Watershed Academy Webcast

Improve Water Quality by Using Cover Crops and Other Conservation Practices

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Slide: Improve Water Quality by Using Cover Crops and Other Conservation Practices

Anne Weinberg
Good afternoon, and welcome to today's webcast titled Improve Water Quality by Using Cover Crops and Other Conservation Systems. This webcast is sponsored by EPA's Watershed Academy and EPA's Office of Wetlands, Oceans, and Watersheds, also known as OWOW. I am Anne Weinberg with EPA's Watershed Academy, and I will be moderating today's webcast along with Erika Larsen, an EPA ORISE intern in EPA's Non-point Source Control Branch. Thank you all for joining us today.

Slide: Webcast Logistics

We'll start by going over a few housekeeping items. First, I'd like to briefly summarize some of the features of today's webcast. We hope you're going to have a lot of questions, and we encourage you to type your questions in the "Questions" box in the control panel and click "Send." If you're control panel is not showing, simply click on the small orange box with the white arrow to expand it. If you have any problems viewing the broadcast or hearing it, just let us know in the "Question" box, and we will post an answer in that same box. This webcast will be archived for later viewing on EPA's Watershed Academy webcast page at www.epa.gov/watershedwebcasts. Also, a PDF copy of the slides is posted on the Watershed Academy webcast page if you want to print that out. Participants are eligible to receive a certificate for their attendance at the end of the webcast, and directions for obtaining this certificate will be presented at the conclusion of the presentations. The materials in this webcast have been reviewed by US EPA staff for technical accuracy. However, the views of the speakers and the speakers' organizations are their own and do not necessarily reflect those of the US EPA. The mention of commercial enterprises, products, or publications does not mean that US EPA endorses them.

Slide: Overview of Today's Webcast

So now that we have completed the discussion of housekeeping items, let's kick off today's webcast. The webcast will be introducing nutrient cycling and the importance of soil health in the agricultural landscape. The webcast will discuss how conservation practices such as cover crops can help to improve soil nutrient retention and reduce nutrient losses. Our speakers will

explain common cover crop types and how a few of these are currently used by farmers in the Midwest. Our take-home point today is that conservation systems like cover crops can be used to provide environmental benefits in watersheds across the country.

Without further delay, let me introduce our speakers. Our first speaker is Dan Towery. He is the president of Ag Conservation Solutions and has operated his crop consulting business from Lafayette, Indiana, since 2005. Dan focuses on continuous no-till cover crops, nutrient management, and soil health in the Midwest. Prior to this, he worked for NRCS -- Natural Resources Conservation Service – for 26 years, including serving as an agronomist for the Conservation Technology Information Center for ten years. Also, as Illinois's state agronomist, district conservationist in two counties, and also as a soil scientist. He also ran a fertilizer plant in Illinois. Dan is currently president of the Soil and Water Conservation Society.

Our next speaker will be Dr. Hans Kok. I'm going to refer to him as Hans Kok. He is the coordinator for the Indiana Conservation Cropping Systems Initiative, which is a program sponsored by the Indiana Conservation Partnership. This program promotes a continuous systematic approach to production agriculture, resulting in improved profitability, soil quality, and the water quality in Indiana crop land. Prior to this, Hans was an associate professor at both Washington State University and the University of Idaho, covering extension programming for conservation tillage and bioenergy. He worked as a conservation tillage specialist for Monsanto and was the state extension specialist for soil and water conservation at Kansas State University. He earned a BS and MS degrees from the agriculture university in the Netherlands and a Ph.D. from the University of Idaho.

So we are very excited about these two speakers and look forward to their remarks. As a final note, we will try to answer as many questions as possible throughout this webcast. However, due to the high number of participants, not all questions may be answered. So please feel free to contact the speakers after the webcast. The speakers' contact information is on one of our final slides and on the "Additional Resources" document that's posted on our website at www.epa.gov/watershedwebcasts. With that, we'll begin our webcast. I will now turn to Dan Towery, president of Ag Conservation Solutions. The floor is yours – take it away, Dan.

Slide: Water Quality, Cover Crops & Conservation

Dan Towery
Okay. So a little background that I'm going to provide, and then we'll talk about some soil basics, some cover crop basics, because this is – the cover crops are only part of this system. Go ahead.

Anne Weinberg
Oh my goodness.

Slide: Part 1: Background

Dan Towery
There we go. It seems to be working now. So again, cover crops are certainly not a new practice, but we're looking at them in an entirely different way.

Slide: These are not Your Grandfather's Cover crops

One of the phrases that we often throw out is that these are not your grandfather's cover crops. Well, some of them are. But it's the whole idea of keeping something growing every day. Today it's cold out, but the sun is shining. When the temperatures get above 50 degrees, we can have green growth occurring. Basically, that's capturing sunlight and turning it into carbon. So we're going to talk about some generalities. I don't know where everybody is located. Most of our talk is going to focus in the Midwest, the Corn Belt, but the principles still apply no matter where you're at in the country. One of the things that Hans and I will be presenting is the whole prospect of balance. By that, I mean a balance between economically viable and environmentally responsible. This is why farmers are interested in cover crops. In the past five years, I have been amazed at the adoption level here in the Midwest. It's certainly part of a little buzz.

Slide: A Little History

But I want to go back and take a look at some of the little history, if you will, of how we got here. Cover crops, like I said, are not new. Before commercial fertilizer, cover crops, manure, they were plowed down and used as green manure, if you will, a natural fertilizer. This was basically about the time after World War II is when commercial fertilizers came in. Cover crops have always been used, or many times were used, on either sandy fields or steep areas to reduce soil erosion, and that is why a lot of people think of cover crops as basically to temporarily reduce soil erosion. Our thinking has changed on that, and we'll be talking quite a bit about that later on.

Slide: 1950 – 1990

So let's look at what's happened, 1950 – okay. Basically, we saw an intensification of the crop rotations. Intensive tillage was used. And very slowly – and I mean, it was slowly -- we started to degrade the soils. Organic matter was reduced because each time we stir the soil, it oxidizes some of the organic matter. The C02 goes up into the atmosphere. We lose the aggregate stability. We'll go into that in a little bit more detail later on, but it's about what holds the soil together. We saw an increase in compaction. And with this combination of decrease in organic matter, aggregate stability, and increasing compaction, the net result was an increase in runoff.

Slide: 1980 - present

From 1980 on – and again, these are generalities we're talking about – we saw a decrease in the amount of moldboard plowing. Farmers were adopting reduced tillage systems, using the tillage system, but multiple tillage trips. And although this helped somewhat reduce soil erosion, we were still oxidizing organic matter. Cover crops were used in the South at this time, but typically what we saw was that they would be tilled very early spring, like early March. So although there was some benefit from reducing soil erosion, the benefits that we're looking for now were not derived. No-till acres started to increase, but we're still at – even today – a very low percentage in continuous no-till. And that is kind of considered the ultimate as far as increasing organic matter.

Slide: Last 10 years

But let's take a look at what's happened in the last ten years because we had this no-till adoption, but then we saw cover crops also increased. Percentage-wise it's still fairly low, but as a percent increase, we've seen a phenomenal growth. It increased in the last ten years in the Great Plains. That may seem a little bit of a paradox that it increased out there, but remember, we're talking areas that add winter wheat in the crop rotation. Some of them, it was a wheat fallow. They were able to intensify the crop rotation, put a more diversified crop rotation out there, and the farmers made money, and the soil actually improved. In the past five years, we've seen an increase in cover crop adoption in the Midwest, the East, and the South. Still fairly low on a percentage-wise, but definitely on the upswing.

Slide: Yields continue to increase but soils have slowly degraded

So our yields continued to increase. This seems like a paradox. Our soils have slowly degraded, but yet the yields have increased. Well, that's due to several things that have kind of masked, if you will, some of what's happened to the soil. We've got improved genetics. This continues to help with the yield increases. I mean, they just get, it seems like, better and better every year. We have improved and larger machinery, the tractors, the planters, sprayers, the combines, commercial fertilizer usage, biotechnology, and fewer but larger farms. Other things that we have are things like GPS and auto steer. We can vary the rate of almost all inputs, seed, nitrogen, phosphorus, potassium, lime. We can do all of that, and this combination has resulted in our yield increase. But – but our soil has not functioned at the highest level of what it's capable of, of what it used to be when we used more of a crop rotation.

Slide: Degraded soil

So this chart kind of shows what – again, with the good aggregate stability, the water can infiltrate through the soil, whereas if we have intensive tillage occurring, the soil seals over, the aggregates break down, and we increase the amount of runoff. Obviously, the amount of runoff is somewhat related to the soil erosion. That's that very top, that top half inch that it's so important because that is where – does the water infiltrate into the soil, or does it run off?

Slide: Cropland – Water Quality

From crop land and water quality, we've got really three main issues that we're looking at: the sedimentation from soil erosion, nitrogen which is lost with the water, and then phosphorus. And there are actually two sources. Most of the phosphorus that is lost is attached to the clay particle, and then there's a certain amount of dissolved phosphorus. This is – when I was in school, we didn't talk about dissolved phosphorus.

Slide: Soil Properties

But it's – it can be an issue in some watersheds. You know, as we look at the soil properties, the physical and chemical, we've done a pretty good job of understanding those. But in the process, the biological component has been pretty well ignored. We still don't know exactly how it operates, but we know that it is extremely important. And by using cover crops, by not tilling the soil, we can change the soil biology. And that's going to have a lot of benefits that we'll get into a little bit later.

Slide: The Hidden Half of Agriculture

Many times when we talk to growers it's – they want to look at plant health and what's happening above ground. And we stress what's happening below ground is as important, if not more important, for that crop because, remember, for farmers to use these kind of systems, they have to be economically viable. So it's that combination of what's happening underground as well as above ground.

Slide: Fertilizer Management – Old School

Fertilizer management, I worked for a fertilizer company. This was back in about 1980. At that time, basically, nitrogen was looked at as cheap insurance. Don't be short. This was a lot of the farmers' attitude. You didn't want to be short of nitrogen. On phosphorus, basically, even if you had fairly high phosphorus soil test, it was like putting money in the bank.

Slide: Nitrogen Losses in Corn

That has changed, however. If we look at nitrogen, we have a very leaky system. That is just inherent, and only about 40 to 60 percent of the nitrogen actually ends up as grain. That doesn't mean that the rest of it is lost. Part of it may be, either carried in the water down through the tile or denitrified and up into the atmosphere. But most of the leeching – and that's going to be most of our focus here because that's what's getting into our water bodies – occurs during the fall and early spring months, when the soil is fallow. So what we're doing with the cover crops is minimizing that fallow period and having something actually growing.

Slide: Most Cropland Soils are Leaky

Soil texture and rainfall affect how leaky. So again, it's going to leak. We can't stop that. We need tile to lower the water table so that we can be timely in raising the crops. But the soil texture and the rainfall, especially if we have above normal rainfall, then we are going to lose some of that nitrogen. And the more the rainfall, again, if you look in the Midwest last spring, we had very high rainfall amounts. We had very high nitrogen loss occurring during those events. Now, that's not to say that we can't do anything about it because it's back to the management that decides how much is, in fact, lost.

Slide: Timing of N Application Graph

This is kind of a busy graph. It's looking at the timing of nitrogen application. We know that, for the most part, corn needs the nitrogen about castling time. So typically, here in the Midwest, that's early July, late June, early July. It needs some early on, but not very much, but it needs to be a form that is readily available. So if we put on fall nitrogen, basically, if we get normal rainfall, soil temperatures are below 50 degrees, we're not going to lose too much nitrogen. If we get a very wet spring like we had last year, then we have the potential to lose quite a bit. The cover crops, as you can see with the – in November, we're going to scavenge some of that nitrogen with the cover crop. In the spring we're going to scavenge more. And again, the amount scavenged is directly related to the amount of biomass produced by the cover crop. So it's all about improving our efficiency. Now, that said, one of the reasons growers put nitrogen on in the fall is because they're quite concerned, if we have a wet June, that they can't – they won't have – won't be able to get out into the fields to put on their nitrogen. The technology has changed quite a bit. You know, it's a matter of basically gearing up, I think, in order to put the

nitrogen on in the side dress form. What we like to see is spoon feeding of the nitrogen, some with the planter, some with the herbicide, and then the balance side dressed. That way you can fine tune, depending on weather conditions, how much nitrogen you're putting on and with the idea that you're putting on what the crop actually needs. So the cover crop scavenges the nitrogen, keeps it in the soil profile, and then, depending on the cover crop, releases that nitrogen back, either that year or the following year.

Slide: Cover Crops & Nitrate Loss

Did a look at what some of the literature shows regarding nitrate leeching from winter cover crops. Anywhere from a 30 to 81 percent reduction in nitrogen loss with the use of the cover crop. Factors affecting that nitrogen loss, the rainfall amount and the timing which occurred, soil type, the amount of nitrogen in the soil profile – because remember, if we're scavenging nitrogen, we're not making nitrogen unless we're using the legume. So the nitrogen has to be in that soil profile for it to capture. So it's all kind of interrelated, and this is the learning curve, I guess, that growers, consultants are going through right now, is understanding the dynamics of this system.

Slide: Iowa Total Nitrate Loss 2002-2008

Another example that was taken out of Iowa over a seven-year period, basically a 56 percent reduction in the amount of nitrogen lost. One of the things that, as you look through literature, it's – you know, there's a lot of variability out there, and we'll go into some of those things that cause that variability a little bit later on. But we know it's a good thing. We know we're going to reduce nitrogen losses. Sometimes things happen, though, that are outside our control.

Slide: Fertilizer Management - Now

So currently, I suspect that all of you have heard of the four Rs. That's being promoted as, for the nitrogen management, it's the right source, the right time, the right amount, and the right place. And they are spot on. However, the right amount, the right time, all these are interrelated, but they depend on where you're at, what soil type, what management decisions you're looking at. And that's where the nitty-gritty comes in, is figuring out what is the right source, time, amount, and place on this field versus a field cross the road versus a field ten miles away.

Slide: Fall Applied Manure & Cover Crops

Let's take a look at cover crops and manure. Penn State has done some very good work with this. Basically, what we found is the nitrogen that's recovered – so again, we're putting the manure down, usually injecting it into the soil, and without a cover crop, typically only 15 to 20 percent of that N is recovered for the next cash crop. Whereas, if we add a cover crop, we can go to 40 to 50 percent of that nitrogen is recovered and put back into the corn crop. Basically, it amounts to some of the nitrogen is in a form that is not immediately available, and this is one of the things that's a little bit hard because we've got to start looking at nitrogen not from just a yearly standpoint, but looking at it from a multi-year.

Slide: Nitrogen Management

So nitrogen management is all about risk and how to reduce it. Cover crops, if managed properly, can scavenge the nitrogen in the soil. Or, actually, we can fix nitrogen by utilizing legumes. However, one has to remember that, again, the biomass in the legume will dictate how much nitrogen is, in fact, going to be available. So put yourself in a grower's perspective. It's about risk and, you know, trying to figure out how to best manage without having a yield reduction.

Slide: Cover Crop Reduces Total P Losses

Let's take a quick look at phosphorus losses. Again, what we found was the cover crops had a 54 to 92 percent reduction in the total phosphorus losses, very significant. The soluble phosphorus varied from a plus eight to 50 percent reduction. I was a little concerned when I came across this increase in soluble P, but what happens is, if we have a rainfall – major rainfall event right at the time when the cover crop residue is decomposing, then we can see an increase in the P losses at that time. But overall, again, very significant reduction in total P that's being reduced. So with that, we have time to take a few questions.

Slide: Questions

Anne Weinberg
Okay. Thank you, Dan Towery, for your excellent presentation. We're going to now have time for some questions from our audience. Erika Larsen is going to pose some of those questions.

Erika Larsen
Okay, great. Thanks, Anne, and thanks, Dan, for that background information. We have one question that came up. It's regionally specific about Lake Michigan and the climate there. The listener here asks: The farmers along Lake Michigan, north of Milwaukee, say cover crops don't really work because it's too humid. Do you have any comments you can add to that, Dan, on your experience?

Dan Towery
Yeah, and it's – I'm not sure that it's humid. Temperature is a big factor. As we move north, the window of opportunity becomes smaller and smaller. We're talking about cool season cover crops, but they still need warmth in order to get growth. All I can tell you is I've been to Quebec, I've been to Ontario. They are using cover crops. The management has to change. Hans is going to talk about some of those seeding techniques that these folks are using. Again, these are not your grandfather's cover crops. We can't wait until harvest is done in the northern climates and expect to seed the cover crops. So I think, before we're done, we're going to answer that question for you. And the answer, bottom line, is yes, they can.

Erika Larsen
Okay, thanks. Great. We have a related question here about temperature affecting nutrient sequestration by the biomass: How does temperature affect nutrient sequestration by the biomass of the cover crops? Can you elaborate on that a little more, Dan?

Dan Towery
Well, yeah. It's a matter of if your plant – let's take two examples, cereal rye or annual ryegrass. Both are cool season crops. Both of them are nitrogen scavengers. But they are going to have a lot more growth when the temperatures are above, say, 60 degrees than if the temperatures are only in the mid-40s. So we're going to have more biomass produced, and assuming that there's nitrogen in the soil profile, then they're going to take that up through the root system and turn that into a green vegetation. So it's just a – it's a constant balancing act. Some years are better than others, and you've got to take that into consideration. It's -- year in and year out, it's going to work, but the degree that it works will vary, again, depending on environmental conditions.

Erika Larsen
Okay, thanks. And I'll ask one more question for this section of the presentation, and it's: How does larger equipment improve yield? You talked about this a little bit, Dan, but if you can add my comments here.

Dan Towery
Well, yeah. It's -- you know, there's only a certain number of field days in the spring and in the fall to get work done. Larger equipment – and again, there's pluses and minuses – but the larger equipment allows to cover more acres in a shorter period of time. So hopefully, you're not out there under wet conditions, compacting the soil, causing other problems. Modern combines, they spit out very little waste grain because they've got them so fine-tuned. They've got systems where they're automated, and, in fact, one of the things that is in the works and probably will be out in the very near future is a grain cart pulled by a tractor without a driver. So again, all of these are about efficiencies. So do you have to be a big farmer to have high yields? Absolutely not, but we know there are fewer and fewer farmers and yet yields keep going up. And part of that is through the equipment that's available to the farmers to get in, get crops planted, get them sprayed, get them harvested.

Anne Weinberg
Okay. Thank you, Dan Towery, for those excellent answers. A lot of nuances in all this business here, so I appreciate you sharing all of that insight. We'll now turn it over to our next speaker, Dr. Hans Kok, who is coordinator of the Indiana Conservation Cropping Systems, to discuss some of the soil basics.

Hans Kok
Good afternoon, Anne. Can we try to give control over to us again on the slides, please?

Anne Weinberg
Okay. We're trying.

Hans Kok
Thank you. It's working.

Anne Weinberg
Great. Thank you.

Slide: Part 2: Soil Basics

Hans Kok
All right. Dan gave you a little bit of a background on what is happening with losses of sediment and nutrients. I'd like to go back to some of the basics that it's all based on. And the first thing we're going to do is talk about soils a little bit. And I hope some of you don't feel like you're going back to college, because that's basically the level we're going back into.

Slide: Graph - Soil is made of

If you look at soil, a soil is basically made up of mineral particles, air, and water, which of course are in the pores that are in the soil, the open areas. And then there's organic matter. And five percent organic matter is pretty optimistic for most soils in this nation. Most of our agricultural land is probably more in the one or two percent, or sometimes even lower. And then we can divvy up that organic matter in things like humus, living roots and organisms that actually live in the soil. So it's a very easy thing to think of. Soil is made up half of something, half of nothing. And that half of something is very important because that is where the air and water is moving around that provide nutrients to our crops or our cover crops.

Slide: Soil Particles

If we can split those fractions out and put them in a jar, the sand would sink to the bottom because that's the heaviest, followed by the silt, the fine particles. And the very fine clay particles would lay on top of that. Water would be on top of that. Organic matter would flow to the top, and the air in the soil would be in the very top of the jar. And like Dan said, we know quite a bit about the (inaudible), about the sand, silt, and clay. We know quite a bit about water movement in soils. We don't know near as much as what's happening in the organic matter. And that's got us in trouble.

Slide: Photo 1

When the settlers arrived in the Americas, they found enormous areas of lush forests,

Slide: Photo 2

and they also found vast prairies across the continent.

Slide: Photo 3

And they brought the latest technology with them that they mainly brought in from Europe, the moldboard plow. The trees were removed and the soil was plowed. The prairies were plowed up directly with the moldboard plow. And for a while, things were very well. Yields were enormous. They were very high compared to what they were used to on the East Coast and what we were used to in Europe. And yields of ten bushels to the acre of winter wheat were just unheard of. That was a new, new record for those guys. And to put it in perspective, right now we get anywhere between 50 and 100 bushels of wheat on those same acres.

Slide: Photo 4

But soon after they did all that - they took down the forest and they plowed up some of the prairie - trouble started. And as we all know, we had serious wind erosion in the Great Plains. This is a picture from the 1930s in Garden City, Kansas.

Slide: Photo 5

But even out East or in the Midwestern parts, we had some serious trouble. This is a picture of central Indiana in the 1930s. The trees were removed. The fields were worked with tillage implements, and the farmers started farming those slopes. And in no time, they had horrendous erosion, to the point where counties in Indiana lost over half their population because people had to leave because they couldn't make a living farming these counties anymore.

Slide: Photo 6

So what actually happened? This is a sample I took a number of years ago in an undisturbed native soil on your right and then, on your left, a tilled field right next to it. This is the same soil type. These samples were taken within 20, 30 feet from each other, and you see a marked difference in what happened to those two soils. So how did we get from this black stuff that came out of the prairie and came out of the forest? How did we get to this sticky yellow clay?

Slide: Soil Organic Matter Timeline

And the big factor that impacted all that was the loss of soil organic matter, as this graph depicts. On the left side, you see the percent organic matter in the soil. On the bottom line, you see a timeline. And this is not just a funny illustration. This is actual data from the Morrow plots on the campus of the University of Illinois in Champaign, Illinois. And you can see that in 1850, when they started working those plots, they had about four percent organic matter. That went down, and today we are under one and a half percent organic matter in these soils. That has a dramatic impact on how that soil actually works. But how did we lose that organic matter?

Slide: Tillage effects on Soil Biology

If we look at the tillage that the farmers performed and the effect it has on soil biology, it's very dramatic. Intensive tillage results in soils that are dominated by bacteria. Normally, we have soils that have a lot of different organisms growing in it. But if we do tillage, we actually beat air or oxygen into the soil, and it burns off this organic matter. The organic matter dissolves, it comes off the top as C02, and water, of course, comes out of that. And in that process, the nitrogen and other minerals that are attached to this organic matter are released, which is the fertility the farmers found so good to work with, especially on the prairies. Every time they plowed, a lot of nitrogen was mineralized from that organic matter that had been accumulated over thousands of years, and that was their fertility. But in the process, they changed the soil biology dramatically. So now we have soils that are dominated by bacteria. Those bacteria live in the very thin water films around our soil particles, and they are not very good about keeping soil particles together because they're basically attached to one soil particle. They do not reach out to surrounding soil particles. And as a result, after years of tillage, our soils changed. They sealed when it rains, which increases the runoff, and it causes more compaction. And that is something I have a very hard time convincing farmers of, that tillage actually causes

compaction, because a lot of farmers will till their fields to alleviate compaction. But as we alleviate the compaction and do tillage, we deteriorate our soil, creating more compaction. So now we need more tillage to get rid of the compaction. So it's kind of a vicious cycle, an addiction, as you might say. Also, in the process of tilling the soils, we disturb soil pores, which makes it very hard for air and water movement to the plants and also for soil biology to move through those pores like they normally do.

Slide: No-till effects on Soil Biology

On the other hand, if we would leave our soils alone a lot more and go back to more of a natural situation where we don't do all that tillage, we get a soil that is dominated by fungi. Fungi are a very different animal or plant compared to bacteria in that they can actually grow rapidly away from soil particles, and they can move throughout the soil over quite long distances. And some of the exudates that come off those fungi will actually start binding soil particles together. They will help decompose residue, crop residues that are in those soils. But the main good thing of fungi, or molds, is that they can bind soil particles together quite well. They can compete with pathogens and actually make for some very interesting things happening in our soils. And one of those are the fungi that come out of those – or the hyphae that come out of those fungi. And they get a very complicated name. We call them mycorrhizae - and both in spelling and pronunciation, I don't know why, in academia, we have to come up with those tough names.

Slide: Hyphae expand effective rooting volume

But let me try to explain this to you. If you look at a little plant root, the brown thing you see on the left side of this slide, in a full tillage system, that little root only has access to water that is immediately surrounding that little root. And in that water are the nutrients that the plant needs to grow. If we reduce the amount of tillage we have in our system, we look at the picture on our right. Those mycorrhizae will actually grow into the root of your corn, soybean, or wheat plant, and they provide water and nutrients to that plant in exchange for sugars they get from the plant. So it's a symbiotic or beneficial relationship. So a plant in a system where there's fungi available in the soil would have a rooting zone that is much, much larger than just where the root can go. Those hyphae can grow far distances away from the plant, reach nutrients and water sources that the plant by itself could not reach. And this is why, in a very dry year like we had in 2012, no-till crops generally will stand up much longer to the droughts than in tilled fields because the plants basically have a much larger access to the water and nutrients in the soil.

Slide: Wheat Seedling Photo

To show you actually some pictures, the top picture shows you a thing that looks like a torpedo coming towards you, and all the little white wires coming off of that are basically those hyphae that have grown into this little root. The lower picture shows you a side view of that. So normally, the tiny little dark part you see, which is actually the root part, would only have access to a very tiny film of water around that. But since there are fungi in the soil now, this little root will have access to nutrients and water in the entire picture you see out there. So you see it makes a dramatic impact on how much fertilizer we would have to give a plant because, actually, this plant can take much more out of the soil than we do in our traditional systems.

Slide: Photo 7

They can be observed in the soil, as shown in this picture. For scale, you see a little bit of a measuring tape on your left side, and in the very center part of the picture, you see some plant roots in the soil. And there's a moldy, fuzzy, white substance around that, and that is exactly what we are looking for. These are the fungi in the soil that help with that process of getting the roots access to more water and nutrients and also helps us bind the soil particles. And this is something you would see in a natural vegetative situation like a forest or a prairie that has not been plowed. So I had farmers come in to my office, when I worked at Kansas State University, being very worried about their soils all getting moldy. But that is not an issue. That's actually a very, very good thing. That is where you want to be on those soils.

Slide: No-till - Soil Biology

The other thing that changes if we reduce the amount of tillage in our soils is the biology of earthworms. And we will see substantial increase in earthworms if our tillage diminishes. It might take a couple of years for earthworms to come back into our system, but as you can tell, earthworms make big burrows, and that improves the water infiltration in our soils. And earthworms eat enormous amounts of crop residue. And that is something we can actually observe in the field. And I wish I could show you a video today to show you what earthworms actually eat in crop residue, but they eat so much that some of our long-term, no-till farmers that have not done much disturbance of the soil for 20 or 30 years are complaining that even in a continuous corn rotation, which produces enormous amounts of crop residue, they do not have enough residue left in their fields.

Slide: Photo 8

Here's a picture of a particular worm, the nightcrawler, or lumbricus terrestris. They live in the same hole for over a decade, normally, and they go up to six foot deep in soil profiles. And they will pull all the residue that is around their hole. They will pull it towards the hole and build a thing we call a midden. And it's like a little shedding roof they build over their hole. And they will pull that residue, over the years, slowly into their hole and use it as food. But first, they build this little mountain. So as you walk through a farmer's field or any natural situation and you see a little clump of residue, dead plant material, laying in an area, if you carefully lift that up, more than likely there's going to be an earthworm burrow beneath that. And sometimes you even see parts of that residue sticking into the worm hole.

Slide: Photo 9

Here's a photograph of a worm hole going into the soil. This is at about three feet deep -- and I realize I had my tape measure upside down in this picture. I apologize for that. You see that dark channel that's right next to the tape measure going into the soil with some tiny little roots going into it. That's the next thing that earthworms bring to our cropping systems. As those earthworm burrows go deep into the soil, you see those roots follow those same burrows. And you see another burrow on the right. You see some dark parts left. The dark is caused by the excretion of the earthworm. As the earthworm eats the soil and goes through those burrows and excretes the soil again on the back end, it's mixed with organic matter from the residue that that earthworm eats. So you get a very fertile layer around these burrows in the soil.

Slide: Photo 10

Plant roots and cover crops really like those burrows, and they really want to grow in there. Here's a picture of a plant root -- this is more than likely a corn or soybean root – that has grown right through one of those earthworm burrows. And you see there is a dark layer in the middle of the picture that is around this root. That is the old earthworm channel site. And you see this root is going down through the earthworm channel and going down into the soil. This makes for easier, deeper rooting for the plants, better access to water, and much better access to nutrients. So plants really benefit from what the earthworms do in the soil. The earthworms are basically doing the tillage for the farmers.

Slide: Tillage results

So like Dan and I have both explained to you now, tillage results in soil that have more runoff, more erosion, more compaction, and more crusting. However, this degraded resource is really accepted as normal by most people. They figure that is the soil they have to work with, and that is what they were given.

Slide: Photo 11

What they don't realize, that doesn't have to be that way. Things can be very differently, and we are basically not farming our grandfather's cover crops, like Dan says. My statement is we're basically not farming our grandfather's soils, either, because we have really degraded those dramatically. The way that works, rains in the central part of the United States are very intense and have very large raindrops that bring enormous amounts of energy down to the soil. If you have a barren soil, as depicted in this picture, a raindrop will splash those soil particles around as it falls on to the soil, and those soil particles will land back on the soil surface, resulting in plugging up of root holes, worm holes, or any kind of little crack in the soil where normally the water would go into the soil. We call this the sealing of the soil surface, and it is very dramatic. It can happen in as little as an eighth of an inch of rain. When this seal dries up, we end up with a thing we call a crust.

Slide: Photo 12

And here's a picture of a crust that that's cut open with a knife, and you see there is a little plant – in this case, a soybean plant -- trying to come out from that crust. This crust can actually be so hard by the pounding by the raindrops that emerging crops cannot get through those, so major impacts both in water runoff and what happens to the crops growing there.

Slide: Photo 13

Now, if we had some more residue on that soil surface, crop residue or cover crops, then that would not happen. The raindrops would be splashing on this residue. The water could still go into the soil, and we would have a lot less runoff and erosion. This is very easily demonstrated by machines called rainfall simulators.

Slide: Rain simulator: splash erosion

This is one I ran here in Indiana on a field where we removed the residue on the left site and not on the right site. And that is really meant to demonstrate this splashing erosion I just

described to you. But look at the two jars that we collected from the bottom of this plot. And if I may amplify those pictures for you, you see there's a lot of muddy water that came off that bare plot, where we had very little residue. On the right-hand side, we had very little water come off, and it was a lot more clear. So we see this time and again, and I've done these demonstrations all over the United States and even abroad on a wide range of soils, anywhere from sandy soils to clay soils, flat soils, steep soils. The same thing happens. As little of a quarter inch of rain on a barren soil and the water will start running off and erosion will start on these soils.

Slide: Slate Test

Another way to look at the differences in soils is with a thing we call a slake test. On the left side is a sample that came out of a long-term, no-till field, and we just hang that in a little basket in a tube with water in it. Since there is a lot of aggregate stability because of the fungi that have developed in these soils and the earthworms that excrete in these soils, that aggregate will just hang in the water there for long periods of time. I've actually had them hang in my office for weeks. If you go to the right-hand side, if you do a lot of tillage on the soil, that soil does not have that strength. The bacteria cannot put those soil particles together like fungi can, and just submerging the soil in water will actually make it come apart and sink to the bottom of the cylinder. If you ask a farmer which soil he thinks he could drive on when it's a little wet in the field, it becomes very clear to them the soil on the left would do that for them, not the soil on the right.

Slide: Soil Health Testing

So other than looking at rain simulators and maybe submerging those particles in the soil, how can we test whether a soil is healthy or not? And there's some new tests on the market right now that we are all testing here in Indiana to see how they work. There's an earthfort test out of Oregon, where we actually look with a microscope how many fungi and bacteria and other critters we have in the soil. It's of course very expensive because they have to look at each sample through a microscope. There's some chemical analysis that can be done. Somebody figured out that the fatty acid content of the soil and the size of those fatty acids is related to what kind of soil microbiology we have in there, so they can run basically a gas chromatograph or a chemical test on there, telling you what quantity of which fatty acid is in the soil we can relate to the soil life. Cornell University does a mix of physical, biological, and chemical tests on the soil and then scores that soil for how healthy it is. And there's a fairly new method developed by the Ag Research Service of the USDA -- it's called the Solvita test, where they look at mineralizable nitrogen plus phosphorus and potash -- another form of testing how healthy that soil is, whether a lot of tillage was done on that, whether that soil was really under a no-till type system. We're only year one of comparing all these tests versus some other things we're checking in the soil, and the data is still a little overwhelming. We haven't found any clear relationships or not a clear winner of, hey, this test does a better job than other tests. Hopefully we can tell you more about that in about two or three years.

Slide: Soil Organic matter % Graph

So that organic matter that we lost in our soils, it is not necessarily an irreversible process. The green line indicates some farmers we work with who, for the last 20-some years, have been able to bring that organic matter content up quite a bit. And we think – actually, we know from

some examples – that we can actually bring that organic matter content probably back to where it used to be when the forests and prairies were first opened up for agriculture. So we can improve those soils again as long as we reduce the amount of tillage. The problem, however, is, like Dan mentioned before, only between five and ten percent of the acres in the United States are under a full no-till system. We have a lot of farmers that might no-till one crop – for instance, soybeans – but then they do tillage in front of beans.

Slide: No-till Corn in Indiana

In Indiana right now, about a quarter of our acres are in a full no-till system, where farmers do very little or no tillage at all throughout the year. But 75 percent of our acres still get some amount of tillage done during a crop cycle. So those soils are not necessarily improving.

Slide: Reduce Soil Disturbance!

What we're working on with farmers is, instead of going to a full no-till system, can we reduce the amount of tillage farmers are doing? And one of the promising systems there is a strip till system, where the farmer basically does tillage but only in very narrow strips in the soil where the corn and soybean will be planted. This works, of course, very well with row crops, but it may not necessarily work with crops like wheat or other crops that are small seeded. And these pictures here show you, actually, the interaction between a cover crop and tillage. On the left-hand side, you see the farmer killed the cover crop and then pulled his tillage implement in strips through the cover crop. On the right-hand side, the cover crop is still alive, and the farmer pulls his implement through it to make those strips and then later will kill the cover crop before he plants the next crop in there.

Slide: Diversity is the key

Diversity is really the key to get ourselves to become better. We can reduce the amount of tillage to help our soils heal, but we need more. We can go to mulch till, strip till, or hopefully to a no-till type situation, where we do very little tillage. But what else can we do? The crop rotations we have in the Midwest are not very diverse. We have farmers that grow continuous corn. We have examples of farmers who have only grown corn in fields for 15 years in a row. Most farmers probably do corn and soybeans and then back to corn. Some farmers may have wheat in there. And in other parts of the nation, we know that rotations are usually not very diverse, either. When I worked in the Pacific Northwest, it was usually winter wheat, spring wheat, and then maybe a bean, and then it was winter wheat, spring wheat again, so very limited. Cover crops, which is our next topic, can add diversity to these systems. And before we get into cover crops, I would like to give it back to Anne and Erika out there, and maybe we can answer some questions.

Slide: Questions

Anne Weinberg

Okay. Thank you, Hans, for that excellent presentation. We're now going to have time for questions from the audience, and Erika is going to pose some of those excellent questions we're having coming in.

Erika Larsen
Thanks, Anne. Hans, there's one question about the Indiana slide that you just had pulled up of cover crop and no-till acceptance. And the question is: The southern part of the state acceptance is very high. Why is that? If you could comment on that.

Hans Kok
Sure. I'd be glad to. It's called necessity. The southern part of Indiana is very steep, very rolling landscape with very thin top soils. If a farmer in the southern part of the state does not take care of its resource of the soil, that farmer is basically going to have rock and no opportunity to farm anymore. And I've seen this nationwide and even worldwide. Where agricultural land is not really prime and not really that good, farmers are very careful not to disturb their agricultural land and really take care of it. In that same slide, you probably noticed that the adoption in the northern part of the state was very low. Those soils are fairly heavy clay soils. They're very deep. They're fairly flat. The pressure on those farmers is not quite there to take care of the resource, and the fact that they have lost over half their organic matter is not really hitting home yet for the reasons Dan mentioned, that we have improved inputs in agriculture that can actually have our yields keep going up even though our resources have really degraded. So it's really the difference in landscape we're dealing with and the resource the farmer has available.

Erika Larsen
Okay, great. Thanks, Hans. We have a couple of questions on the effects of pesticides on soil biology, one specifically on the effect of glyphosate on soil biology or other pesticides and their effects on fungi.

Hans Kok
Sure. Of course, you heard in my resume I worked for Monsanto for seven years, so 90 percent of the audience is tuning out at this point to this answer. There have been over 90 studies done on the effect of glyphosate on earthworms alone. And yeah, if you put an earthworm in a jar of glyphosate, that's not good. Glyphosate is basically a mixture of an acid, like vinegar, with a soap to get it into the plant, like dishwasher detergent. So that is not a good environment for a plant -- or for an earthworm. If you look at the rates that glyphosate is put on the soil surface, it is so miniscule, even if you include all the breakdown products of the glyphosate. In those 90 studies, they found very, very little effect, if any, on the earthworms. Now, there are some other chemicals in agriculture we're a lot more worried about. One of those is a new group of seed treatments. It's called neonicotinoids, and preliminary studies from universities right now indicate that those may have a negative impact on some of the beneficial life organisms, especially insects, in the soil. And that could actually help the bad guys that we're trying to protect our crops from to be more prominent in our soil. So we may be doing something not quite right by taking out the good guys and letting the bad guys grow for us. So yes, I think we need to be vigilant about any chemical we use, whether it's fertilizer, whether it's an herbicide, whether it's an insecticide, a fungicide, whether that has an impact on our soil life and the microbiology that is in our soil, and whether that's negative or positive. That's a very good question.

Erica Larsen
Okay, great. Thanks. So we have a question about nitrogen losses to tiles by worm holes, earthworm holes. The listener asks: Can increased worm holes result in increased nutrient losses to tiles?

Hans Kok
Theoretically, that could happen, and one of the reasons we get this question a lot is that a test was developed where we blow smoke into a tile, and then we see, in a no-till field, we see the smoke come up everywhere in the field because all these earthworm holes have basically gone into the soil. And so actually the connection between the tile and the soil surface, theoretically, is a lot better. The thing people have to keep in mind, that those earthworm holes are not things we drilled with a drill. These were developed by earthworms, and they have this black layer around it that I just showed you, which is very absorbent area where a lot of nutrients can be actually cut off before they ever get to the tile drain. That said, we need to be careful in situations where we drain our soils that we need to make sure that we don't lose a lot of the water with potential nutrients in there over the winter months. And that is why a lot of farmers in this area are working with tile control structures and drainage control structures, where they try to stop the drainage water from leaving their fields in periods that they don't need to be dry, those fields, and they only let the water out in periods when the crop needs that extra rooting depth out there. Keep in mind that if we didn't have those extra earthworm holes, that water would run from the fields and just end up in the creek, stream, or ditch by surface runoff. And we still have a lot of farmers that are applying their nitrogen on the soil surface rather than knifing it into the soil like most of our no-till farmers are doing, where it is much more locked into the soil and a lot less available for runoff or percolation throughout the soil.

Erika Larsen
Thanks, Hans. And could you just elaborate – we have a question here: How does no tillage work?

Hans Kok
No tillage -- that is a whole webinar in itself, which I would entertain to give someday to you guys at EPA. But no-till, to put a very simply, means we are not going to do any tillage in the soil between the harvest of one crop and the planting of the next crop. Now, that is the blank, easy statement. Now, what is tillage? Actually, planting a crop with a planter, in itself, is a tillage operation because we open up the soil a little bit, we drop that seed in there, and then we close the soil again. When I worked in the Pacific Northwest, we have big chisel type pieces of equipment that basically work the soil, till the soil in the same process where they put crops into the soil. So in that case, we would not call that a pure no-till system. They call it direct seed system. The pass of a fertilizer machine going through the fields – and hopefully it is a machine that actually places the fertilizer under the soil surface – that, in itself, is a little bit of tillage. So what do you call a pure no-till system and what you do not call a pure no-till system is a discussion that probably will rage on for the next decades like it did for the past couple decades. But no-till basically means no tillage, especially not inverting tillage like moldboard plowing, disking, or chiseling, between the harvest of one crop and the next crop being put into the soil.

Erika Larsen
Okay. Thanks, Hans. We have time for one more question for this section, and it's about strip tillage: Does strip tillage harm the fungi, or is it a proportional sort of ratio, meaning the less tillage, the less harm?

Hans Kok
That is correct. The less tillage, the less harm. So what we're doing in a strip till system, normally, is that about one-third of the soil still gets very intensive tillage. So in that zone where the tillage occurs, we're not accumulating the benefits of not doing any tillage. And we may disturb some of the earthworms. We may still lose some organic matter in those strips. But if two-thirds of the fields do not get any tillage, in those areas, the benefits of increased organic matter, increased earthworm counts and stuff would really accumulate. Those systems also set themselves up for some traffic -- control traffic, we call that. If we put those strips in the same spot every year, so the tractor tires run in the same spot in the field every year, we can have zones that are actually never disturbed and zones that are slightly disturbed for our crop growth. So there are some variations in strip till that can work. The one reason a lot of farmers do not go to these no-till systems is that when you make the change from a soil that has been tilled for over a hundred years, and you quit the tillage, before the soil biology has really changed over, there are some very tough years the farmers have to go through. And in those tough years, the soil biology is not active, and these soils might be very cold in the springtime when it's all covered by crop residue. That's one reason why farmers do tillage in the spring often, to warm up those soils. After five or ten years, depending on what your soil type is and a number of conditions, in a full no-till system, the soil biology will be so active in these soils that we do not find those temperature differences under crop residue versus tilled soils anymore. So that is another reason farmers like to do those little strips of tillage still versus a complete no-till system. Like I said, there's a whole seminar we can spend on what the other reasons are, why farmers have trouble with switching systems.

Anne Weinberg
Okay. Thanks, Hans, for those excellent answers. We're now going to turn it back to Hans to discuss cover crop basics.

Slide: Part 3: Cover Crop Basics

Hans Kok
Thank you, Anne. Like we talked about just before we took a couple questions, one of the things we can enter into our systems are cover crops. And again, you're going to feel like -- very basic for some folks, and boring, and for other folks, this is going to go way too fast and be information overload. I apologize for that. But we have over 450 people online right now, so I don't know each of you personally, so I don't know at what level we need to talk here. I hope that comes out in the question and answer afterward.

Slide: What is a Cover Crop?

First question, then, is what is a cover crop? Dan gave you a little bit of insight in that already. I'd like to go back to some basics. But basically, what a cover crop is, it's something that grows between corn and soybean, usually between the corn and soybean, as in the corn is harvested, the cover crop is planted, and then the soybeans are planted. So it's usually after the harvest of those crops. However, sometimes we can put those cover crops when the corn or soybean are still in the field. And we are really pushing that envelope right now in how much earlier we can plant a crop in a commercial crop that we have growing in the field. We can use grasses, like annual ryegrass and cereal rye. Dan mentioned both of those – very different crop. Annual ryegrass is kind of like your lawn. Cereal rye is more like a wheat field. They're very different, very different management, very different growth habits. But somebody gave

them almost the same name. I don't know why that happened. We can use brassicas. Those are crops like turnips and radishes that are pretty popular. We can use legumes, like clovers and peas, and those can usually make their own nitrogen, if necessary. And then more and more popular are mixes of these cover crops. So we can actually accumulate the benefits of each of those individual cover crops in a field.

Slide: What can Cover Crops do?

So what can cover crops do for us? Well, they can do a number of things. Weed control -- I learned a long time ago that you can use any herbicide you want to, but the best weed control is a healthy, growing crop. So shading out of weeds is one function that cover crops can give us. The other one is they can take the nutrients away after our corn or soybeans come out of the field so they're no longer available for our weeds. In that process, cover crops can take those nutrients that are left over in the soil that would otherwise be lost. 2012 was a great example. We had enormous amounts of nitrogen left in the field because our corn yields were terrible here in the Midwest, yet the farmers had put fertilizer on the fields for normal yields. So cover crops were shown to take up enormous amount of leftover nitrogen out of the fields and carry it over to the next crop. Some of the legumes can produce nitrogen. This is very limited. The farther north we go, the harder that gets. So that's very limited, what we can do with that. The biomass we grow in these cover crops, especially if we pick cover crops that are good for haying and grazing, they can really provide for some feed for cattle. Of course, all this extra biomass on the soil surface gives us erosion protection, increases the amount of infiltration, like I showed you with that little rain simulator. The roots that go into the soil from those cover crops, as they run away, they leave little channels throughout the soil where we can hold water. And we can also increase the rooting depth for the next crop that comes in. The cover crops we usually pick are because of their strong, strong rooting system. They can go deeper and through tougher soil conditions than our commercial crops can, so they can basically open up the soil for rooting of our commercial crops. But in looking at cover crops, we should really ask ourselves the question, how many months do farmers use their soil? In a corn-soybean rotation, that is really, really limited on how long we use the soil. It's usually only about five months. All the other times in the year, we can keep that soil alive by catching the solar energy. Like Dan mentioned, the sun is shining today, not everywhere in the nation, but you still can get some solar energy out there.

Slide: 5 Months of Crops Graph

Seven months we normally don't use our soil. Now, realize there are some rotations that have winter wheat in them. There are some others that use the soil a larger part of the year. But if we look at your average corn-soybean rotation, we use the soil only about five months out of the year. Seven months out of the year, that soil is just lying there. The farmers are doing tillage or other ways to control weeds that normally would grow on there because Mother Nature doesn't like bare soil. Something has to be growing on there. So we have seven months of unused solar energy outside of a commercial corn or soybean crop. Granted, especially a year like this winter, we have quite a bit of frost and snow and ice on top of that soil. But on average, we can probably double the amount that something is growing in the field, use that solar energy, tie up some of this nitrogen that may be lost otherwise, and actually start helping to improve our soils. And this is all on top of doing less tillage, or this can even be done with tillage.

Slide: Shallow Groundwater Nitrate-N Concentration after beginning Cereal Rye Cover Crop

A great example is from the Chesapeake Bay, where, in the 1980s, they had a severe drought. And they were doing some testing on the cereal rye as a cover crop. They planted that cereal rye at the end of the drought in those fields that, just like in 2012, had an enormous amount of nitrogen left in there that was not taken up by the crop because of the drought. When they started using those cover crops, they noticed over the next couple of years that the – the next decades, actually – that the amount of nitrogen coming out of those farming systems went down dramatically. In a no-till system, that started out a little quicker. But even in the tilled systems, by the mid-90s they had a lot less nitrogen coming out of those systems. So cover crops were very effective about capturing this nitrogen.

Slide: Rye Total N Uptake for Three Planting Dates

And just to give you an illustration how they tested some of those things, other than measuring the actual nitrogen in the water, this is a test they did in '98 where they planted a cereal rye cover crop on October 1st, the blue line; October 15th, the red line; and then October 30th, the green line. And you can see the amount of nitrogen taken up as they measured throughout the whole winter. So for the cover crop that was planted on October 1st, if we look at our graph, we can see that, by March 15th there was 160 pounds of nitrogen taken up by that cover crop. Had we waited a month in planting that cover crop, to October 30th, we would have had only about 70 pounds of nitrogen into that cover crop. So a big difference in how early we plant the cover crops and what kind effect that actually has on our growth of the cover crop and the uptake of nitrogen.

Slide: Photo of Cover Crops

More typical, we see cover crops like this. This is what a lot of cover crops in the Midwest look like this year. This is, again, an example of cereal rye. It was put on after the soybeans were harvested in this field. It did not grow a lot, mainly because it turned very cold in October and it hasn't warmed up yet. So we have very, very little cover crops out there, but a lot of these cover crops have very deep rooting systems. We dug 17 holes all across Indiana to look at these cover crops, and we found that even a field like you're looking at in the slide right now will have roots to two or three feet deep underneath these cover crops.

Slide: Planting into Cereal Rye Cover Crop

The next phase, of course, is what do we do with the next crop? And you have this cover crop in the field, and this gentleman is just planting the cover crop right into that cereal rye and then will come back into the field very soon to kill it after that. Sometimes they use herbicide. Sometimes they use rollers to kill that cover crop and then plant their next crop in there.

Slide: What cover crop to use

So the question is, what cover crop can we use? We talked about having grasses out there, the cereal rye, the annual ryegrass. We can use oats, which is a crop that freezes out in the Midwest. Triticale is another one of those grasses that is very good for livestock for feed. And then a lot of farmers have used wheat for many years as a cover crop, but there are some disadvantages to wheat. It has a very shallow rooting system, it doesn't take up as much

nitrogen, and it can potentially carry some diseased into the next crop. The legumes we talked about, one thing people have to keep in mind, if you're going to use a legume and you want to actually produce nitrogen with it, you have to inoculate them. You have to get those bacteria started in the ground that actually start binding the nitrogen. If they're not available in the ground, those bacteria, it will take a long, long time for those to develop. Our most successful legume here in the Midwest is crimson clover. It's planted in the fall, it goes through the winter, and it grows a lot in the spring and produces nitrogen at that point. Austrian winter peas, which is grown in the West as a commercial crop, is used as a cover crop here, works well. And then probably some of the more popular ones are the brassicas, especially the oilseed radish. There's a lot of pictures of that thing drilling big holes in the ground and growing to enormous proportions but taking up nitrogen and alleviating a lot of compaction. If cattle is involved, canola, rape, or turnips is usually a better option. And there's a picture of a little turnip on the bottom of your page here. That is very good cattle feed, but, again they can take up quite a bit of nitrogen out of our soils. And then, like we discussed earlier, mixes of all of the above.

Slide: Model developed by the Midwest Cover Crop Council

I know this is a very busy slide. This is a model developed by the Midwest Cover Crop Council that helps you select what cover crop you should use. If you look at the top of the picture, you see we typed in the in the state of Ohio here as an example. We typed in Adams County, which is in southern Ohio, and then the model comes back with a calendar that runs from February, on the top, to February of the next year. And then, on the left column, it gives you all the options of cover crops that potentially could grow in that county, and even some mixes on the bottom out there. The green bars in the graph really indicate where it's best to plant a cover crop, what time of year that works. So you see, for instance, winter barley can be planted from late August to basically the middle of October. If we do the same simulation here for a northern county in Ohio – and I'll switch to that right now.

Slide: Henry County Example

This is Henry County in northern Ohio. You see those bars changed. And I'm going to go back to the first one now to show you what happened. Southern Ohio, northern Ohio – you see those bars get quite a bit shorter, so the window to plant those cover crops is narrowing dramatically. The other thing to keep in mind is that most of that time we have a crop growing in the field. So you look, for a northern Ohio county, you see there's very limited opportunity to actually put that cover crop in the field. We get into the yellow. That means it's risky. You could actually lose your crop through freezing. And then the red bars you see in the bottom are indicating that some of our legumes like clovers can actually be frost seeded, we call it, this time of year. You put them in the cold or frozen soil, and they'll come up as the soil warms up. So we're limited in amounts of time that those cover crops can actually go in the ground, and that's why a lot of our cover crops actually go into the standing crop, because that opens up a whole window.

Slide: Date of Planting: Annual Ryegrass

Why is that so important? Well, here's an annual ryegrass that was planted, on the left, on September 15th. On the right, it was planted on October 15th. And by November 4th there was 11 inches of growth on the left-hand side, two inches of growth on the right-hand side. Two inches of growth on a cover crop is very risky going into the winter. We can lose them due to

frost, and also, of course, it doesn't take up nearly as much of the nutrients that were left over in the soil. So early planting of cover crops is paramount. That's why oftentimes we go into the standing crop.

Slide: Seeding Options

Normal planting methods for cover crops include drilling or planting. Those are the best ways to get a cover crop established because you get the best seed to soil contact. The seed really comes up nicely if we have enough time left after harvest.

Slide: Photo 14

A planter is even a better option because we save about half the cover crop seeds, and we can really precisely put the seed into the ground with the planter more so than with the drill. But again, in a lot of years, not enough time after harvest to do that.

Slide: Seeder on 'vertical tillage tool'

We have farmers using these ever-popular vertical tillage tools like large harrows and tillage tools that are supposedly one pass, cut the residue up, and then move to the next phase of the crop rotation. We really recommend people put seeders on there. This is a Valmar air seeder that is mounted to this device, and it's putting seed on the ground and gets the cover crop established.

Slide: Seeder on 'vertical tillage tool'

Here's another example of one of those big air seeders on a tillage tool. So these are reduced tillage systems where we try to get the farmers to incorporate cover crops in there.

Slide: Photo 15

But as I mentioned, it is usually necessary to get the cover crop established in the standing crop. This is a machine developed by some farmers. It's a machine normally used to spray fungicides or even apply nitrogen late in the growing season. They remodeled that machine to have an air seeder on there. You can see, behind the cab, there's a big red box. That is the air seeder, and then they put hoses out to the boom on of front of the machine that blows the seed of those cover crops in the standing corn in this case.

Slide: Photo 16

And this is what it looks like as the farmer is going through his standing corn crop. So those machines are very tall. They're standing tall on their wheels, so they only bend over the corn somewhat. And then they plant a cover crop long before the farmer actually goes into the field to harvest that crop.

Slide: Photo 17

And then a very common thing nationwide to plant cover crops is by airplane. Go over the standing crop, throw the seed out of the airplane, and get the cover crop established early.

These methods only work if we get some rain. If it doesn't rain, the seeds will just lay on the ground, and we lose the advantage of having gone in earlier.

Slide: What Cover Crop to use? Single species (crimson clover)

So the big question is what cover crops to use. Do we use a single species? This is a picture of a soybean field that has a crimson clover crop growing in it. This is in April, and you can see that it's very actively grown.

Slide: Cocktail Mixes

Or do we go with mixes? We usually call those cocktail mixes. Here again, you see the crimson clover, you see radishes, you see hairy vetch, you see buckwheat. There are a number of different species growing in here. Our farmers are absolutely the front runners in figuring out what works. I know farmers that use 13, 14, or 15-way mixes, with that many different species in there compared to just using one species. But that is really, really dependent on what your goal is out there, what cover crop mixes you use out there.

Slide: What Cover Crop to use?

And if you look at those goals of a cover crop, are we just trying to get the nitrogen to carry over from one crop to the next one and not lose it in our drain tiles? Are we trying to produce some of that nitrogen? Are we trying to reduce compaction? And that's when people often refer to crops like annual ryegrass, with its enormous rooting system, or those radishes, those (inaudible) oilseed radishes that can do that. Do we need cover on the soil? After a soybean crop comes off, there's usually not a lot of soil cover in the field. Cover crops can really help us out doing that. Are we trying to get back that soil organic matter? Do we want to restore the soils we've lost over the last hundred years and get them better? Several cover crops can really add a lot of organic matter to our soils. The nice thing is they do that in the off season, not impairing our corn and soybean rotations in the soil. Can we actually reduce the amount of herbicides we use by using cover crops to reduce the weed pressure? We've seen some farmers being very successful getting rid of some of those weeds that are now resistant to glyphosate, like mare's tail, and by using cereal rye in the rotation and being able to suppress those without having to refer to different kinds of herbicides out there. And for the cattle farmers, grazing and forage is important. Now, based on any of those goals you see out here, it really makes a difference which cover crop you would select or what mix of cover crops you would select.

I'll give it back to my colleague Dan here, and we'll wrap this thing up.

Slide: How Cover Crops Improve Soil Health

Dan Towery

So basically, we're using the cover crops to improve our soil health. The roots from the cover crops, we can increase the pore space in the root zone. Basically, it's kind of like putting the soil on a steroid, so to speak. That's going to help improve the infiltration in the drainage, and cover crop pores are more stable than tillage-induced pores. Again, it's back to that example that we do the tillage, and tillage begets more tillage. Whereas if we can get the pores from the cover crops, we can increase the infiltration. Basically, if you look at the bell-shaped curve on

the runoff if we're looking at going into a stream, we can reduce the flash that frequently occurs because we're going to go through the soil, frequently into the tile, and then down into the creek, instead of just running over the surface.

Slide: Soil Health

So soil health, big push by NRCS. Farmers, basically it's resonating with them. Instead of talking about reducing your soil losses from six tons to four tons or whatever, we're talking about making the soil better. The spade you see on your left, that was a soil that started out at 1.2 percent organic matter. It's four percent now. Yes, it took 20 years, and it was continuous no-till and continuous cover cropping every year, but nice granular structure. I mean this is – this would be considered primo soil type because of the characteristics. So again -- and what this does is it's - we can make the soil more resilient. So if we have extreme weather events -- and certainly, if we look at 2012 compared to 2013, I think we could say that we had some extreme weather events – our soils can help buffer those extreme events. Both in 2012 and 2013, we saw growers who had been using cover crops with higher yields than fields that had no cover crops in them. So it is a very hot topic. If you look at any of the farm publications, they are full of stories about cover crops and their management. So we're looking at these cover crops as much, much more than just reducing soil erosion. That's how we thought of them in the past. Now they're functioning at a very high level. They're capturing or fixing nutrients. They're bringing life back to the soil. The soil is – we don't give it the respect it deserves. We treat it like dirt, so to speak. It is actually full of different soil microbes, and if we can make them more active, then there's all kinds of benefits that we can get from it.

Slide: Soil Health Principals

So these are kind of the generic soil health principles. Those of you that may read internationally, it's frequently called conservation agriculture. What we're talking about is minimizing soil disturbance. Again, it's – one of the things that Hans and I had talked about is general guiding principles. Then it has to be tweaked for the local conditions. But minimizing soil disturbance – keep the ground covered year round. We can have something growing year round. We can have residue basically armoring the soil so that we don't have naked soil exposed to the elements. Keep a living root growing as much as possible. It's hard to believe that even some of our grasses, when the ground is frozen, the roots continue to grow below the frozen layer. And although we've had a mighty cold winter, where we have snow cover, it insulates the soil and we really don't get that deep of a frozen soil as one would expect. So keep a living root growing as much as possible. This is a game changer, folks. And as much diversity, either in the crop rotation or in the cover crop mixture. Those four principles, given a little time, and we can increase the profits for the farmer, and we can help the environment because we're going to have a lot less soil, nitrogen, and phosphorus going into our streams and rivers.

Slide: Keep Something Growing Every Day Possible

So, you know, for as complex as we make it, it's basically imitating Mother Nature. If we keep that thought process, imitating Mother Nature -- yes, we're going to be using herbicides, yes we're going to be using big equipment. But it's the basic process of leaving the soil undisturbed, having something growing every day that we possibly can. It doesn't have to be on every acre. We encourage growers to start out small. There is a learning curve associated

with using cover crops. And we don't want a person to have a train wreck, so to speak. But we've got growers that are putting on 4,000, 6,000 acres of cover crops yearly and are very successful with it. So it's – the water quality benefits are there. One of the things I've got to throw out is cost share dollars are extremely helpful to get a person started, but if approached properly, they will become an integral part of this crop production because it makes him money, but only if it's managed properly. So anyway, I'll turn it back to Hans now.

Slide: Conquest of the Land Through 7,000 Years

Hans Kok
Thanks, Dan. Actually, when Dan mentioned cost share, the Conservation Technology Information Center just did a survey, and thousands of farmers across the nation were asked about cover crops. And 62 percent of them responded that they grew cover crops without any cost share or ever having had any cost share. So that's pretty impressive to show you how beneficial those things are. Some people think they're only out there because of cost share.

I'd like to close up with four slides, and it's a little preachy. But coming from Europe, I feel that I need to kind of impress this on us here in the United States. The earth is littered with civilizations that have gone under. And in the 1930s, NRCS came out with this publication, Conquest of the Land Through 7,000 Years, where one of their NRCS folks went across the world to look for those civilizations and tried to figure out why they went under and why they didn't keep going. And a lot of them went under because they did not take care of their soil resource. Salinization of irrigation water brought down a place like Iraq, which is supposedly the Garden of Eden, according to the Bible. We have many civilizations, even in Europe, where they lost their agricultural land because they went on to the steep hill slopes and started farming those when population went up and got tremendous erosion, which flooded their bottom lands, which were their fertile lands. And Europe is now on their third agricultural revolution, where they had to start all over again, lost enormous numbers of population, and had to build up their whole system again. In the United States, we tend to think that technology will really get us out of this bind and we don't have to worry about it too much.

Slide: Photo 18

I think we've had some very, very clear warning signs already that that does not necessarily work.

Slide: Photo 19

We have the Great Plains example. We have the Piedmont example of erosion, where whole areas are now under forest. Same here in Indiana, we have whole areas under forest that at one time were fertile crop lands. There is a different way.

Slide: Photo 20

And this is a picture of my friend Carlos Crovetti (ph) in the county of Chile, where he, in the 1960s, bought a very severely eroded farm. It was so severely eroded he had to use bulldozers to close the erosion gullies before he even could start farming. In 30, 40 years of farming this in a no-till way, he has actually built top soil, brought up his organic matter content dramatically, and has been very successful in stopping erosion and hauling very, very

economically viable and successful crops off these fields in 30, 40 years. The sad thing is that a lot of his neighbors are still using the moldboard plow and still eroding their farms away. The penalties for erosion are obviously not severe enough in our society. So if we want to protect our water resources, our soil resources, we'll have to really rethink how we do certain things.

Slide: Water Quality, Cover Crops & Conservation

With that, Anne, I would like to bring it back to DC and open it up for questions for both Hans and Dan, please.

Anne Weinberg
Okay. Thank you, Hans and Dan, for that excellent presentation on cover crop basics. And I liked your last set of slides particularly. I like the preaching, so thank you for sharing that. We will have time for a few more questions, but first I have a few final announcements.

Slide: Speaker Contact Information

First, if your question does not get asked today, or if you'd like to contact our speakers, you can find their contact information on this slide. This contact information is also posted in the "Additional Resources" information posted on the Watershed Academy website at www.epa.gov/watershedwebcasts.

Slide: Next Watershed Academy Webcast

And also at this time, I want to announce our next webcast that is going to be on May 14th on living shorelines. Please check back with us, again, at our website at www.epa.gov/watershedwebcasts for more details that will be coming in April.

Slide: Participation Certificate

And also, please do not forget to download the certificate. This certificate can be downloaded from EPA's server through the link that is on this slide. Please type in this link in your browser to download the PDF document. You can also personalize the certificate with the names of everyone that's watching from your location. Finally, when the webcast is over an evaluation survey will be shown on your computer screen. We encourage you to answer the evaluation and give us feedback as we always try to listen to the feedback and improve our webcasts. With that, we now have time for questions for our speakers, and Erika is going to lead us through that.

Erika Larsen
Okay. Thanks, Anne, and I'd just like to give another thanks to Dan Towery and Hans Kok for this great presentation today. We really appreciate you joining us on the webcast on cover crops. So I'm going to start by asking just a few questions specific to Hans' presentation on cover crop basics, and then we'll open it up for more broad questions on the entire presentation for both you, Hans, and Dan. So we have a few questions about the economics of cover crops, and maybe we can start there: How costly is using cover crops, the costs for seed, planting, fertilizer, et cetera, and what is a cost estimate per acre of planting a cover crop?

Hans Kok
Sure. Be happy to answer that. That's one topic we, on purpose, dropped out of the presentation to keep it real basic. But you can make a cover crop as expensive as you want to. If you want to spend $80 on seeds, that is not too hard to achieve that. Normally, we try to tell farmers, stay under $30 in seed cost. And then, on top of that, if you use an airplane or somebody else putting the cover crop out, that's going to be an additional $15. So $45 an acre is not unheard of for cover crop planting. The fact that we have about eight percent of our farmers in Indiana doing this without any cost share indicates that it pays for the farmers. The same survey I mentioned earlier by CTIC that mentioned that 62 percent of the farmers do not get any cost share when they put on their cover crops, that same survey also showed that most farmers expect a five to ten-bushel increase, five bushel in soybeans, ten bushel in corn, after they start using cover crops. In the year 2012, we had some dramatic examples of what happened with farmers using cover crops. We had yields as much as 60 bushels to the acre, which is basically more than a third increase in yields, and oftentimes in the very first year farmers were using cover crops. So we can spend a whole other hour on cover crops and on the economics of that, but that is a quick sketch on the back of a napkin here.

Erika Larsen
Yeah, thanks, Hans. I think that was helpful. So a question here from a reader: For a typical reduced tillage farmer, if you had to choose between tweaking the nutrient supply by ten to 20 percent or using a cover crop, which would provide more benefit to reducing nutrients in surface water?

Hans Kok
Okay, you're going to get the academic answer to this one – it depends. There are so many factors, you cannot give a generic answer to that one. Again, in some years you may be able to really reduce the amount of nutrients you have to apply because you saved them in a cover crop. However, we don't even know yet how quickly those nutrients are released into the next year. Again, that depends on weather, moisture, a whole bunch of conditions. What we generally tell our farmers, if you start using cover crops, do not change your nitrogen management or your nutrient management. Keep a close eye on it. Take measurements. Look what your crop takes up. Look what your soil nutrient amount is. Yes, we have farmers that have been in 20-year no-till and ten-year cover crop who put on dramatically less fertilizer than the university recommendations. We cannot go out there and tell farmers to try to start doing this unless they have those two very important things: long-term no-till, long-term experience with cover crops. We are afraid that if farmers start to throttle back on the amount of fertilizer they put on their fields based on the fact that they've just no-tilled for a couple years and just tried cover crops, I think we're setting ourselves up for some bad economic train wrecks with farmers. The potential absolutely is there, but it's going to take quite a while to achieve that.

Erika Larsen
Okay, thanks. And the next question talks about the widespread use of cover crops: In your opinion, what is preventing this widespread use of cover crops and no-tillage in agricultural landscapes across the US?

Hans Kok
It's called time. They are so new that it's not really happening. The Chesapeake Bay is really a hot bed. We have a lot of cover crops there. North Dakota has some very intense cover crop

areas, and I said in Indiana we have almost a million acres of cover crops, which is about eight percent of our farm land. For that to spread to other areas, number one, we need more information out there for people to make decisions based on that information, basically education. The other thing is, keep in mind, we went from an industry that was virtually non-existent about ten years ago to an industry that is now moving millions of pounds of seed across the nation. That takes time to basically meet the demand of farmers that want these cover crops out there. So before the cover crop adoption can grow much larger, I think we'll see somewhat of a spike in seed cost because they need to catch up with that. And Dan, you've been involved in these cover crops longer than I have. Do you have any opinions on that?

Dan Towery
Well, you know, adding cover crops and no-till is almost like changing jobs. There's a long tradition with tilling the soil. You know, it used to be that when farmers were doing intensive tillage, who could be out there, who could be tilling the ground all night? Well, cover crops are not without their risk. As I said earlier, the yield increases we talked about, that is with proper management. Weather throws in an unknown many times. And if farmers don't use the proper management, they can see a yield decrease. For example, in 2012 we had a dry spring. An experienced grower, he wanted to maximize his nitrogen from his crimson clover. He let the crimson clover grow. Well, it sucked water out of the soil profile. And so he had to reduce stand. It didn't turn out too bad, but it still wasn't real good. The other thing is we've got things -- crop insurance has been an obstacle. We've got a lot of rented land. If a farmer is spending money on cover crops to improve the soil, if he's only got a year-to-year lease, that doesn't work real well. This is a long-term improvement, and we're looking at around 75 percent of our farm ground is owned by absentee landowners. So that's a big change. But anytime we're talking about major changes, it does take time. And you got the early innovators, and then you've got the late adopters. And so we're in that change mode, if you will, and so it takes time. It takes time.

Erika Larsen
Okay, thanks. And a question for both of you here, just a general question: Can you talk a little bit about the incentives that are available for farmers for using cover crops?

Hans Kok
That's a very local issue, and I encourage people to go talk to their local conservation office, both conservation districts and NRCS office. Sometimes 319 funded watershed projects have some cost share available with them. NRCS has some cost share money available through the CSB program, and those rates are in the $40 an acre, $42 an acre, so it basically pays for the cover crop and the application of the cover crop, if you're smart about how you buy your seed and what mixes you use. Some of our conservation districts have lower rates available for people who are not eligible under the NRCS programs. Those are usually in the 15 to $25 an acre range, so it's basically helping the farmer get started. It's usually on fairly small acres, too. And then, like the 319 grants, they can have some substantial cost share money available in there, too.

Dan Towery
One of the things that we've done here in Indiana is a person can get cost share assistance on the same field for three years in a row. And it's the idea that, after three years, he should see –

beginning to see the benefits of the cover crops so that he will continue to use them without cost share assistance. I really like that model. I know, in other states, somebody planted radishes once and they say you're not eligible anymore. So there's some different philosophies. And again, that's part of, I think, the learning curve of just figuring out what works and what doesn't work.

Hans Kok
And not to be flippant about it, but one of the farmers once told me, he said, "No-till and cover crops are like marriage. You can't just try it for one year and say, 'Well, that didn't work,' and let it go." I know that's a bad example because that's exactly what happens in this country with a lot of things. But it takes some perseverance. We really tell our farmers try it on small acres. Put some strips out. Don't do a whole field. Put some strips out where you put cover crop down, no cover crop. If you go to no-till, try a couple of fields where you back off on the amount of tillage, and just do it on a small scale so you really can figure out whether it works in your operation and how you can get started. The big thing in Indiana that we do – and we've done this in many other states – is farmer-to-farmer networks, where farmers talk to each other and explain to each other how these systems work. Do not make the same mistake your neighbor farmer has made ten years ago when he started in that system. So education and farmer-to-farmer communications are a huge component of these adoptions of these systems.

Erika Larsen
Okay, great. And we have a few questions about some participants in the Southeast looking for specific cover crop varieties that might be more useful in the Southeast because the soils are used much longer than five months in the South compared to the Midwest. Can you address some of the possible challenges that the southern U.S. might face?

Hans Kok
Sure. We're dealing with very different growth conditions than we do have here in the Midwest. We have much higher temperatures. We have even more intense rains causing worse erosion. We have some interactions between insects, fungi, and the soils that are a little different than here. So yes, you're looking at different species. The ones we've mentioned mainly in our presentation are species that grow over the winter in the Midwest. Down South, there are a number of other species available at that work much better in the warm season of the year, things like cow peas, buckwheat, sorghums (inaudible) grass. There's a whole slew of cover crops that work down there. A very good resource to look into some of those things is a book called Managing Cover Crops Profitably, and that is produce by SARE, Sustainable Ag Research and Education program. And the easiest way to find it is to just type in "Managing Cover Crops Profitably" into your Google, and it will pop up. You can read the entire book for free online on the SARE website, or you can buy it for $19 online. It's a very good resource. It shows you a lot of cover crops, and for each cover crop, it has a little map of the United States with it that shows you where the cover crops can be grown profitably. The little model I showed you that gives you windows of when to plant cover crops really only works for the Midwest. So we do not have something like that for the Southeast. So it's a different suite of cover crops. There's quite a bit of research going on in the Southeast. I would encourage you to take a peek at some of your extension and university websites, and go talk to your local NRCS office to see whether they have any guidelines as to what cover crops are available for your area and whether there's cost share available.

Erika Larsen
Great. Thanks, Hans. That's very helpful. We have a question about furrow irrigation, and the question is specific to the Rio Grande Valley in the southernmost tip of Texas. Does no-till and cover crop, do they work well with this method of irrigation? Can you comment on that?

Hans Kok
Well, furrow irrigation is a very disruptive system where we do a lot of tillage in the system, basically. And we have found one management practice to be very beneficial out there to reduce erosion, and that is polyacrylamide, PAM. And getting that material to the soils has really helped us dramatically in reducing the amount of erosion. However, furrow irrigation; again, you need a lot of tillage to get those furrows going. And unless we start changing our irrigation systems -- and there's a huge up-front to this -- to drip irrigation or even sprinkler irrigation systems, it's going to be very tough to incorporate a lot less tillage in those systems. Yes, it can be done, but it's usually fairly costly to go that way. Cover crops are a very interesting animal in that whole ecosystem in that they will use water, but if they can improve the soils, they can also reduce water. We found for our irrigated farmers in eastern Kansas, for instance, once they started going to a no-till system, they could cut out one or two irrigations because the no-till really accumulated that much more water over the off months, sort of fallow months, that they could reduce the amount of irrigation they did. We found the same thing in the Columbia Basin of eastern Washington state and northern Oregon. Rio Grande, where the temperatures are much higher and with that much tillage and shortage of water in that region, I wouldn't even claim to be an expert on what those folks could do out there. I'd entertain an invitation to come look and help you figure stuff out, but I cannot really give you an answer right here.

Dan Towery
And just to add to that, I know I was out in California, and furrow irrigating cotton. And I asked the grower, "What are those small tractors running up and down?" And he said, "Well, those are some rows we didn't get compaction on." Because with the furrow irrigation, they're relying on gravity to move the water from one end of the field to the other. So they needed – if the soil wasn't compacted in those furrows, it wouldn't go all the way to the other end. So yes, it's hard to know where to start when you're having that kind of a production system.

Hans Kok
There's some interesting stuff going on. The Howard Buffett Foundation is actually having a research farm – is that in Arizona or New Mexico, Dan? Arizona, where they are looking at irrigation systems and how we can do that while improving the soils. So again, furrow irrigation, yes, I know it's extremely prevalent. It may not be the best system for improving soil because it requires an enormous amount of tillage and an enormous amount of compaction.

Dan Towery
And it's about the least efficient irrigation –

Hans Kok
Yes, with the water. It's not very efficient with the water usage. And it's easy to sit here in a wet climate to make those observations, but that's the reality of it.

Erika Larsen
Thanks. Okay, our next question is about water quality benefits again: Can the environmental water quality benefits of no-till be offset if the manure or fertilizer is not able to be incorporated?

Hans Kok
Very good question, and we are fighting that battle with your office, actually, as a matter of fact, in some places where it is mandatory to get the manure worked in with tillage, which really offsets a bunch of the benefits of no-till. If we can come up with systems – and they do exist – where we can inject manure into the soil so that it is not on the soil surface -- and that's going to take some adjustments on the farmers' side and on the EPA side to get to successful systems on here -- I think we can do it. And most of our no-till farmers are huge fans of manure in their system because it brings, again, more microbiology into their soils. They see the benefits years after they apply one manure application out there. Now, keep in mind, in a no-till system, especially if the topography allows for this, a fairly small amount of manure added to a field should not result in a lot of runoff in a lot of those fields. If we have a lot of crop residue out there, and especially if we really get a growing cover crop at the time of the manure application so the nutrients that are trying to escape the system are immediately taken up by one of those cover crops, that could be very beneficial. So a two-pronged approach, in my opinion. You have to have a cover crop if you apply manure, whether it's solid chicken manure or a liquid dairy manure. And then the other thing is, if it is a kind of manure that can be worked into the ground, let's get applicators going that can do that. In Europe we've been using applicators to place all the manure in the soil for a long time because there's just too much population around those fields. They will not put up with surface application of manures. For us, it's more an environmental issue, that we don't lose all those nutrients.

Dan Towery
And I've worked with a couple of growers who have been using no-till cover crops, have the improved soil that we talked about, better infiltration. They actually can apply liquid manure a half rate, and it just almost immediately just goes into the soil - again, and then come back, like two, three weeks later, and apply some more. So, you know, the issue with having runoff, it doesn't apply there. Now again, it's how do you know when the field is ready for that kind of management. That's the tough part because, still, we don't have the criteria to know exactly when is -- especially if it's a sloping hill, when do we have the potential of a water quality issue by using that management?

Hans Kok
I think a lot of our issues with manure and water quality are really caused by – I'll call them bad managers. If we put a bunch of chicken manure on frozen soil, we are just putting a huge sign on there saying, hey, we're causing trouble. And we should not be doing that. That is very obvious. But it's a very nuanced solution that we need to find to this and not a clear, hey, you cannot do this or cannot do that, in my opinion.

Erika Larsen
Okay, great. And we only have time for one more question. We've had a lot of really great questions come in here. But if you could just provide a brief response on this, Hans or Dan. We've had a few questions come up about ways that you can add fungi or earthworms or other

soil bacteria to the soil in addition of implementing cover crops. So can you comment on the best way to add this type of fungi into the soil?

Hans Kok
Sure. Before I answer that – we answer that question, I would like to thank Anne and you, Erika, and the others at EPA who made it possible for us to be on this webinar and all the pre-work you've done with this. And especially for you, combing through all those questions we see pouring in on the question window here, and making heads or tails out of it and accumulating them for us. Thank you very much. As to whether we can just add those things to the soil, that is a mixed bag. We have actually tried to seed earthworms in fields, but look at this parallel. If I'm going to put earthworms in a beautiful black soil, they probably like living there. If I put earthworms on a parking lot, they're probably not going to be very happy. So it's a little bit like the old movie. If you will build it, they will come. And so if you create the environment for the soil biota to really be thriving, they will return and they will come out there. We've had several companies that sell these products in jars and gallon drums or 50-gallon drums, telling us that if you put that on your soil, your soil is going to improve. But if we do not cut back on the amount of tillage we do, if we do not incorporate more diversity in our crop rotations, especially cover crops, I don't think those organisms we buy for good money are actually going to survive in that environment. We really need to create the environment. Once you create that environment, and you would have some issues, you could think about introducing those. I'm a little leery about it. Are we setting ourselves up for a new kudzu by introducing soil organisms that don't really belong in certain ecosystems that we have? Where do they come from? Who decided that those would be good ones to add to the soil? I'm a big fan of just letting the soil do its own thing and just treating the soil really well, managing it well, and let the soil biology respond to that.

Dan Towery
Yeah, I kind of concur. I use the analogy of we had people who would pen raise pheasants and then release them. And you have a 98 percent mortality. Providing habitat is – that's what it takes to get the populations. And I think that you may be able to jump-start it a little bit initially, but providing the right conditions, i.e. minimal soil disturbance, living root, that is the way that we're going to really make strides in improving our soil biology and the way the soil functions.

Hans Kok
I know there are a lot more questions out there, and we've talked to Anne and Erika about potentially getting some of those questions to us. I would like to caution you, we both have daytime jobs, too. We'll try to get to those questions, but it might be a while before we can answer you.

Anne Weinberg
Okay. At this time, that will conclude our webcast today. I want to thank you, Dan Towery and Hans Kok, for talking to us about conservation and cover crops. And we understand you do have daytime jobs, so I appreciate your participation on this. We will try to answer questions as we can. And thank you to Erika Larsen for serving as our question and answer moderator. And of course, thanks to everyone who joined us today. That ends our webcast for today. Again, thank you for joining us.