Climate Webinar – Feb 2014

Thank you all for standing by and welcome to our Feb webinar entitled 'Predicting carbon storage of Great Lakes forests in the year 2050: scientific challenges and management decisions'. These webinars are an initiative of The Ohio State University Climate Change Outreach Team, a multi-departmental effort within the university led by Ohio Sea Grant, Office of Research, Ohio Supercomputer, OSU Extension, and eight other OSU departments to help localize the climate change issue for Ohioans and Great Lakes residents. I'm Jill Jentes Banicki from Ohio Sea Grant & Stone Laboratory, and joining me today is Dr. Peter Curtis, professor within the Department of Evolution, Ecology, and Organismal Biology at The Ohio State University. Dr. Curtis is the director of the Northern Forest Carbon Cycle Research Program at the University of Michigan's biological station where for the past 20 years he's been studying the flow of carbon into and out of the Great Lakes (GL) forests; one of the only programs in the world that is doing this. His research is widely published on how these ecosystems will respond to rising carbon dioxide levels, how climate and land use will affect forest carbon storage as well as the roles biological complexity of these forests will play in a changing climate. We're very excited to have him here to discuss his research today.

But before we do, a few logistical issues as we get started. During our presentation all participants will be in a 'listen only' mode. Afterwards, I will conduct a question-and-answer session. If you would like to ask a question during the presentation, please feel free to use the 'chat' feature located on the right-hand side of your screen, and I will collect and pose your questions out to Dr. Curtis at the end of his presentation. We have over 100 participants on the webinar; a great diverse group representing governmental agencies, academia, and nonprofit groups from the GL and around the country. Please keep those questions coming throughout the presentation, and we should have a great Q&A session. As a reminder, this webinar is being recorded and will be posted on to our website for later viewing. Also, we will post a webinar survey in the 'chat' feature towards the end of the hour. Please take a few minutes after the webinar to fill out that survey. It will help us continue to bring you better webinars. So without any further delay, I'd like to introduce Dr. Peter Curtis who will present 'Predicting carbon storage of Great Lakes forests in the year 2050: scientific challenges and management decisions'. Dr. Curtis, I'm going to, well you're already unmuted and we're going to pass you the ball.

Okay, thank you, Jill.

And you should be all set.

Okay, I think I can flip over to the webinar. Are we all looking at the first slide?

Yes, you are in good shape.

Okay, thank you and thank you, Jill, and thank you everyone. Welcome to this OSU Climate Change webinar. I'm Peter Curtis, Department of Evolution, Ecology, and Organismal Biology (EEOB), and I'm really happy to be here and have a chance to talk to you about some of our, my own research, that of my group, and consider this question about scientific challenges and management decisions as they relate to the future role of our forests in the Great Lakes (GL) region as that regards carbon storage.

Before I get started I want to call attention to co-authors on this talk; my colleagues Christopher Gough, Gil Bohrer, and Knute Nadelhoffer from Virginia Commonwealth University, Ohio State, and University of Michigan respectively. Really the results I'm going to be talking about are the results of a team effort, and they really come from the entire group. So with that let's get started.

I'm going to switch to the next slide. I'd like to take just a minute or two to go over our roadmap that I'm hoping to cover in today's webinar. I'd like to start a little bit of discussion that really serves as an overview, a big picture overview of why carbon storage by forests is important to put this in a broader context. To get us all on the same page about how exactly this happens in a forest, how carbon storage takes place, and then outline why it is we're concerned about its future. So really set the stage. I'd then like to briefly consider a couple ways that we actually project or predict what the carbon storage will be like, specifically the role of modeling and then also measuring different forests that allow us to do this. I'd then like to kind of dive into the research that we've been conducting that links canopy complexity to forest carbon storage, and this will get us right down into the work that's been coming out of our group at University of Michigan Biological Station. And then I'd like to conclude by considering management options, how we can actually manage forests to increase complexity and thereby help sustain carbon storage into the future. So that's where we're going to go, if the technology serves us… Well, let's see if I can do this…

Okay! Let's take this overview, big picture. Why are we concerned about carbon storage in forests? I like this illustration. This is from tony King from Oak Ridge in a review paper a few years ago, and if I can get my pointer, there we go, my laser pointer. Hopefully everyone can see that on the screen. Where we often talk about sources of CO_2, or CO_2 sources, and CO_2 sinks. And in the source area these, a familiar ones for many of us is fossil fuel emissions, and these are places that CO_2 are emitted. And this includes things like fossil fuel emissions but also the results of land-use change, deforestation, that result in CO_2 emission that represents a CO_2 source, as well as other natural disturbances like pest outbreaks, and then the natural process of decomposition results in the release or a source of CO_2. Now this CO_2, much of it ends up in the atmosphere or all of it does initially, but some of it will be taken up out of the atmosphere into what we call CO_2 sinks. Now this process of removing CO_2 from the atmosphere is almost entirely driven by photosynthesis, so these producing sector sinks is where it first ends up. Although the results of that, in this case could either come from agricultural or harvested products can be frozen or stored in the consuming sector as outlined here. So we go from CO_2 sources, like fossil fuel, to CO_2 sinks where it is stored in forests and agricultural products, agricultural land and harvested products. So the activity of these sinks helps to remove CO_2 from the atmosphere and lessens the impact or helps mitigate the impact of fossil fuel emissions and climate change. Now among these CO_2 sinks, in the terrestrial biosphere forests are thought to be the largest sink, terrestrial sink for atmospheric CO_2. So this is why we think that forests are important in the carbon cycle, in storage of carbon by them.

How does this actually work when we're looking at a forest? And this is going to be pretty brief. This is really a primer on the forest carbon cycle using this illustration to help us. And so there are really three key points that I want to make sure people understand as you think about how forests actually store carbon or the process of carbon storage by forests. And those key points are the following. Carbon storage or net ecosystem production, so I'll be using 'net ecosystem production' is synonymous with 'carbon storage', it's sort of our technical term in ecology. But this process of carbon storage is the difference between large processes, that is the carbon that is being taken up through photosynthesis. And so this is taking place in forest canopies, and then really the only place the carbon, the only way that carbon can be taken up is through photosynthesis. But it's the difference between that process and the CO_2 is lost through respiration, and respiration can happen both from what we call heterotrophs, and this is primarily bacteria and fungi, and from the green plants themselves through autotrophic respiration. And so the key point here is that carbon storage is difference between what's taken up by photosynthesis and what's lost by respiration. Now it follows, and this is also sort of important in understanding this, is that this process can be either positive when the ecosystem is gaining carbon or when photosynthesis exceeds respiration, or carbon storage can be negative when an ecosystem is losing carbon, and that occurs when these lost terms, respiration, is beating photosynthesis. Carbon storage can be positive or negative, and that would indicate whether it's gaining or losing carbon overall. And then finally my last key point is where this carbon is actually stored. And its storage pools as we call them, the ones that we're interested in here are relatively long term, years, decades, or sometimes can be centuries. And where that carbon is stored is either in wood, and that would be in the stem or the roots, or in soil, soil organic matter, soil carbon. So three key points is (1) carbon storage is the difference between photosynthesis and respiration; (2) it can be positive or negative at the ecosystem level; and then (3) most of it for forests is stored in wood or soil. So that's how it actually works.

North America, so our part of forests figure into this on a broader scale. North America, our best estimates are that the eastern forests are currently a very important carbon sink, our eastern deciduous forests. And this is a graphic that was made by Cam Hayes who's at Oak Ridge National Lab as a modeler. And it shows estimates of carbon storage in different parts of the continent, the North American continent, by different areas. So by forest lands we can see here in these three panels, crop lands, other lands. And he's basing these estimates on three different ways of gathering data, the inventory data, forward models, and then what are called inverse models. I'm not going to go into the details of the way these models. The inventory data, for example, is actually going out and inventorying carbon storage, for example. And this is coded. The color is coded by the dark blue areas on these maps are showing lots of carbon storage up here. If they tend down towards green there's very little carbon storage, and then areas in the map that are in orange and red are actually losing carbon, are carbon sources. So carbon sinks up here, carbon sources down here. I just want to draw everyone's attention to these panels here which are in broad agreement that these eastern forests typically show up as blue in this map, so indicating strong carbon sinks. So there is a lot of carbon storage going on there. So our question then, so we acknowledge that currently in 2014 our eastern forests, and in many places these are further north, these are deciduous forests, these are important carbon sinks. The question that we're posing is will these forests continue to be important carbon sinks in the future. To put it another way, would we expect to see on this map these areas continue to be dark blue, or would they start to shift into the green or red? And our concern is that this would have important implications for climate change mitigation of the ecological service that these forests currently provide. So why might we be concerned that this would no longer, this would not continue to be the case? Why might these forests not continue to be carbon sinks?

There are two major reasons why ecologists are concerned about the future strength of this carbon sink, or the carbon storage capacity. And the first is that our eastern forests, our GL and forests in the northeast, generally are getting older. This is, it goes back to the legacy, the land use of our forests. In the GL, I think as many of you know that these forests were clearcut about a hundred years ago, between 1860 and 1930, and they've been regrowing since then. But our current harvesting of these forests is not, does not prevent, the average age from increasing. We're actually cutting at below replacement levels. And so if we look at this plot here. This is data from our, what's called the Forest Inventory Analysis Program with the US Forest Service. And what they show is across the eastern region, across a 20 state region, that the average age, the median age of these forests has been increasing from approximately less than 60 years in 1991 to on the order of 70. And if this process continues we can expect to see the average age of our forests increase to where by 2050 it could be well over 100 years old. The forests are getting older, which is a natural ecological succession. Why is this a concern now? So the forests are getting older.

Well this is what it boils down to. Now we're changing slides. Ecological theory predicts that as forests age we should expect a steady decline in carbon storage. And this theory goes back to a seminal paper by E. Odum in 1969, it's referenced at the bottom of the slide, called the 'Strategy of Ecosystem Development'. We've taken the illustration right from his paper, which he's plotted years of forest age or forest succession, and on this he's plotted both photosynthesis, respiration here on the dashed line, the actual forest biomass, and then in the shaded region in the middle is carbon storage or net production. And what he proposed is that this period of maximum carbon storage occurs fairly early in forested collections, perhaps at age 30. Somewhere between 20 and 40 years, so while the forest is still quite young is the period of maximum carbon storage. This also coincides with the period of maximum wood production. However, as forests age, and particularly as they approach 80, 90, 100 years old, the wood yield, or wood production, and carbon storage slow down and in fact approach 0. And you can see in terms of carbon storage, the shaded area, is getting smaller and smaller, so that by the age of about 100 we'd expect there would be very little if any net carbon storage occurring in these forests. So if we go back to that other slide as we see these forests age we'd expect those dark blue areas to be shifting down towards green, and that ecological service to gradually go away. So this is the concern then, if this ecological theory is correct, then we would expect to see actually quite rapidly now a decline in carbon storage in our GL, in our northeastern forests.

Okay.

Now, what do we use to look forward in time? I want to very briefly describe for people if you're not familiar forest growth models, sort of a typical model, and how these might be used to forecast carbon storage, and indeed these are our most powerful, among our most powerful methods for inferring carbon storage in the future. And I've just taken this as an example. This is the so-called TRIPLEX-management model and it's actually produced by a group at the University of Quebec in Montreal; an excellent model. But indeed it, as well as many other growth models, include that fundamental theory of age related declines in carbon storage within the framework of the model. And this model indeed does that, and this is typically embedded in relationships between leaf area and photosynthesis, abbreviated here GVP. And so this model as with others can predict the climate forest carbon storage because of these relationships. And this is, to illustrate that, I've just take another example from literature; recent paper from a group out of the USGS of South Dakota, predicting or using a model, in this case the FORE-SCE model to predict carbon sequestration in the southeastern US, and these are coniferous forests. And this just gives you an idea. They used this model to both establish and then validate predictions in the past, and actually current right in here, and then running the model forward in this case to the year 2050 to predict what carbon sequestration or carbon storage would be like in different components of these forest ecosystems. And indeed this model as well predicts the decline in forest carbon sequestration in part due to these age-related constraints as is embedded in the model. So these models as well as others, and they're extremely valuable, and indeed may very well be correct for these systems, predict age-related declines. So this is where we stand.

I and my group have been looking at this in a variety of ways, and we've found that when we're, if we focus our attention on temperate, deciduous forests. So those forests growing in the temperate zone, and that also are dominated deciduous species, they lose their leaves in the wintertime. If we actually look at data where people have measured carbon storage, net ecosystem production as it's described here, in forests of different age, we don't see the predicted decline. So that measurements of carbon storage in these forests does cast some doubt on the generality of this idea of declining carbon storage with forest age.

So at this point, my colleague, Chris Gouph, and others and students have assembled data from 40 forests, or measurements from 40 different temperate, deciduous forests from North America, Europe, and Asia, and I'm not seeing, I hope this zero line is showing up on your screen, it just appeared on mine. But that's neutrality right there. And what we're not seeing is any consistent decline over time in these forests of different age. So out here at 200 years, these forests are still sequestering, storing significant amounts of carbon. And if we look here in the shaded area, between ages of about 75 and 110 or 120, there's certainly no consistent evidence for decline in carbon storage. There's some actually very high points. You have this system down here is losing carbon, and this is following a clearcut; it's a very young forest. And perhaps we see some high activity in young forests, but certainly no obvious and consistent evidence in decline in these temperate, deciduous forests. So this certainly got us wondering if this is in fact a general pattern across all forests, these predictions of declining carbon storage.

And indeed if we were again to look at our own data. And so now I'm going to jump right into some of our data, and before I introduce our team, but in one particular forest, one we work in, about a 90 year-old forest in northern Michigan. Instead of seeing a decline in forest ecosystem production or net ecosystem production as we would predict for an aging forest like this, we saw exactly the opposite. So what I'm showing here is a 14 year record, from 1999-2012 of net ecosystem production. And what we're seeing is over this record we see an actual increase in carbon storage, a significant increase, just following along the line here, rather than a decline. And this increase is occurring at the same time that the total amount of leaf, the leaf area index, the leaves are actually declining somewhat as a result of the decline of the early successional species that have dominated this system for the 100 years, the aspen and birch. The open symbol here are declining as these species die. And the later successional species, the oak, maple, and pine, are increasing, although not at the same rate. So that overall the leaf area of the forest is declining somewhat. While at the same time the net ecosystem production is going up. So this was quite a head-scratcher for us, which suggests that something else is going on to maintain this sort of production. So that's really been the major theme of our research for the last, most part of the last decade.

So let me introduce some of the research program, our research program, the Northern Forest Carbon Cycle Research Program at the University of Michigan Biological Station, the UMBS. I've mentioned the names before. Here's a photograph of the gang a couple years ago. Here are the principal investigators. We also have students and other associates who are intimately involved with this. Work takes place at the biological station here where we call the 'tip of the mitt' in northern lower Michigan. I want to be sure to voice our appreciation and acknowledge the generous support of the US Dept of Energy, Office of Science, and other institutes within the DOE that have provided very generous funding and continue to fund this research we hope well into the future. This is the team. And I'll talk a little bit about how we generated the data that I showed you in the previous slide.

So how do we actually measure carbon storage in forests? So I'm going to take a few minutes to describe that process. So a primary instrument, the primary tool that we use for measuring carbon storage is called a so-called eddy covariance or eddy flux tower shown here. It's about a 150' tall, about twice the height of this canopy. You can see a couple of researchers on here. It's a heavily instrumented tower. It allows us to monitor the exchange, the active exchange of CO_2 in the atmosphere and the forest below. So what we're able to do is measure the CO_2 concentration on turbulent eddies of air as they mix between the atmosphere and going down and sweeping down into the canopy, and then actually on the reverse swing as well. So we can measure CO_2 concentration of the air as it passes into the canopy and as it comes back out of the canopy. And so in a very simple sense if the CO_2 concentration is higher as it goes down into the canopy than it is when it passes back from the canopy, then somewhere down here carbon has been stored. That would indicate net uptake. The CO_2 concentration on the downswing than the upswing, then the reverse is also true. If the CO_2 concentration is higher going up than when it's going down, then this system is giving off or losing, on average losing CO_2. And these measurements are taken ten times a second or as we say at 10 Hz, and then we typically aggregate these measurements to one hourly average that gives us a better idea of what's actually happening. And I want to show you an example of what those kind of data actually look like.

So this is a single day's worth of data from this what we call our flux tower. And I'll have to point out that actually in this case negative numbers here, the blue numbers, are uptake. This is what we call the meteorological convention that when these numbers are negative it means the system is taking up CO_2, somewhat counterintuitively, its positive when it's losing CO_2. So this is one day a couple decades ago, July 9th, 2000. This is at night, and this system is on average losing CO_2. Sun comes up, and so it picks up steam, it's gaining on that uptake of CO_2. Sun goes down, and it's losing … and has a net loss of CO_2. We do these measurements 24/7, 365 days, and now we're well over a decade of continuous measurements. And this is one of about several hundred towers which are scattered around the world.

We work within a network of both in the US and internationally. So a number of these carbon cycle monitoring sites in operation. So this is our primary tool that we use for studying CO_2 exchange in this forest. The so-called footprint of the tower, it goes out about a kilometer. So we're measuring about a square kilometer of forest using this technique.

But we also, we complement these studies, these measurements with very detailed ecological studies of forest carbon storage as well. So we're interested in not only these short and longer term dynamics, but we also want to know where the carbon is ending up. Is it for example in the herbaceous understory layer? Is it up in the canopy? Is it in soils? And at what rate is it leaving those soils? So we're taking quite a few measurements on the ground. This is looking down at our map of one of our sites with permanent spots surrounding the tower, which is right here. So lots of studies. It's sort of like trying to find a missing penny. We're trying to find where that carbon is, and how long it stays in different places in the ecosystem.

Okay, so that's how we take the measurements. So let's talk about some of the information that we've found that's shed light, that has shed some light on this, this bit of a puzzle between aging forests and increasing the sustained carbon storage. But one of the important results that we've found is that in the older plots that we've studied, that they have higher complexity, structural complexity, and they also have higher wood production.

I want to spend a little bit of time describing how we do this. We measure canopy complexity using a laser range finder, what's called lidar, and this is shown here and this is one of my former students Brady Hardemann, who's now at Boston University. And we use this to essentially map the vegetation above us and map the leaves. And Brady has developed a mathematical expression which we termed rugosity that describes the distribution of leaves above him as he's walking with this instrument, the laser range finder connected to a laptop computer, as he walks through the forest. This results in images like this one, which allows them to describe the complexity of the range of leaves within that canopy. So I'm showing you three different panels, A, B, and C, from source plots of contrasting complexity, structural complexity but similar amounts of leaves or similar leaf area index. So Panel A has a low rugosity or a low complexity compared to Panel C, which has high rugosity, so we see here that it's about 29 and here it's about 8. And so you can sort of see this as these little boxes has to do with the amount of leaf area at that height. And in Panel A, this plot, this source plot, has fairly uniform distribution of leaves, leaf area, colored boxes, compared to Panel C, where we see evidence for canopy evidence for canopy gaps, emerging trees here. More well developed midstory and understory canopy as well. So this would be an example walking through the forest about 40 m with this instrument with the distribution of leaves above you. A complex canopy, or rather a simple canopy, and a complex canopy down there. Low rugosity, high rugosity.

So we developed this tool for measuring complexity, and then what Brady found, what Brady Hardemann found was that as forests age, as they got older, rugosity climbs steeply. And particularly during this period of about 40 or 50 years to about 90, at which point it seems to plateau. It seems to even off in forests above about 100 years. We have, we don't have too many of these older plots. We're looking to increase that number. But certainly in this period, in this range of about 70 or 80 years of increasing complexity, and overall even including these older plots we see a nearly exponential relationship between complexity and net primary production as well as carbon storage. So this is a key insight. These aging GL forests that there was a relationship between complexity and carbon storage, and Brady combined that, pulled that information into a simple model in which he's relating, and this is the output of the model, net primary production of wood, so carbon storage, as a function of complexity, leaf area index, or in this case site fertility. What he found was that rugosity was the best predictor, was the most strongly related of these variables to wood production, and that as stands age or as those forests age complexity or rugosity can increase. So this established the linkage, a functional linkage between complexity and wood production. And I should mention that we're now establishing what the mechanism is here which appears to be strongly related to resource use efficiency, particularly the way these forests use incoming light.

So that was a key insight as relates canopy complexity, stand age, and wood production. So this led to an emerging conceptual model for our group that suggests that leaf arrangement, that is complexity, is more important to carbon storage than leaf quantity, the actual amount of leaves, as eastern forests age. And in this plot I've shown the development of overall leaf area, which tends to increase quite quickly and then plateau by 50 or 60 years. While complexity takes longer to develop, so in these rapidly growing young forests complexity is still quite low, but this starts to increase around age 70 or 80, and will increase rapidly to some point. We don't know when this actually plateaus, in which case other factors may come to dominate uptake and resource use efficiency. So we suggest that this is a key dynamic here with increasing complexity and resource use efficiency in these older forests. And this is a model that we're continuing to test, and my next slide illustrates some of those efforts.

This is an area of active research for us. We are continuing our efforts to better quantify the canopy structure complexity as well as the light and nutrient environment within canopies. And I should point out here that canopies are complex and difficult areas to work. We wish in any case that we had a team of sort of trained squirrels or monkeys or something that could get us up into the canopy. We're using different sorts of hoists, so poles as my student Alex Fotis who is extending a fish eye camera into the canopy on the end of carbon fiber pole. Here's actually Chris Gouph experimenting with yet a higher pole, ours is hydraulically activated pole that will get us up on the order of 22 m. These are all by the way getting better descriptions of what's going on inside these canopies making them more complex. We'd like to be able to develop true, full 3-dimensional characterizations of our canopies. We're showing a young canopy and an older canopy at our site. These are very laborious to collect, and we're looking for ways to simplify that. Alex is looking into putting a time dimension into this. We think that actually these forests may behave differently, structurally simple ones versus structurally complex over time. So we're adding a fourth dimension if you will, a time dimension for our characterizations to further test this model and this idea that structural complexity is so important.

So that's where we're going with some of our efforts in the future. So let me now gears, just sort of wrap this up. O before we do that, I do want to mention the role of biodiversity, and I'll do this very quickly. This is an illustration from a paper of ours from 2010, but the point of it, it's very important that species diversity, the number of species that are present, can have a big impact on resiliency. We saw this in our own system in stands in which there were many middle successional species were codominant, and when those early successional species died, which is increasingly happening, that primary production the effects of that decline, or rather the deaths of those species, was low because these early, rather the mid successional species were there to fill in. And so when he had higher diversity, the change, the effects of the death of the early successional species, the aspen and birch in our case, the effects were small when compared to those mid successional species were not present. So in our case, very clearly greater diversity equated to greater ecological resilience. But how can we put some of these, what are our possibilities for putting some of these insights into forest management and the way forests operate managed within the forest products industry, and within our state and federal lands, and how we manage those. And I've modified a graph that was from Klaus Puettmann and his colleagues in a book on a critique of silviculture which essentially plots different kinds of forests along axes of simple or complex or in our case having a low or a high carbon climate change mitigation potential, those are added to this, as a function of their management. So increasing management intensity here, increasing complexity on the x axis. And so if we go from a essentially an early successional forest after some stand initiating disturbance, that could be a fire, that could be a clearcut, and then natural ecological succession would result overtime, over many years, decades, or centuries into a complex, old growth forest. Our forest management on the other hand is generally aligned with keeping forest complexity or forest structure simple. We can look at this along a gradient of natural regeneration, perhaps with some thinning, and even a stand management, all the way up to clearcut and intensive plantations. So here is the management intensity. But almost all of these keep with the consequence with having simple structure. What we suggest is that there are, we need ways of thinking about bringing structural complexity into our management options. And so we would argue that new management tools are needed to promote structural, compositional, and functional complexity that would then allow for greater carbon storage for example and as well as other benefits of structural complexity and biological complexity in terms of ecological ecosystem services.

So here are some challenges, and I'd like to conclude by mentioning and highlighting that there are in fact groups that are working, currently working to develop and test these management tools. I'll take the liberty of highlighting a project that the Nature Conservancy is spearheading. And here I want to thank actually the managers, the Nature Conservancy scientists based at the Marquette office, this would be Tina Hall in the upper Peninsula of Michigan, and Doug Pearsall and Kim Hall who are down in the Lansing TNC office who shared of these results with me. It's a very exciting project that's along the Two Hearted River in the upper peninsula of Michigan. The site here is this left-hand icon. It's part of their forest reserve there, and it's part of a broader forest Michigan forest restoration strategy. But what these scientists and managers have proposed, and I actually I have a hypothesis, is that by forest management tools one can contain more natural diversity of species, age classes, and structural attributes than just by waiting to see that this happened naturally. And they've done this through a series of experiments. And I've just shown here an aerial photograph of the study site along the Two Hearted River. And what you can see here is are different cutting experiments with different sized gaps, so small, medium, and large gaps. You can sort of see these literally to see whether or not these experiments mimic or produce the same effect as we would see in naturally successional or forests between natural disturbances. So we're interested in whether or not these ecological attributes of old growth forests are mimicked using some of these harvesting techniques, like creating different sized gaps. Merchantable wood, harvested woods is coming out of these gaps and can be used as you would any other sort of wood. For controllers there's a control area here, and a restoration cut area here that these experiments can be compared to. So it's very exciting. These and there are other examples of forestry professionals, conservation scientists, who are actively working to test whether or not we can create complexity, enhance ecological services in our managed forests, so very exciting. And thank you to the TNC for sharing that information.

So I'm closing in on the end of this. I'd like to finish off with just a few concluding thoughts. I'm going to pass the ball over to Jill who's going to help me with this because it wasn't working from my end when we tested it. So I'd like to send the audience, and again thank you for joining us, away with a few concluding thoughts. Jill, thank you, if we could have the first of those ideas that I hope I've able to communicate. And that is that as our GL forests age, the early successional species will be leaving us, this is aspen and birch, but as they age they become structurally and biologically more complex. Next slide or next bullet point. This increasing complexity is a process that sustains carbon storage. It also promotes ecological resilience, and enhances biodiversity, and it's an important point that these more complex forests like these will be able to harbor a greater diversity of organisms which might be displaced by climate change. I think that's another benefit. Increasing complexity sustains carbon storage, promotes resilience, and enhances biodiversity. And next slide.

It's very important that or putting in place innovative forestry management practices that may accelerate forest complexity. We may not have to wait 200 years for a complex forest to develop. We may be able to do this ourselves. And lastly, that with increasing complexity, carbon storage in our GL forest should not decline substantially by 2050. We hope that there's a mechanism and that this is born out of some of our data analysis it engages these areas that continue to be important carbon sinks, and to help mitigate climate change globally.

Thank you very much for your attention. I think we have a few minutes for questions if there are any. I'd be happy to try to help respond to them.

Okay, thanks Dr. Curtis, and we got a lot of questions. So we've got some really great questions during your presentation, so let me get started and I'll ask Dr. Curtis as many as we can. The first question, and let me hand, I'm going to hand you back the ball just in case you need to go to a certain slide.

Okay

All right. The first question was a clarification question. A couple people were asking what the difference between 'carbon storage' is as opposed 'carbon sequestration'?

I'm using those interchangeably. So when carbon is sequestered someplace it's effectively stored. Sometimes this might imply a little bit longer period, so you can have short-term storage or long-term storage. But I think in many cases people when they're thinking sequestration, they're thinking decades, perhaps millennia, but they're really, they're synonymous.

Okay. Another question we had was if you have a sense of the scale of carbon being stored currently or potentially in forested systems relative to that being emitted from fossil fuels?

Yeah, now that's a good question. So… Biological… So there's a tremendous amount, and I don't have the numbers right in front of me, but it's a small fraction at this point. Biological carbon sequestration/carbon storage, the majority of which we think is in forests, but there are substantial amounts going on in the agricultural soils, for example. But this is a part of the solution, it is not adequate to address all of it. So we're looking at a fraction, it's not an insignificant fraction, but it's still a relatively small fraction of the total amount that's being emitted. Considerable amounts of carbon go into the oceans, of course, or other carbon sinks. Although the turn over there can be quite rapid. So it's part of the puzzle, but it can't solve the problem on its own by any means.

Okay, thank you. Another question we had was, and this was a general question. Are there tree species that store more carbon than others?

Well, yeah, that was a good question. We have a couple of things going on here. A rapidly growing tree will store more carbon more quickly than a more slowly growing tree. But if we're taking a long view of this, a tree which is going to live for three or four, five hundred years will hold on to that carbon a lot longer than would a tree, like an aspen tree, that has a lifespan of 100 years. So aspen early on grow very quickly, store that carbon quite quickly, but they also die and fall over and that carbon, much of that will return to the atmosphere when they decompose. An oak tree, a red oak tree for example, grows more slowly, but by the same token, in the short term it stores carbon less quickly certainly. In the long term it's going to hold on to that carbon a lot longer. We tend to think, we prefer to think of the entire ecosystem, and what you'd like to see is a transition between rapidly growing, early successional species, and then later, more slowly growing species that basically take up carbon and hold on to it a lot longer. So there's two ends of that. There's certainly two parts to that question. The short, the fast growing, short-lived species versus more slowly growly, long-lived.

Okay, thank you. Sorry, we're getting more and more questions, so I'm trying to go through.

Keep them coming!

As you're talking there's more questions. Uh… another question we had was dealing with how do we, and this is more of a management, we have quite a few that are management questions, so let me go through a few of those. How do we balance the desire for old growth forests and the habitat they provide with the need for carbon sequestration?

Well those are actually, those are… I would argue that those are completely compatible. In fact, an important benefit or conclusion here is that old growth forests are important carbon sinks, and they continue to be. And there's a variety of kinds of evidence. Unfortunately there's so few old growth forests that are left, and particularly not in temperate deciduous forests. There are just almost none. So it's difficult to actually get a number on that. But there are a few reports out there that indicate that, as our data would suggest is the case, that old growth forests continue to be important carbon sinks, and they continue to take up carbon. So on the one hand this is good news. Now what we do have to balance is of course the need for wood products, and so we have ongoing needs for sustainable production of forestry, of forest products, and we need to very carefully balance that with our need, I think our need, to increase the acreage of older, complex forests. And this I think is where it's so exciting to have management tools coming online which do balance those two things, that they can generate the complexity while also yielding a useful product, in this case wood, from those systems. Yet maintain that carbon storage capacity. That to me is the real challenge. I'm hopeful that in terms of aging forests that we can remove from primary consideration that these should be cut so that we increase carbon sequestration, or rather they should be cut because they're no longer storing carbon,; they're not part of that benefit. And we, I think our data shows that ecological service, carbon storage, continues well into the hundreds of years of age. We'd like to see many more old forests out there.

Another question we got was dealing with some guidance for urban forest management. In your research if you could give some guidance. Are there certain trees with certain leave structures and canopies that are better to plant in urban areas in order to assist with mitigating carbon emissions and urban heat island effect… Any idea the extent to which these smaller urban stands can help with climate change mitigation, and do you need large, sorry this is kind of a large question, do you need large canopies to get more meaningful mitigation impacts, or is it worth planting area tree stands in urban areas?

Yeah, no actually that's a great question. There are a number of groups now that are looking very carefully at urban forests, and the role that they play. And I think the picture is becoming clear that they play quite important roles. Of course there are a suite of challenges that they're, working in urban forests that you might not have in natural forest systems. So I'm… you know large canopies that might drop limbs on people, and those sort of things are very real concerns, and so you have to manage the forest for people walking around underneath the trees, and there may be a different way than you would in unmanaged forests in the upper peninsula of Michigan. But in general I think native species that actually have long lifespans. Now this means that they need to be resistant to pests. They need to have resistance to the sort of stressors that may be present in urban environments, but maybe less so in … further away, natural areas. But long-lived trees, a diversity of them, this issue of biodiversity is very important. We never know where the next pest is coming from or what communities invested heavily in ash trees, for example, as those trees of course and now emerald ash borer is wreaking havoc on those areas. So a diversity, thinking diversity, thinking native species, I'm a big proponent of those, as well as thinking intelligently about what climate change is going to, thinking proactively about climate change. So all other things being equal, planting something that's not right now at its southern range limit, in which case it might be outside its range limit in upcoming years. You're going to plant a tree that lives to be 80 or 100 years old, you want to be sure that its climate envelope, if you will, will be appropriate when it's reaching those older ages. You're not just thinking in the next decade. We'd like to have big trees that are going live a long time and hold on to that carbon. So do think proactively about what you're planting, so maybe something that's currently at the northern or northern part of its range so that as these ranges migrate northward with climate warming that those trees will still continue to be well within their appropriate climate regime.

Okay, another question we had was dealing with carbon sequestration that is below ground or at ground level, that a couple people were asking that your research seems to be focusing on the living above ground pool of carbon. But a couple questions asked about research on carbon in like woody debris and standing dead snags in forests.

Yeah, that again is a very good question. We've actually spent a lot of time and effort quantifying how much carbon is going below ground, and there's a lot there in terms of production. And in the end some of that gets stored in carbon, in soil organic matter, in soil carbon. There's a lot of current interest in how carbon becomes stabilized in soils. This is particularly important for clay soils, some more fine texture soils that are better able to form aggregates. But soils that we work on in this part of Michigan are very sandy, and are a little bit simpler in that regard in terms of their ability to hold on to carbon. But absolutely this is extremely important. We, as these forests age they actually are increasing the store of course woody debris, or snags and so forth. This becomes an important tool although it's relatively short lived depending on the species, an oak log will remain an oak for longer than an aspen log. But we're in the process calculating exactly how much carbon will be returned to the atmosphere following the death for example of these early successional aspen species. So um… not disturbing soil is a great way of releasing the carbon in it. In fact it's a key element of forestry, minimizing the disturbance to soils so that carbon that does become sequestered, that does become protected within the soil environment, and that's really where it'll remain the longest. In soils there it has the potential for remaining there for centuries, if not longer. But really mostly if it doesn't get disturbed, and so that dynamic of how carbon gets into the soil is a fairly slow process in forests, but then how it gets protected and what we need to do to keep it there; very very important research questions and an active area of research by our group as well as others.

Excellent questions.

A few more questions. O I'm being … longer.

No, no, by all means.

The next question we had was do we know if a warmer climate in the future will adversely affect and stress our immediate and old growth forest species, and if so which more southern trees are logical replacements for the species which might effected?

Well we have a lot of … well I'll try to get the first one. We'll probably change an old growth forest. With rapidly increasing temperatures this is, affects all of our systems, our natural systems. I would posit that a complex old forest, let me back up, old forests, forests that lived for 300 years, two, three, four hundred years have seen a lot of climate change. So trees are, a mature tree is a robust organism that actually has considerable ecological climate amplitude if it's healthy. So that as complexity increases I mentioned resilience also goes up, and so we would argue that old growth forests are more complex. They should have greater ecological resilience. Now that of course resilience only goes so far, but our feeling is that these complex older systems will in fact be better able to continue functioning, continue to provide ecological goods and services in the face of a warming climate than would more simple systems. So with biodiversity, complexity comes resilience. So that's the first part.

Now thinking about southern species… You know, you don't think that, we have a whole rash of southern oak species or oaks that have more southern distributions, chestnut oak for example is here, but it's distributed well into the south. Tulip tree, rhododendron again has, grows a lot here, but has a primarily southern distribution. These would be certainly candidate species. Think about ones that do well, species that do well in the south. I wouldn't necessarily be planting southern pine all over the place, so it's an interesting problem and I think there are urban foresters, there are modelers, there's a very active group out of the US Forest Service, Delaware Office here, Lou Iverson and others that know a lot about species migration, and I bet close to there the resources they have at the Forest Service to think about that. But we're fortunate to have quite a few eastern species that have high level of biodiversity, and we should think about that. But avoid species whose primary distribution is north of here it would only make sense.

Okay, thank you. The last question is could you talk a little bit about the role and impact of the selective or clearcutting and the capacity of carbon storage?

Well, so those are two different things of course. Selective cutting might sweep in a whole variety of approaches including perhaps gap creation, or other kinds of cuts short of clearcutting. So but clearcut is an easier one. There's a whole variety of reasons, mostly economic, why this is a problem that it is. But it's very problematic when it comes to carbon storage for a number of reasons, but the disturbance it usually comes along with that is part and parcel of it. And there are arguments that this may mimic fire and other stand-initiating disturbances. I don't want to get too far into that argument. But clearcutting as a, and then the response of that is typically even aged stands makes it very difficult to generate appropriate levels of complexity in with clearcuts.

On the other hand, selective cutting, if we go into that with an idea of mimicking and promoting complexity, I think we can achieve quite a bit. The amount of data out there is fairly small at this point, which is why I think demonstration projects, like the one on the Two Hearted River, are going to be so important. Can we actually do this? In a way it sounds good on paper. We need large scale demonstrations that this is possible and economically feasible before we're going to see large scale adopting of those approaches. But having said that, there are quite a few other selective cutting regimes out there, which also might be put into play. We need to study them more.

Okay, well thank you so much, Dr. Curtis! This has been very interesting. I would like to, since we're a little over time, I'd like wrap up if we could. I wanted to again thank you, Dr. Curtis, for your willingness to talk with us today about your research on carbon storage. A really, an excellent discussion. Also, a thank you to Ohio State University, National Sea Grant College Program, and Ohio Supercomputer for funding this webinar. I did want to remind everyone that our survey url for this webinar is in the 'chat' feature, so please take a few minutes to fill that out. I also want to refer you to resources and an archive of all the previous webinar presentations, which are located on our http://changingclimate.osu.edu/ website, as well as our new regional site at http://greatlakesclimate.com/. This webinar series is sponsored by The OSU Climate Change Outreach Team, and we'll continue next month with registration up soon. We'll keep you posted. Thank you again to Dr. Curtis and all the participants on this webinar. We hope that this was beneficial and hope you’ll join us again in an upcoming webinar. Thank you again, Dr. Curtis, and everyone have a great afternoon!

Thank you, Jill! Thanks everybody for attending.

Thank you!