long term in soil, and then ultimately on income and even gender equity has been looked at.

So one of the big unknowns in my view is we promote these technologies to improve soils, but we don't know how they perform often, particularly on a stressed environment, when soils are degraded, can we use a technology that really provides food every year to also improve soil fertility? So quantifying the biomass by these multipurpose legumes…what's the data, and particularly in terms of pigeon pea. This is based on Chiwimbo Gwenambira's work. She's in Zimbabwe and doing a PhD with us in Africa Rising, working with the Malawi farmers closely, and has gone to almost 100 fields where she's dug pits trying to get to the roots so we look at below ground what's going on.

Something I actually dreamed about doing in the '90s, so it's really great to be getting back to it and seeing the next generation press this on and try and test. Because we can't even calibrate models unless we really understand the interaction with…crops, which currently are still rigid in Malawi, although they're trying in some places some other options. And this degraded soil we talked about, and different weather conditions, and different market conditions. These are very complex environments.

But one aspect is to understand performance. So when we talk about a tradeoff, here's one last issue here. In terms of – I just want to point out that on one hand, a sole pigeon pea, which some farmers tried, even though we think of this as a very good intercrop, because it grows slowly at first – I think farmers wanted to particularly -- it's new to many farmers in this part of Malawi, although other areas it's widely grown and sold all the way into India, as many of you know.

Like major ports, I mean anyone who eats Indian food is eating pigeon pea, and it's eaten to some degree in Malawi…So pigeon pea is incredibly productive. The roots are about ten percent of the biomass you see here, 12 tons on farms, which is a phenomenal amount of biomass. And then when you combine it with ground nuts, the ground nuts suppress the pigeon pea a little bit, and so that in particularly in the current system where farmers often grow pigeon pea in the south it's maize/pigeon pea, you get the least amount of pigeon pea biomass. But there's still a significant amount, four times is enough to really support soil rehabilitation.

And then what about grain. Pigeon pea grain again you get the most over two years from a sole pigeon pea, but you get substantial amounts when you grow it with legume, and then the least amount with maize. It's quite competitive with pigeon pea. But you may think, well, why don't farmers adopt sole pigeon pea? Well, if you look at it over two years, and look at a maize pigeon pea intercrop each year, you start to see the reverse relationship. And then obviously the maize is there, or the maize is grown in rotation, then you get quite substantial amounts of maize grain.

And small amounts of pigeon pea. So it's a whole different scale when we start to talk about maize. Maize is very productive. That's why people grow it. And also it's – maize is life, in Malawi. It's a very important cereal around the world, in fact. But it's you look at it in terms of protein, you see that pigeon pea does a little bit better, but generally you can see why the focus on maize based systems, even though it's not ideal for soil regeneration.

So we're just trying to explore these tradeoffs so that people understand them better. And I want to point out – this is one of the last things, I hope really a take home for you. Is that currently a lot of the focus is on sole maize, or even a

rotation of maize, such as maize/ground nut. And in some work from some while ago, countrywide, in Malawi, we found that just adding fertilizer, you can improve your durability. In other words, make it more stable crops, so less variability. This is a coefficient of variation here.

And so typically on farm we get about 20 percent variation, and but you can reduce that by adding fertilizer. You get a more vigorous crop. But the only way you can really reduce it and get a very stable in other words resilient crop, which is what this talk is partly about, is if we had a pigeon pea in the system. And in fact we also – maize/macuna did this as well. But is less popular with farmers because macuna is eaten in only a few areas, and is more for traditional ceremonial use, and is – has to be heavily processed, sometimes multiple hours of fuel wood required to leach out the poisons in it.

So Macuna certainly is very effective also, but pigeon pea is something you can eat and sell, much more easily, in terms of fitting into this current farming system. So pigeon pea with maize you can use half the fertilizer rate and really reduce variability. Although we weren't able to measure soil changes over a short time frame, and a tremendously large major effort, for a maize team back in the day, at…however you'll notice that the only – you weren't able to see differences in organic matter, which takes five to ten years.

But the fact that maize, when it's grown, after a pigeon pea doubled up system, or after macuna, in fact it is more stable a yield. That in itself tells you that probably that is a system that's improving the soil performance. That's the indicator we're using there. So we need to keep exploring different legumes such as lablab, climbing bean in colder areas, pigeon pea in different combinations, and getting new varieties of pigeon pea, such as this one I showed you that had that tremendous amount of fuel wood.

Unfortunately, a lot of the improved variety of pigeon peas keep getting shorter, they call them extra-extra short duration. There are some medium duration ones have been released in Malawi. I was talking about more throughout India and Africa we focus -- a lot of breeding efforts have been on super short types of pigeon pea, and yet what we need is medium and long duration types, in my view, that provide some food but also give us this real rehabilitation. And I want to take you through it from again from some of our crop simulation models. We can start to look at effects in different weather conditions, for different soils.

We have some papers on the climate change impacts, but here I want to focus on soils and such, what our talk is today. So you have high fertility soil on the left. We compare it to a low fertility soil, typical of most of Malawi. High fertility soil, one of the things we have to keep in mind is that then maize in the maize/pigeon pea intercrop, we're just looking at maize, because farmers usually do that initially, and we don't want to put farmers' maize at risk in any way. We

have to make sure that this doesn't happen here on the bottom left, where an intercrop in the first two years has put maize yields at risk of going dead.

We want to make sure we are promoting systems, and this is partly because of competition of a high maize crop in this high fertility condition. Every other year, slowly the soil is built, and so maize yields responded, right? And this is the low fertility condition, more typical of most farmers. Maize by itself was just about 20 kgs of nitrogen, just it was very modest over time, and you have to do some rehabilitation in order to make a difference here in terms of through the pigeon pea kind of improving.

And you can see that the intercrop is exciting in that you always want a maize crop every year. Rotation is every other year, but benefits aren't more substantial in terms of rehabilitating the soil. And we continue to explore this, because we think that there's some circumstances where maybe there's too much water use, where, again, you'd have to look at mulching and ways to improve water infiltration. So there's tradeoffs here we have to think about. We're not deploying these everywhere, but we're just seeing that in fact some of these systems can cause minimal risk to the farmers, but really do some soil rehabilitation, while providing a doubled up legume crop, a thing they can eat today.

So we're working on a schematic with the help from Africa Rising communication team, from IITA, and trying to show how there might be different sustainable intensification pathways for different farmer groups. One of them where farmers really need to rehabilitate part of their farm, suppose they have a hectare, so a third of it can go into this ground nut/pigeon pea, and then that's moved around, and followed by maize bean intercrop, to make sure you're addressing human nutrition needs, and improved value crops to sell.

So, the final slide. What I want to focus here is that there may be different pathways for different groups. Entrepreneur farmers, this lady here, they link into markets. She might be able to start in invest in the latest soy bean and pigeon pea varieties, inoculants of the soy bean, advanced post-harvest processing. And it's fairly straightforward in terms of intensified but sustainable production system. This is a pathway that has had occurred elsewhere. Soy bean has been pretty rapidly adopted in some places.

But what about farmers that maybe with, where labor on farms, how can they rehabilitate the soil? Because they started on a degraded site it's very hard to get out of that cycle of poverty as we talked about. And so we're seeing through education, because -- personally I think that one of the reasons that green manures and some of these perennial pulse options have not taken off as fast we like is because we're working on them -- we have to acknowledge for 20 years or so -- is because in fact they need some education.

You need to have access to the seed, but also need to have far more information. Currently there's no recommendation about ratooning pigeon pea, for example. So we can start working on that with our extension colleagues, and eventually help all farmers get into more sustainable intensification. Thanks very much. And in addition to all the co-authors, from IITA and MSU on this talk, I also want to acknowledge the long term relationships and support we've had from many donors and amazing farmers, as well as academic colleagues from around the world. Thanks very much.

I think I wanted to just end with this top takeaways both from Geoff and I that we want to increase food security. I think we're all in agreement here there needs to be ways to regenerate productive capacity of soil. But these won't get adopted unless they fit very closely with farmer's needs, and Geoff and I are completely in sync with this. I think that's the general feeling now. But one of the ways I feel is through crop diversification with multipurpose pulses, whether you're supporting a more organic or conservation agriculture approach, or sustainable intensification/integrated nutrient management, whichever approach, we do all agree that we need more diverse soil cover.

And one of the more practical ways – the first step – whatever future steps you might want to do, like Faidherbia albida which takes decades but eventually would be...one that's called winter thorn, some evergreen agriculture approaches are very important, but I think the first steps involve multipurpose pulses such as pigeon pea and common bean, but that's my experience. And I look forward to discussion.

Questions and Answers

Julie MacCartee: Great. Thanks so much Geoff and Sieg. We're thrilled you were able to join us from your remote locations. And we could hear you both well. And we greatly appreciated your presentations. As you can see, we've had a lot of chatting going on in the chat box. Thank you to all of our participants for chatting and answering each other's questions and asking a lot of great questions.

As a reminder, this webinar is being recorded, and we will make sure that you have the PowerPoint, the recording, a transcript of all this chatter in the chat box. Everything you need will be sent to you via email. In a week or so after this seminar. So keep an eye out for that. And we'll go ahead and spend about 30 minutes on Q&A with our presenters. So we've had a lot of questions come in for both of you. And I'm going to kind of synthesize some – pick some back and forth.

But one question that came in both during Geoff's presentation and Sieg's presentation was a desire to know a little more about the relationship between soil and nutrients getting into human diets. Claire Baker, Savannah Henderson, both asked about how we can improve bioavailability of nutrients in soils by working through some of these improved soil based interventions. And I was hoping that one or both of you could speak to that question. And so shall we start with Geoff? If you have any comments on that one.

Geoffrey Heinrich: Yeah. I'm not really an expert on that. And so I'm looking more to Sieg to see what she has to say. I mean I think there are some important connections. One of them often is zinc. If zinc is deficient in the soil, then it's often deficient in the food, and that has a lot to do with people's sort of immune systems and resilience. But yeah. I'm hesitant to say more than that at this point. Going to hand it over to Sieg.

Sieglinde Snapp: Okay, well, if I get you right, in fact, as I mentioned, up north, we've worked some with Rachel Bezner Kerr in a hospital there…And there has been improvements in diversity of diet, and also child under five height and weight gain. So that's a system to check out. But yes, sometimes legumes – and now they've moved onto looking at sorghum and sweet potato and just even some African yams. So a huge range of diversification. And I think that's well proven that one of the most important things is just to have – a dietary diversity can really improve nutrient availability as well as some of these new, more iron fortified bean varieties, for example.

So I think diversification is really key here. Along with education. Because people are sick, they still can't translate their improved diet into -- health gains. So I think check out Rachel Bezner Kerr, Andy Jones, and some other people's work that are nutritionists. But we certainly are trying to collaborate on such efforts, and we think it's very important.

Julie MacCartee: Thank you to both of you. Excellent answers. We had – Dick Tinsley, who is an Agrilinks regular, asked a question wanting to delve a bit more into the labor requirements for farmers. And the fact that household decision making and labor can be a real constraint. And in a lot of cases, it's not a matter of whether a soil building technology works or not. But whether the farmers can realistically, labor-wise, adopt that technology. So, Sieg, we thought maybe you had done some studies, and could address that question.

Sieglinde Snapp: Certainly. And Geoff should come in here, too. CRS is very aware of this. So we keep examining the interactions with weeding -- a major labor constraint in Malawi in sub human tropics. And some of our drier areas work weeds are used a lot for fodder and it's not such an issue -- But so in terms of labor, it is difficult to get good data and understand this. So one of the areas we looked at is where female headed households – which are labor constrained, because you have one less adult in them. And which technologies they adopt, and which ones they're doing trying out things.

I saw in the chat people were surprised how women are innovating. I'm not at all surprised by that. I find particularly when you have technologies that are appropriate that women are very interested in, there is tremendous amount of innovation. And very, very concerned about, to – we have to work in collaboration to see which systems will, you know, reduce labor requirements. We may even have to work in certain areas where there's market linkages, and where education is done with herbicides, which is a classic way around the world that we reduce labor that may not get with everyone's worldview, but I think we have to definitely straight on address this issue of labor.

And in some ways intercrops are very effective. Pigeon pea can suppress a lot of weeds. We can look at some different striga suppressing because it causes a lot of long term problems. So we have an integrated approach, and this has been a top priority of Africa Rising at different sites around the world, and I think would be synthesizing some of those lessons, and we'd really like to keep this discussion going, because I think that's one main reason why some of the agroforestry systems haven't taken off, as we'd like to see them, as fast.

Maybe this farmer regeneration approach will work. Looking forward to learning more about that. Because when we plant seeds, and then uproot trees, as we've done with…it's just too much labor. So apparently we haven't seen adoption except for people who can afford, like choose to hire labor. So I think that those questions are spot on, and it's a work in progress, but we have to pay attention to it, absolutely true.

Julie MacCartee: Geoff, would you like to chime in?

Geoffrey Heinrich: Sure. Just make a couple of quick comments. I think Sieg put it nicely. But in terms of labor, some of the major requirements are for land preparation and for

weeding. Also, women's labor for sourcing firewood. With the green manure cover crops, you often get a weed reduction benefit. And the second thing I've seen in working with – is if you really can improve the organic matter in the soil, and improve the soil tilts, that you can often eliminate the need for the land preparation. As long as you've got a mulch on the soil, you don't have to chill all that soil, which is actually the way they do it here in Malawi. It's a massive amount of labor. But you can just plant directly, without tilling the soil. And that's a huge savings.

And then like systems that Sieg was talking about. Some of the benefits of generating fuel wood, also would be labor saving. I'll leave it there for now. Thanks. But I think it's a really important question, and it has to be considered every time.

Julie MacCartee: Wonderful. Thank you both. We had a couple of questions come in that we think Jerry would be best positioned to answer. One specifically for Jerry from Howard Davis. Back at the beginning, Jerry had mentioned some research on a $1.00 soil investment and a $5.00 return. So we'll let Jerry speak to where that research came from. And then also Elon Gilbert asks – are USAID and other donor projects effectively addressing soil and natural resources management issues in Malawi and Feed the Future projects in Malawi?

Jerry Glover: To address the first one on the five to one return on investment, the International Food Policy Research Institute publication, *The Global Cost of Land Degradation,* which I believe is listed as a 2016 publication, but it is available for downloading on their website. So if you Google 'Global Cost of Land Degradation IFPRI', it should come right up. I haven't looked into the details of how they arrived at that figure.

In terms of effectively addressing soil and natural resource management issues, specifically in Malawi through Feed the Future projects, well, I guess the key term there is effectively. I mean I'm very proud of the work that our research is leading to. Sieg is one of the partners on that work. We're seeing some great progress. In terms of developing solutions that produce impacts and results in terms of soil improvement, but also in terms of household livelihood.

So I mean I can't provide a clear cut answer. One can always do more. We should always be doing more. Looking for bigger and better impacts. But we certainly are addressing them in the projects through the Feed the Future initiative.

Julie MacCartee: Thank you, Jerry. Geoff, we had a question that came in during your presentation that I thought I would ask. From Glen Burnett. He asked – since some of these processes take longer, maybe five years, what do you do to create immediate benefits and still create long term change? What is that interplay between short term benefits, if any, to produce long term change in soils, and how do you market those short term benefits, versus the long term benefits to farmers?

Geoffrey Heinrich: Very good question. It's often an issue. We're trying to promote improved soil management technologies. But I think the system that Sieg is talking about – if you intercrop with pigeon pea, hopefully don't get as bad a reduction as some of our yields showed, but you shouldn't get a major reduction the first year. You might get maybe 80 percent. But after that your maize field should go up. And actually there's some good complementary analysis or experiments with maize pigeon pea systems in Mozambique.

But you get immediate cash benefit. Also, if you intercrop with some of the other legumes, you get a food benefit. For example, if you intercrop with lablab, you can get green leaf benefit for food. You can eat the green pods. And processing the dry bean takes a bit longer, but you also get food from that. So the key thing is to have some immediate benefits like that in terms of food or income. And then while the soil might take two, three years to really start seeing an improvement. Thanks.

Julie MacCartee: Thanks very much, Geoff. Sieg, we had a question that came in during your presentation. A couple of questions about phosphorus. Mike McGauhey asked – for doubled up legume systems, are there challenges of providing sufficient amounts of phosphorous to get optimal results? And Anna Elise Stratton also asked what about phosphorus? Is there significant impact on phosphorous bioavailability in phosphorus limited soils? Would canavalia be an appropriate addition to the system?

Sieglinde Snapp: I'm really pleased you ask that. Because I didn't get to touch on phosphorus, which is one of my favorite topics. So in fact pigeon pea and ground nut are well known in the scientific literature to be able to access sparingly soluble pools. What does that mean? What it means is that unlike nitrogen, which is highly available when you add this fertilizer, and about 50 percent efficient, the crop uses 50 percent of it, in terms of phosphorus, about 80 percent often gets locked up in soils. That's being generous. Often 90 percent.

So we're only talking about 10…sufficiency. So that past investment, whether manure or fertilizer, in phosphorus, we need to access that. And pigeon pea happens to produce a lot of organic acids…some papers in Science on this. Ground nut, too, we have literature that says in certain soil types plants that can access that phosphorus and recycle it. So we're not a zero sum game. We can actually use certain species, which are well known to be able to access some of this phosphorus.

Compost is also – has organic acids and can often access past phosphorus. That said, we need to make investments every now and then in phosphorus. Whether that's on a – once in ten years we invest in a massive amount of manure, or fertilizer, or once every year – I think the most important thing is that we then recycle it. So we know we have certain species that can cycle it. I'm sure there's

some green manures I'm not so familiar with that literature, but pigeon pea, when we've measured the phosphorus in the leaves, has a very high level.

So it needs it, but it also has ways to access it. And so this should not be overlooked as a way to biologically ameliorate and make the soil more productive through whatever investments are made by farmers, wherever fertilizer/compost that they can afford let's make sure that it's used in a very good way, and that does require more than something like maize that can grow for four months. We need something that can grow for ten months, two years, like pigeon pea, that can keep accessing that phosphorus and making it available for other crops like maize.

So compost and other things, and thank you for bringing this up. Yes, we're about integrated nutrient management. But compost takes a lot of labor. And fertilizers are very expensive. So let's get the biggest bang for our buck. Whatever compost and fertilizers farmers can afford, let's make sure these are used well and so we need nitrogen fixation, and we need accessing of the phosphorus, mining it, if you will, so that it's used rather than just locked up forever in the soil.

So, to do that, there's only certain species. In the north, they happen to be legumes that allow you to do that. And to do it in a significant way, you have to have a perennial or semi-perennial shrub or vine or even tree to do that, because it takes time to access it. So without those in the landscaping, we're really just throwing away a lot of fertilizer. So I think the combination of compost, fertilizer, and the right suite of legume options is important for our maize based systems to perform in a sustainable way. Thanks.

Julie MacCartee: Thanks so much, Sieg. We had a question that I think builds a little bit on what you were just saying about fertilizer being expensive and in some cases being wasted. And maybe we can pivot to Geoff to start answering on this question. A question about the relationship between fertilizer subsidies and all the practices you've been talking about today that build soil. Is fertilizer helping boost yields at the cost of soil health? Are subsidies of fertilizer potentially inhibiting some of these soil building practices that you're referencing? Do you have any comments on fertilizer subsidies and whether those should be promoted as part of a package?

Geoffrey Heinrich: Yeah. Thanks. Governments love to subsidize fertilizer. Actually, to some extent, you could say it's a good thing. You're maintaining fertility levels in the soil. That's an important public good. And I think when the World Bank removed – or what was it, back in the late '80s, early '90s, a lot of the fertilizer subsidies were removed, and crop yields in this part of the world crashed. So fertilizer in itself is not a bad thing. The problem is I think there's too much focus on seed and improved varieties of maize.

And we aren't making those investments in improving soil health overall. So some of the figures are quite stark. 40 percent of the fertilizer that's applied is lost just in rain and runoff. And probably other ways. Or the effectiveness of the fertilizer that's given out is much lower if the organic matter levels in the soil are low. So we're losing a lot of the potential benefit of those fertilizers, both from erosion, and from the lack of soil health. So there is a really valid argument to say actually whether you maintain the subsidies or not, we still need to do other investments to make those subsidies really pay off.

And actually so ICRAF and agroforestry – the evergreen agriculture partnership from – are making some inroads with COMESA to look at replacing some of the fertilizer subsidies with fertilizer trees. It's either faiderbia or glacidia. I think that's a good start. I think there are lots of other things that need to go along with it. But yes. I think there's much that needs to be done. Thank you.

Julie MacCartee: Thank you for your adept answers to these questions. We have about ten more minutes. So we'll ask you a few more along the way. We had an interesting question come in from James Brett Harrison, who wanted to know a bit more about the future of research. What further research regarding green manure and cover crops and/or nitrogen fixing legumes would you, the presenters, like to see done in Sub-Saharan Africa? Or, more generally, some of us here on the webinar are in positions to carry out that research, or actively designing said research, and would appreciate your advice.

Sieglinde Snapp: Maybe I can come in. So I want to point out that we found, when we were working on macuna and other green manures, and agroforestry in Malawi, some work done in Zimbabwe in 1920 that was published in *Zimbabwe Agriculture Journal* – so we had worked for a long time on green manures and agroforestry. And I'll very much support these efforts. But what we don't have is this third way, this middle – something that gives us food today. And even in the US, cover crop adoption has gone up, but mostly when it's used for grazing, or when people are paid.

So there has to be investment beyond fertilizer subsidies in green farmers to be able to rehabilitate their soils. And one of the straightforward ways would be if we had investment in types of crops that could be used for food. So whether it's teaching people how to use lab lab or makuna as a food source – can look at it from that way, reducing the pesticides, toxic chemicals in those seeds. At the same time, increasing the long duration of pigeon pea. Like I said, nobody has looked at it as to ratooning. Nobody in other words to cut it and let it come to a second year.

Nobody has seen how different varieties – I mean we recently did a bibliography that was on our website. If you Google perennial grains in Africa, you'll see that this idea of multipurpose crops that can go for several years hasn't been developed. There's been no green investment, no agronomy. A little bit. But

really pie in the sky type work. Hasn't been much on the ground agronomy to try and develop practical options – not just trees, but something that farmers can use now, such as grasses and vines and bushes that they can use for a couple years that produce grain for food, which people really need to invest in.

So I think there's been a lack of that. Also, understanding the interactions with weeds. It's come out today very little research has investigated tradeoffs in sustainable intensification labor requirements. I think we're moving towards more multidisciplinarity, but it's difficult sometimes to have enough funding to bring together a full team and to focus on research. Because we always rightly end up having to do development along the way.

So we need to see more partnerships, in my view, with NGOs and such, so they can be more the development, and then as academics, can support capacity building in Africa, and Latin America, and South Asia, so the people can do their own research on sustained intensification in support of their government to improve their policies and so on. So I think capacity building more generally in the so agro-ecology area is lacking and obviously having more options that are practical.

Because we have to admit that we have been there in terms of green manure. So I'm challenging everyone to take the next step. Thanks.

Geoffrey Heinrich: Yeah. I mean I'm in 100 percent support of what Sieg was just saying. There are so many different ways that you can manage green manure cover crop systems that it's really good to have some strong evidence in terms of what's effective. And actually in that process, I think it's really important we have farmer participation also, so would really get that perspective right from the beginning. But what Sieg was saying – we really need a middle way that's going to work well for the soil, but also really work well for farm households both in the short term and long term.

Another area where some research might be useful I think is in terms of policies and incentives that really will help with adoption. Yeah. And the last thing I'll comment is we're – it's great to be working with Sieg, here. But CRS started working with Africa Rising to look at some of these systems in a longer term way. And we'd like to do that in Malawi, too. But I think the connection between the research and development process, and participation of farmers, is crucial. Thanks.

Julie MacCartee: Thank you. I'm going to pass the microphone over to Jerry to ask a question to the presenters.

Jerry Glover: Thanks. Given the Paris meetings on climate change over the past week, and the fact you both have worked in different parts of the world on these issues for a couple of decades or more, I'd like to get your perspective on the feedbacks

between soil degradation or soil restoration and climate change. And of course what your sense is as we move forward, growing populations, greater land constraints, and so on. That's for both of you.

Geoffrey Heinrich: I'll take a first crack. So I think in the beginning of the presentation, I was saying, and it's worth emphasizing, that to avoid a food crisis, we really need to improve the soil. And I think that's a given. So investments there are not important, they're essential in helping us deal with the problems coming not just from climate change, but from an increasing population, the need to produce more food in situ.

The other thing is, if we do have climate change – so some areas will have more water, some will have less. But in either case, building up the soil organic matter and its capacity to absorb water and retain water is crucial, both to prevent flooding and make sure that water resources remain much more available. And there's a huge amount we can do. Actually, Mike McGahee sent me a note saying maybe we should be looking not only at the soils for productivity, but also for their capacity to efficiently manage water.

Maybe as crucial. I think that was a really important point. The last thing, in regard to climate change – I got some comments from Roland Bunch, and he was – he's done more calculations on this than I have. But if we can really improve the soil organic matter to a really good level, like four percent in the soil, that's almost the equivalent of having a forest in the terms of the amount of carbon it can sequester. It can sequester a very large amount of carbon. And I think I don't know the figures exactly, but I think the sentiment is certainly true.

Just a couple comments there. I'll hand over to Sieg.

Sieglinde Snapp: That's a great point, Geoff. Really, so great to be working with you again. I would also point out that adaptations to climate change that in agronomy we talk about instead of genetics by environment by management to increase yield we talk about to improve performance, we need to understand options by context. And so we need to make sure investments are made in education so the adaptation capacity of the farmers is increased in rural communities to be able to cope with climate change.

Because it may take different forms in different places, whether it's an increase in weeds, this is probably one of the biggest problems facing people that aren't thought about and the intense storms, and droughts, both are occurring more and more frequently. So adaptation is very important. So investment in education, in helping household community level things, just kind of…developments so that people have resilience networks such as grain storage, and have other different range of livelihoods.

So on the crop level, I think crop diversification. Although many people would agree…policies still are promoting more and more sharecropping and

consolidating land, as we're seeing in Rwanda. So we need to keep providing evidence, and our advantage as scientists is to try and find data to try and remind people of the benefits for resilience in terms of just diversification of cropping and animal options, rather than moving -- for smaller farmers I think it's very dangerous to move towards relying on just a few crops, and then assume the markets are perfect, and people will be able to buy and support their way out of extreme situations.

So, we still need to have local resilience and policies that support education and local markets, not just market value chains. So a holistic approach I think is just vital in this rapidly changing world. And an education-focused one.

Julie MacCartee: All right. Well, we have reached our official end time at the top of the hour. I don't want to keep anyone too much longer. So I'm going to go ahead and wrap up, and say an extremely grateful thank you to our two presenters for joining us remotely and for giving some really excellent presentations and answering as many questions as you could.