Prairie Pod Transcript

Season 6, Episode 51: Prairies do that: climate change resiliency through grassland restoration

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Guest: Dr. Dan Hernández, Professor of Biology, Carleton College; Dr. Sarah Hobbie, Ecology, Evolution, and Behavior Professor, University of Minnesota

Podcast audio can be found online at mndnr.gov/prairiepod

Transcript:

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Megan: Hey Prairie Pod listeners, I'm Megan Benage, regional ecologist with the Minnesota Department of Natural Resources.

Marissa Ahlering: And I'm Dr. Marissa Ahlering, lead scientist with the Nature Conservancy in Minnesota, North Dakota and South Dakota.

Sara Vacek: I'm Sara Vacek, wildlife biologist with the U.S. Fish Wildlife Service, based out of the Morris Wetland Management District.

Mike Worland: And I'm Mike Worland. I'm a wildlife biologist with the Minnesota DNR Nongame Wildlife Program.

Megan: We are part of the Minnesota Prairie Conservation Partnership and we're here to help you discover the prairie.

Marissa: Discover the prairie.

Sara: Discover the prairie.

Mike: Discover the prairie.

((music playing and sounds of Dickcissel calling))

Megan: Hey, welcome back to the Prairie Pod. Marissa, I am pumped because we're going to talk about how amazing the prairie is today. I mean, when do we not talk about that?

Marissa: Yeah, every week. Every week.

Megan: Every week through July and August at least. (Laughs)

Marissa: Well I talk about it every week but yes, I talk about it with you in July and August. (Laughs.

Megan: That's true, that's true, we do talk about it every week probably maybe every day of our lives we talk about it. We just don't record all of those conversations (laughs) which is maybe a good thing if you think about it.

Marissa: Yeah.

(Laughing.)

Megan: But today we're going to dig into the world of prairies and carbon. Marissa what are we going to hear about?

Marissa: Yeah, dig in, we're literally going to dig in, we are going to dig into that soil. I know you love a good um pun there Megan, so.

Megan: I do like a good pun. (Laughs.)

Marissa: Yeah.

Megan: Get me - -

(Laughing.)

Marissa: You know we, trees get a lot of attention when it comes to carbon sequestration but prairies also store a lot of carbon and they have some perks that forests and trees may not, so we're going to talk about a lot of that. You know our prairies have been so good at feeding people with the rich soils that they have and so it's maybe not surprising that they're also really good at storing carbon and we have talked a lot on this podcast or at least a fair about anyway about adaptation and, and how we adapt to climate change and we have certainly mentioned how prairies store carbon throughout the seasons but today we're really going to explore what that means what that looks like and how they can also really help us combat climate change through storing carbon and sometimes even pulling more of that carbon out of the atmosphere where it's causing us so many challenges.

Megan: This just seems like such a timely topic, like the alliteration to talk about. Oh ho! I almost got it all the way to the end of the sentence. I can think of another preposition. (Laughing.) Oh gosh, but before people get the wrong idea this is not a podcast where we're pitting trees against the prairie. We need all of our ecosystems to be healthy and

functioning; we just want people when we talk about climate change mitigation and strategies and adaptation to make sure that prairie is part of that equation because our grasslands are incredibly powerful at helping us basically figure out how to mitigate climate change. And so we just want to make sure that people while you're thinking about trees, you're also thinking about prairies, because the two together are how we're going to get there. Well, and oceans and - -

Marissa: Wetlands and all the things. Yes.

Megan: - - wetlands and all other ecosystems. So before you start thinking that you have to choose, you don't, but it's the Prairie Pod, so we're going to talk about prairie today. That's how it works.

Marissa: Yeah, 100%.

Megan: All right. Let's introduce our guests, and Dan, we're going to start with you.

Dan: Hi, Megan. Hi, Marissa. I am Dan Hernandez. I am a professor of biology at Carlton College in Northfield, Minnesota.

Megan: Sarah?

Sarah: Hi, everybody. Thanks for having me on. My name is Sarah Hobbie, and I'm a professor in ecology, evolution, and behavior department at the University of Minnesota in the Twin Cities.

Megan: Awesome. Tell us a little bit, each of you, just to get us started here. What's the favorite thing about your job?

Sarah: Oh, that is easy. My favorite thing about my job is that I am rarely bored. Maybe when I'm grading exams or term papers, I admit I might get a little bored, but I feel like I am challenged all the time in my job, and I love that about it.

Dan: I agree it's a great question. I think the best part of my job is the time that I get to spend with students. Carlton is an undergraduate institution, and so I'm getting to work with students from their first experience as undergrads through their senior year in figuring out what they want to pursue after that. Especially in getting to work with students in research and exposing them to working in prairies, doing research for the first time, understanding whether that's an experience that they want to have as part of their career, that's a really fun thing that I get to job in my job.

Megan: Well, and I can tell you for both of you, one, being a prairie ecologist, yeah, you're never bored. There's always something different and new to think about. And we were, Marissa and I were once college students once upon a time, and I still like think about the things that I learned at college and how they shaped my career and who I am as a person. I still think about those professors that I spent time with, and even teachers who weren't professors but were at the university, I think about what I learned from them, so it's, you guys are making a difference. It's going to be good. Should we pivot and talk a little bit about everybody's favorite topic, right? Which is like starting really heavy here, but we need to talk about our overview of emission reduction goals and

how we're thinking about getting those accomplished. So Marissa, specifically for Minnesota, what are our climate change targets?

Marissa: Well, in Minnesota, we, with the governor's administration right now has committed to net zero by 2050, and 50% reduction by 2030 in the climate action framework, which is pretty exciting. I would say at The Nature Conservancy specifically, we are actually across all three of the states in which I work, Minnesota, North Dakota, and South Dakota, we've set a goal of 8 million metric tons per year by 2030 in terms of how are we going to contribute to these goals. And the big picture goal I would say is, you know, I think what largely as a global community, what we're striving towards is limiting that warming to 1.5 degrees Celsius. And that is likely to mean, you know, cutting emissions in half by 2030 so that we can start to reach these goals. And so, you know, the governor's goals, The Nature Conservancy's goals, everybody's goals are going to be pretty critical to helping us get there and achieve those targets. One of the things, Megan, I think we should also mention is that there are a lot of pathways to reduce emissions, and I don't know if you want to talk a little bit about that so that we can kind of get the big picture of like where prairie can fit into that process.

Megan: Yeah, and I like how you laid this out, like you truly laid it out as these umbrella like pathways, and then underneath it, there could be lots of different things that you could do in that category. So there's basically three big ones, right? One, you need to find a way to reduce your current rate of emission, so and a way that you could do that as an example is you could switch to renewable energy, you could improve your building efficiencies, I mean, you could upgrade your appliances, these are all basic things you can do that also save money in your pocket at the end of the day. Minnesota passed the 100% clean energy law, which requires 100% clean energy by 2040, and so that is a goal that we are striving for. So the other two categories would be you would avoid new emissions, and so one of the ways that you want to do that is make sure that any carbon that is currently stored stays stored, so you want to avoid the conversion of ecosystems. So you want to make sure that you're not converting our precious prairie that we have left because that prairie is ancient, and it's been here for a long time storing carbon, and so we want to make sure that we don't convert it to other uses, because it's already working hard, it doesn't need to be doing something else, it's already doing a lot as it is. And the third umbrella is you can increase your carbon sequestration, and one of the ways that we primarily do that is through the reconstruction of prairies. So that's obviously near and dear to Marissa's and my heart, and I'm using prairie in many of my examples just so that you can see the connection that prairie has a big role to play here. And Marissa has a funny pun in our outline that says that's what we're going to dig into today again, which could be our bumper sticker for this whole climate change episode. But I also want to mention that out of all these strategies, they tie nicely into DNR's climate change mitigation plan. So we have goals for fleet efficiency, renewable, and energy efficient installations, you've seen this if you visited some of our state parks, how our new buildings are constructed, maybe the camper cabins that get put up. We're doing that with an emphasis and a focus on renewable and energy-efficient design. And then, of course, through all of our easement acquisition and then management work, that's another strategy where we have protection goals for different types of ecosystems. I think one of the big ones right now

is working on - - well, we're always working on prairie, but also peatland conservation is a big one that we're focused on. So all of these things sort of dovetail into what we're trying to do with climate change mitigation.

Marissa: Yes, peatlands can play a huge role in climate mitigation as well.

Megan: They can because they're all carbon. That's like literally what they are. And we're lucky because I don't want to go on a peatland rant, but I'm going to go on a mini-peatland rant. There's a lot of peatland in Minnesota, like we have quite a bit, and different types of it, which is also fascinating and can be its own podcast. So it's not just something that's in northern Minnesota. They occur all across the state, and so it's just another interesting strategy where we can I don't want to say leverage our wetlands, because that sounds like we're just using them, but we can basically use the conservation of our wetlands to help in climate change mitigation, which is awesome.

Marissa: Yeah.

Megan: All right. We're talking a lot. We got to hear from Sarah and Dan. That's what we're here for. We're going to learn from them. So okay Sarah, we're going to start with you. What makes prairie a good ally in the fight against climate change?

Sarah: Yeah, so prairies store a fair amount of carbon, and they store it in their soils, and so preserving prairies, as you mentioned previously, prevents that carbon from being emitted to the atmosphere as CO2, and restoring prairies can promote accumulation of carbon in soils. And so restoring prairies can potentially slow the rate of carbon dioxide increase in the atmosphere and preserving the prairies that we have can reduce our contributions to rising CO2 in the atmosphere.

Dan: Sarah is exactly right, that the ability of prairies to store carbon is a really important component of prairies, but whenever we talk about carbon sequestration of an ecosystem, we also have to think about the fact that protecting that system or restoring that system has a lot of additional co-benefits. And so if we only focus on carbon sequestration with prairies, we miss all of the other amazing things, many of which you've talked about in other podcasts that are part of prairies, right? The threatened and endangered species in Minnesota depend on prairie. And so protecting existing prairie or restoring prairie provides habitat for those species. It provides other co-benefits like retaining nutrients or recreation value or providing habitat for wildlife, game and nongame wildlife. So there's lots of additional benefits I think that it's easy to get focused on prairies doing this great job of sequestering carbon when we're talking about climate change, and we get this amazing bonus of all of these other things that prairies do.

Marissa: Yeah. I think that it's a really good point, and I think that's one we need to keep making. It's like biodiversity benefits alongside carbon benefits because I think, you know, we talk about both of these crises we're facing a climate crisis and a biodiversity crisis, and so places where we can have both of those benefits is super awesome, so thanks for pointing that out, Dan.

Dan: And Marissa, there is some carbon mitigation strategies that don't include those co-benefits, right? And so when we have situations where there are multiple benefits to

a single action, and some of that is climate-related, but some of it might be biodiversity-related, it's really important to not forget that piece because it's different than some other strategies that only maybe sequester or minimize emissions of carbon.

Megan: I could be totally biased here, but I like when we focus on ecosystems for a climate change mitigation strategy. Just because if you're focused on an ecosystem, it's as you guys are both describing here, it's already doing all of the other work for you. Like if you have a healthy, resilient, diverse prairie, not only as you're describing is it storing carbon, but it's a healthy, diverse, resilient prairie, so you get to go see grassland birds, you get to go see bees, you get to see all of these different kinds of places. It could also be a place that where traditional foods are for different tribal communities, and so there's just all of these connections and interactions, and I like when we think about that big picture and less siloed about what our approach is going to be.

Marissa: Yeah. So Sarah, you were talking about prairies storing carbon. Can you tell us a little bit more about where that carbon is stored in the prairie and how it gets there?

Sarah: Yeah. The majority of the carbon in prairies is stored in dead soil organic matter, we call it. And then the way that it gets there is that plants take up carbon dioxide from the atmosphere through photosynthesis, and then they make sugars, and the plant uses those sugars to build biomass, and when the plant dies, both aboveground and/or sheds dead leaves or roots, then that detritus and prairie most of that detritus is coming from dead roots, it ends up in the soil, and some of it gets basically transformed into soil organic matter that can actually persist for a really long time, and so that's another kind of benefit of carbon sequestration in prairie soils that we haven't talked about too much yet, which is that, that some of that carbon can actually last if it's not disturbed on the order of centuries to millennia. So once it's there, it's going to stay there for a long time before being returned to the atmosphere. So the carbon is stored in prairies both in living roots belowground, but the majority of it is stored as this soil organic matter. And so the plants are essentially acting as kind of carbon pumps, removing carbon dioxide from the atmosphere into the solar organic matter where it can persist for a long time.

Megan: I really like that you said carbon pumps. I've never thought about them that way. I've always thought of them as, I've only thought of the end point, and I've only thought of them as like a safe, like it's where you're putting your money, but in this case, it's where you're putting your carbon. It's just stored there. But I like you describe it as a pump because it's an active process that's continuing to happen as opposed to a static thing where you just, you put your carbon in there and you're done. Like no, it's a process that's constantly moving and functioning, so that's maybe a better way for me to think about it. So okay, I have a soil health background once upon a time, former Megan worked for NRCS in Soil Water Conservation Districts, and we worked a lot with agriculture producers on soil health systems. Basically, to try to mimic some of what these natural systems are doing to help us become more profitable as we're farming, but also even more conservation-minded, right? And so I'm just wondering if you could describe a little bit what happens when we convert a prairie to row crop agriculture. Like, what happens to that carbon? Why is it lost? And if you then try to go and reverse and reconstruct a prairie, which is as we've talked about many times in this podcast, is

really hard to do and is not necessarily a recipe process, like it's very complicated to rebuild an entire ecosystem. Obviously, it's got billions of organisms in soil alone. So Dan, just tell us a little bit about what's happening when we make that conversion.

Dan: Sure. As Sarah pointed out, this carbon that's in the soil is there because plants have done photosynthesis, grown roots, those roots have died, and the dead organic material is in the soil. And the reason that it stays there for centuries or millennia is that it's protected, it's chemically protected and physically protected from the bacteria and fungi, the microorganisms in the soil that want to use that carbon as an energy source, but they can't. They can't because it's physically and chemically protected. Physically may mean that it's in a clump of soil and it's not, doesn't have access to enough oxygen for those bacteria to get access to it, or it could be attached to some other molecule chemically that's really hard to separate. And so that carbon isn't accessible for those microbes that want to eat it. But when we play, we break up the soil, we expose that chemically and physically protected carbon to the atmosphere. We expose it to oxygen, we take those clumps of soil, and we break them into smaller pieces, we allow the microbes access to carbon that they didn't have access to before. And microbes are always respiring carbon. This carbon pump of plants putting carbon into the soil, there's also a pump out of that system that is the microbes doing their thing, living their lives, and using that carbon in the soil as their energy source. On average - -

Megan: Is this true, so you said plowing, I just want to ask a follow-up question. This would be true for any tillage that we do, right? Like.

Dan: This would be true for any tillage. You know, a surface till, a deep till, the degree to which tilling happens is going to have larger or smaller impacts, but if you disturb the soil, then you expose that protected carbon to the ability for microbes to use it as food. And so the number of microbes, the biomass of microbes can go up, there's more to eat, and as they eat, they then exhale CO2 in the same way that we eat carbon and exhale CO2, and put that CO2 back in the atmosphere. This is always happening in those soils, but by breaking up the soil in any way, it allows for that to happen to a greater degree. And so we can see systems over long periods of agriculture. We can see systems lose carbon over time. Doesn't all happen at once; it happens year after year after year until that carbon that built up over millennia in prairie is being lost on average. Those row crops are not putting substantial amounts of carbon back into the soil, and what is going in is maybe being lost again as the next year's tilling happens, and that carbon is broken down again by those microbes. So the contrast of this is restored prairies that can move this back in the other direction, right? When we stop tilling and we put perennial vegetation back on the landscape, even if it isn't the perfect prairie, those plants are still perennial plants, they're still doing that carbon pump that Sarah talked about, and that accumulates carbon into soil that's been depleted over time. And so those restored prairies have the capacity to accumulate carbon and store that carbon because it's been lost over a long period of time in agriculture.

Sarah: I just wanted to add one thing that the other thing that we do when we convert prairie to row crop agriculture is that we're harvesting material, we're harvesting those crops, you know, and so we're removing carbon that would otherwise just die and enter the soil through our harvest, and the plants that we grow as crops, we've generally, you

know, not me, but breeders in the past have bred plants that are generally putting a lot of their biomass into whatever it is that we want to use those plants for, you know, whether it's food or forage or, you know, or feed or fiber, and so unlike prairie plants that have really extensive, deep root systems, the crop plants that we grow generally don't produce so much root biomass because we bred these plants to produce aboveground parts that we can use. And generally then that material is removed, and so besides disturbing the soil and promoting that loss through decomposition that Dan was talking about, we're also reducing the organic matter inputs to the soil because of the kinds of plants that we grow and also because we're harvesting material.

Marissa: Yeah, that's a really good point.

Megan: Yeah. When you think about healthy soils or a soil health system, I prefer to say system because you're trying to mimic an ecological system, you need that return of carbon, just like you're describing, in the form of leaves, stems, stalks, and so that's really what the whole healthy productive soils is all about is trying to make sure that we see this as residue as resource, and not as something that needs to be removed and taken away from the field. It's actually serving, as you both just described, a really important ecological process that's essentially feeding your soil in a way that's if you are farming that land is advantageous to you because you're reinvesting in that soil, which is essentially the life blood of the farm, so anyway. I'm on a tangent.

Marissa: Those tangents are important for conversations. One of the tangents I was going to ask about was thinking about timeframes, and I was wondering if either of you would be willing to share sort of general like how long does it take when you are plowing up a field or how long does it take for that carbon to be lost versus how much time does it take to be gained if you're going to restore? Are they approximately equal? Do you see, I mean, I know there's a lot of variability around that, but it'd be interesting to know like do we know much about what those timeframes look like.

Sarah: Yeah, I mean, you start to see rapid decline right away when you till. You know, when you first till a soil that's never been tilled before, you'll see pretty rapid decline that continues over decades, and then to build that back up, I would say we have less information about how long that takes, and Dan, you can weigh in here because you looked at this directly. When we see accumulation over decades, one thing that I will say is that there have been some studies that have shown that, you know, even after multiple decades, we may not get back up to the carbon level that we see in an unplowed prairie, and we don't quite understand, you know, why that is. But we do have information that suggests that, you know, once you start to restore a prairie, once you stop tilling that, you'll see accumulation that continues over decades.

Dan: Yeah. I think that there's a challenge in the fact that for many of the places that we plowed up, we plowed up the best places first, and we don't have records of what happened to those best places when they were plowed, and for the entire duration that they were plowed. And prairies are really heterogenous landscapes, and so we are able to see like how long it takes for marginal agricultural land to go from productive to unproductive, and maybe even abandoned, but for really high-quality agricultural lands, we're still in a period where with some nutrient inputs, those soils are able to produce really strong crops even after all of this tilling that's happened over a century or more.

When the same thing goes for restoring prairies and looking at the pattern of what happens afterward. Having long-term studies of what happens for decades and decades is hard to do, and so we have some places where we've monitored this over long periods of time, 10 years, 20 years, and then we rely on looking at prairies of different ages and trying to model what the rate of accumulation is by looking at how much carbon is there in a 30-year-old prairie or a 40-year-old prairie or a 50-year-old prairie. Can we get an approximation of whether these are still restoring carbon? But because these systems are really heterogenous, it's not a perfect estimate of how long that accumulation might happen. For sure decades. We've measured it over decades, we know that, you know, 20, 30, 40 years these systems are accumulating carbon. Do they do it for a century? That's a harder question to answer, and will they get to that initial level that they were at before? There's evidence like Sarah said that we won't, but that may be complicated by the fact that growing seasons are longer and species compositions of changing and the impacts of climate change on these systems may mean they can store even more carbon than they could before, or that they will all store less carbon than they did before. Those are open questions that we won't get to answer for several more years.

Megan: Yeah. That's what's fun about science. There's so many unknowns and things that we still have left to discover, and just to give you an idea, way back, way back in season 3, we talked about prairie roots with Justin Meissen from the Tallgrass Prairie Center, and we sort of put him on the spot and we asked him not specifically about carbon, but how long does it take to form an inch of topsoil. And then we had this funny moment off mic where he was like why would you ask me that. Because it's so complicated, right, and so basically the bottom line of what we came to is that there's lots of things that go into forming soil, including paramaterial, topography, climate, the organisms that live in the soil, and the big one, time. And so we ended up with saying essentially it could take anywhere between 30 to 1,000 years to form an inch of topsoil, depending on all of those factors, and in some cases, it could be centuries, so it's complicated, it can take a long time, and for me, when I think about carbon being part of that soil, it just, that's a long time. Like to me, it just reinforces in my mind how important it is to preserve what we have left because we don't have that kind of time when we're talking about reaching these climate change goals. And so you take the time that was already given to you in a way by making sure you preserve the remnants that you have essentially, so that's my take-home message from that long, how long does it take to build an inch of soil.

Marissa: Yeah, I agree. Preserving what we have left is absolutely key, and restoring more to start that accumulation process now, no sooner time than the present, right? It's important.

Megan: We can come up with another catchphrase, Marissa, with just like they say for trees, what's the best time to plant a tree, 100 years ago, what's the second best time to plant a tree, right now, okay, what's the best time to reconstruct a prairie, 100 years ago. What's the second best time right now? Today.

Marissa: Right now, today. Yeah, absolutely. Well, speaking of trees, I am wondering if Sarah, if you'd be willing to talk a little bit about what advantages prairie might have not

to say, you know, over trees or instead of trees, but in addition to or what are the perks that prairie might bring to our carbon storage and sequestration questions?

Dan: I'm really glad that Sarah got to speak against the trees question.

Sarah: That's okay, yeah, don't get me on a tangent because I have other work that I'll tell you.

Megan: What did your kids say to you, Marissa? You, - -

Marissa: You speak for the grass. That's what my girls tell me. I speak for the grass.

Megan: You speak for the prairie grass. Yeah, so trees are great. This is not anti-tree, there's just some things they just don't have, which is our argument for why prairies need to be part of the equation in addition to, it's not a subtraction, in addition to.

Sarah: Yeah. I think it's important for people to understand that, you know, if you look on a per unit ground area basis, that trees, forests actually do store more carbon than prairies, and wetlands and prairies are comparable to one another in the amount of carbon that they store. However, forests and wetlands aren't suitable to grow everywhere, and we wouldn't necessarily want to have only forests on our landscape, and this goes back to what Dan was talking about earlier that, you know, we value prairies not just because they store carbon, but also because they provide habitat for diversity of other organisms, you know, birds and mammals, and insects, and Dan talked about how our threatened and endangered species are concentrated and our grasslands and our prairies, and so where prairies are suitable for the climate then conserving them or restoring them is a great way to store carbon and get all these other benefits as well. So I think this is, you know, we really have to pay attention to which ecosystems are appropriate where on the landscape, and that has to do in large part with climate. So in the Upper Midwest, we have a really steep climatic gradient as we move from west to east, that the precipitation increases moving eastward, so in the eastern part of Minnesota, we have, you know, had historically had temperate forests, whereas in the western part of the state historically we had prairie before a lot of it was converted to agriculture. And so, you know, trees don't grow well where there's not a lot of water, but prairie plants do, so it makes sense to, you know, if we're trying to use ecosystems to store carbon, we want to, you know, focus on the ecosystems that are appropriate for a particular place ecologically. So, you know, where prairies are suited to the climate and the soils, it makes sense to focus on prairies in terms of both conservation and restoration in a carbon storage context. And then, of course, we get all these other benefits that Dan mentioned previously.

Megan: So you're leading us right into this next, because I know people are going to ask, right? What about fire? It's going to be the next thing, like because a common I think misinformation or mistruth, I don't know if that's a word, but a common misperception that we hear is that because prairies are disturbance-dependent ecosystem that relies on fire and grazing as two of the mechanisms for that disturbance, that once you burn it, all the carbon is gone. And so we needed to help set us straight here about how does the management of prairie when you think about fire and grazing actually interact with its ability to store carbon?

Sarah: This is a really interesting question because it's true that burning does remove some carbon through combustion. It's primarily removing aboveground biomass through combustion, and so if you had a prairie that you burned less frequently relative to a prairie that you burned more frequently, you probably would store less carbon in the more frequently burned prairie than in a less frequently burned prairie. But remember that prairies, you know, have a lot of biomass belowground, and generally prairie fires are not burning up the carbon that's in the soil, and they're certainly not burning up the carbon that's, you know, in the root biomass belowground. So fire does remove some aboveground biomass through combustion, which does reduce the amount of carbon that's returned to the soil through, you know, aboveground detritus. Another thing that fire does, which we found in some of our long-term experiments up at Cedar Creek north of the Twin Cities is that there's not only carbon in that biomass that's burned, but there's also nitrogen, which is an important plant nutrient. And when you burn that biomass, you also volatilize that nitrogen, and so over long timescales with repeated burning, that also can drive down soil nitrogen availability and that can also limit the amount of plant growth, and so that can also that effect that's happening through the loss of nitrogen can also reduce, you know, return of carbon to the soil through detritus. And, you know, if you're in a transitional ecosystem, you know, at the ecotone between forest and prairie, you know, burning also can reduce the biomass of trees, which also reduces the amount of carbon stored in wood, so I would agree actually that, you know, frequent fire is going to likely reduce the ability of a prairie to store carbon, but fire may be necessary to maintain, you know, native prairie biodiversity and prevent woody encroachment and invasive species, and so, you know, I think we've been talking about how we value prairies, you know, not just as ways to store carbon, but we also value prairies for their biodiversity. And so, you know, we have to think holistically about management to achieve, you know, all of the goals that we have for managing these prairies. And so it is true that we, if we're just focused on carbon storage, you know, maybe we wouldn't want to burn so much, but if we have other goals for management, then, you know, I think we have to weigh the, we have to, you know, assess those tradeoffs in a way that benefits versus the - - the benefits for biodiversity against the potential costs in terms of carbon sequestration.

Dan: Another important piece about fire is that we just talked about how these systems can lose carbon through tilling, and now we're talking about losing carbon through fire. And it's worth remember that not all carbon is the same and that carbon that is lost through fire is newly sequestered carbon. It was just photosynthesized that year, maybe in the last two or three years, and so the stuff that's burning, a lot of that stuff is not chemically and physically protected from microbes, and so it can be eaten by microbes and through decomposition release through the atmosphere pretty quickly. Only a really, really small percentage of the carbon that comes in through photosynthesis ends up being stored in the soils for centuries or millennia. And so tilling and fire are really different in terms of how they impact carbon sequestration because one is sort of cutting off the potential of a little bit of that long-term carbon to be stored, and the other is really opening up the potential for lots of that long-term carbon to be released.

Marissa: So I was wondering. I'm thinking about like Sarah, you were talking about frequent fire. And so in my brain, I was also wondering like what does that mean and

frequent fire and is there a tradeoff between like doing it regularly versus, you know, every so many years and in terms of how much carbon may be lost or maybe it doesn't matter. I was just wondering what you meant by frequent fire and if it matters, like how often you do it.

Sarah: Yeah, I think it's going to scale. So, you know, the more frequently you burn, the less carbon you'll probably end up with in the soil sequestered, but again, I think it comes back to your management goals and, you know, where you are on the landscape. So we have some long-term fire frequency experiments that Dan and I have both worked in that are, you know, right at the prairie/forest border. So if you want to maintain prairie or oak savannah in that system, you actually have to burn pretty frequently, you know, two out of every three years, because if you don't, you'll get a lot of woody encroachment by hazel and other things coming in. But, you know, if you were in a system that's further west, for example, and maybe, you know, doesn't have woody invasives present in the immediate landscape, maybe you could get away with burning less for your biodiversity goals, which might promote, you know, more carbon sequestration. So I think it depends on the specific system, but I think it scales in that, you know, the more frequently you burn, the less carbon that you'll end up storing.

Marissa: It is helpful to think about that, the scale of the timeframe but also the scale of the amount of carbon relative to different sort of practices in terms of what's being lost in the system, so.

Megan: I don't know why I keep coming up with these financial analogies today. We must be close to payday or something. But as you were describing it, Dan, I was thinking to myself that the soil is your long-term savings plan, you know, the money that you don't tap into or you shouldn't, and then like the aboveground biomass is your short-term savings account, where you're like I'm intending to save this for a vacation, but I also might buy a sweater later today. So that's just how I'm sort of thinking about the two, and so it's more of an impact and more of a hit if you withdraw from your long-term savings account, which is the soil.

Sarah: Yeah, and people have used that analogy in the scientific literature, they talk about it. - -

Megan: It's not just me.

Sarah: - - Yeah, they talk about a carbon debt that you accrue basically by conversion.

Megan: See, the financial analogy makes sense.

Dan: And we produce carbon budgets. You know, we think about carbon budgets as a way to understand the inputs and the outputs. I think the difference in the bank account analogy is that when we're talking about short-term versus long-term carbon sequestration, we're really talking about like different forms of money. Maybe it makes sense to think about like money in checking versus money in retirement, something like that, where it can do so much more and is so much more stable, and has such a greater long-term impact if it is in certain forms than it is in other, more rapidly turning over forms.

Megan: Your soil is your retirement fund. That's the best analogy I've ever heard. I like it so much. So we talked about fire. How about grazing? Do we see the same kind of loss aboveground, or is it different because, well, I'm sure it's going to be nuance because of what, it's the how, not the cow, what kind of grazing are we doing, how long, how many animals, but I'm still going to ask you the question. What about grazing impacts?

Dan: Megan, you are exactly right. Like all of those are really important to understanding how grazing impacts carbon sequestration. It's also complicated by the fact that cows produce greenhouse gases, and so when we think about the impact of grazing on sequestration of carbon, we also have to think about budgets again, and having cows means that there are greenhouse gases being produced. In many cases, having cows means that that grassland stays grassland. And so all of those co-benefits that we talked about, benefits to threatened and endangered species, grassland birds, insects, mammals, those are all supported by having grazing on the landscape, and that is not part of the carbon budget, but again, we have to think about that and the way that grazing can maintain those landscapes, those grassland landscapes. But just like you said before, the impact of grazing is a lot like the impact of fire in that it matters how much you do, how often you do it, how many animals are on the landscape, what the productivity of that landscape is, whether we're talking about flatland or steep slopes, you know, whether there are erosion issues associated with it, what type of animal, right? We sort of default to thinking about cows, but if we're talking about sheep or we're talking about bison, we might end up with a different outcome, but all animals can have an impact on the amount of plant material that is ending up in the soil. They can also have other effects by changing the composition of plants in a system, all grazers are picky to some degree, and so if they're eating some plants more than others, that could affect the total amount of carbon that's being produced in that system over time. How much time it has to recover. Some systems can rebound really rapidly from a certain amount of grazing, and so they might actually see a pulse of more growth and greater sequestration after grazing, but just like fire, if you're repeatedly grazing the same place all the time really intensively, you might not see that same impact. So all of those factors you talked about in building topsoil, you know, climate and organisms and topography and all of those, that is also relevant for thinking about how grazing influences how much carbon is stored in a grassland.

Megan: So we're all, okay, I think I know the answer to this, but I'm just going to ask it anyway. So you mentioned bison, you mentioned sheep, you mentioned cows, we can easily also mention things like rabbits and wildlife, right? Deer, elk, all these things. Are all of our grazing animals producing greenhouse gases?

Dan: Not at the same level, not even close. So there's a huge variation in how much greenhouses gases are being produced by different livestock species, and then if you include native species that broadens the scale considerably also. So for example, if you had to eat meat and you only cared about greenhouse gases, then you should probably eat chickens and not eat cows. But chickens aren't maintaining grasslands on the landscape in the same way that cows might be in certain areas of the country. And they may not even be the appropriate species to raise for a particular person in a particular situation. So again, I think it's too simplistic to say well, this one produces more greenhouses than that one, so it is definitely worse. It's complicated by, you know,

what's the history of production in that area, how does it relate to the land uses of that place, how does it maintain particular landscapes, those things are worth considering when we think about our choices, not just in what animals we're producing, but in what animals we're choosing to consume.

Megan: So I just have one more sidebar question about this. I'm on a tangent and we're going to go with it, but so if you think about a bison and a cow, like bison obviously evolved with the prairie, they're adapted to the prairie, they're naturally part of the prairie. Is there a difference there between when you think about an animal that that is what it's designed to do versus a cow that is a livestock animal and we could put them on grasslands, but we can also put them other places?

Dan: Yeah, the greenhouse gas emissions from livestock, or from any animal, is a product of their biology, just like your own greenhouse gas emissions, Megan, are just a product of your biology, and we all produce - - all species produce different levels of this. But it's a product of these animals eating a really hard-to-break-down material. So grass is hard to break down, and these animals for the most part can't do it directly, and so they have bacteria living in their guts that do that work in an environment that leads to the production of methane. And so it is the burping of methane by cows, by bison that put more greenhouse gases into the atmosphere. If you feed animals a different food source that's easier to digest, easier to break down, like feeding cows corn, you have to suppress those bacteria that are living in their guts to allow them to eat that more simple food source, because they evolved to eat this more complex one. And they do produce less methane as a result, but it's complicated by the fact that we're now growing feed and row crop agriculture instead of having them graze on grass, and it, again, affects the budget of where we think about the carbon coming into a system and the carbon going out.

Megan: Yeah, because you're also losing your retirement plan in the soils when you think about all the carbon that's stored there. Oh, gosh. It's complicated and I like it.

Marissa: It's super complicated, and the management piece in particular is one I think about a lot, and yeah, there's so much context and nuance, but thank you both for kind of talking us and walking us through that.

Dan: I think the management piece is also super important because grazing can maintain grasslands against woody encroachment in the same way that fire can, and as you know, it's getting increasingly difficult to do prescribed burning to maintain those grasslands with climate change. And so in some cases, if fire isn't appropriate, it's too costly, it's too complicated, it's places that might be too remote, grazing may be the best management tool for maintaining that grassland, and yes, it may come with some methane emissions, and yes, it may even come to some degradation of that grassland. Maybe the overconsumption of a key species or something like that. But if it's the only way to keep that grassland in place, it may be the best way. So I do think that this is really important when you think about management.

Megan: And the flipside of what you just said is that yes, it might come with degradation, but it might also come with positive impacts where, for example, the Minnesota Bison Conservation Herd, where we have reintroduced bison at different protected prairie

lands, we've seen changes to the prairie that arguably are positive, so we've seen plants being able to persist that we haven't seen before because there's these wallow areas that now make bare ground, and we're seeing ground nesting bees in places that we didn't see before because this complex interaction of species is happening. And then we also see in some cases stimulation of plant species because there's a chemical reaction that happens when the enzymes and the saliva of the animal touched the plant, and there's a communication that happens there that we don't fully understand that then the plant is stimulated to grow more. So hopefully, we're not messing the listeners up too much with how complicated it is, but it is I think the bottom line to just simplify it out of the gate is that it's important to think about this as a multidimensional approach. So it's really important to think about biodiversity in addition to carbon storage, and then also calculate all of these costs and benefits in there, and it's not a simple equation of store carbon good, release carbon bad, it's not that simple. There's other calculations that need to be made in there when you start thinking about what is the best choice at the end of the day.

Marissa: And I think that for me, it's like the, you know, understanding that the largest bulk of the carbon storage is in the soil, and that that keeping that prairie and that grassland there is going to keep a large amount of that soil carbon, and that the things we do on the surface to manage it for biodiversity may have some impacts here and there, but those are small trade-offs to make for the biodiversity pieces while largely storing most of that soil carbon in place, right? So I think that's kind of how I, my take-home from this, too. Dan did a great job talking about grazing, and one of the things you alluded to there was the fact that cows made certain plants and not others, and so one of the other questions I have them from that is, you know, how does the plant community diversity aboveground impact the soil carbon? Like does that have an influence with that aboveground diversity is? I don't know Sarah, if you can talk to that a little bit.

Sarah: Yeah, so we've got some experiments up at Cedar Creek again that I alluded to earlier, but there have been a number of experiments actually around the world that have looked at this question, and it seems that increasing the number of species in your community increases the amount of soil carbon, and this is most likely because when you have more species of plants, that leads to overall greater plant growth and more carbon returned to the soil. And then I think there is some feedback that operate, so Megan's been alluding to soil health all along, and, you know, as you increase the amount of carbon in the soil, that actually has soil fertility benefits, carbon-rich soils can hold more water, they also can hold on to more different nutrients, so that seems to also then further promote plant growth, which then returns more carbon to the soil. So more diverse prairie plantings seem to be, have more soil carbon, especially if those plants are different kind of in the ways that they make a living. So, if you have a mix of, you know, warm season grasses and nitrogen fixers, and cool season species that can increase the overall growth of the community and increase soil carbon.

Marissa: Yay diversity, right? Like we do, we do that--

Megan: (Laughing…) (Two speaking at once) Marissa, you beat me to it!

Marissa: We do that all the time in this podcast, yay diversity in so many different ways.

Megan: Yay diversity! Sarah, you just proved that we know what we're talking about like telling them this all the time. If you had to wager a bet, bet on diversity. It's going to help you out every single time. When in doubt, add more species, native species, let's be clear. So well, okay, let's pivot just a little bit and talk about math, math is my favorite thing. Well, it's one of my favorite things. I do like the math, which is funny because every time I tried to do math on this podcast, I've done it wrong, but it doesn't take away my love and joy for it. So one of the things that we often get asked is, you know, what is this prairie doing. And so it seems like it would be reasonable to consider how do we actually calculate how much carbon is being stored in that prairie. As another way to demonstrate to people with kind of this numerical equation, right? Here's another benefit that you're getting. Here's how much storage you're getting out of this parcel of land. Here's what it's doing, basically answering that question. What do you think, Dan? How do we do the math?

Dan: That's a great question. It's either fairly complicated math or it can be really easy math, like addition. So the more complicated is if you want to make an estimate of how much carbon your prairie will store over the next 20 years, and you know a little bit about the type of prairie that you have, you know, something about soil type, you know something about climate, maybe you even have some measurements of like existing amounts of carbon in the soil or something like that. There are some really great models out there, and some of those models are just based on we've measured carbon over time in a bunch of places, and we can sort of like extrapolate out from that and make an estimate, and some of them take into account things like climate, things like species composition, those sorts of things, too, to give an estimate. For a given region, we're pretty good at having a range of a reasonable estimate, and when we measure it in a more detailed way within that region, we end up with numbers that tend to fall within that range. So if you're okay with a range, then that's a great way to do it. If you're not okay with a range, if you want to know exactly, then you have to measure it yourself. And measuring soil carbon is relatively easy. It requires a fancy instrument to do the work, but it really is just taking a sample of soil and running it on that instrument to measure how much carbon is there, and then you wait a period of time, and you do it again, and that can be a decade, that can be two decades, that could be longer. But that is by far the best way to know how much carbon your actual system is actually storing. The problem with that method is that you have to wait 10 or 20 or 30 or 40 years to get the answer, and I think that there are places where that's been done. We've done that in the natural lands at Carlton College, the Carlton Arboretum. We have a series of restored prairies, and we've been able to look over 20 years at the exact same place, taking a soil sample in the exact same place repeatedly over 20 years, and watching the carbon accumulate in that exact place. What we see is that if you look at the ranges that exist for this area, that our direct measurements fall within that range, but where exactly it falls depends on which prairie we're measuring. And so those differences, the heterogeneity in prairie have an impact on exactly how much carbon is being stored. So it really just depends on the goals. It depends on the goals of who is doing that estimate or who is doing that direct measure in terms of which is best.

Marissa: Yeah, thank you for that, and I have two follow-up questions. One is I'm curious that range that you're seeing, like what is the range of variability you're seeing in

those prairies. Maybe we'll start with that one. Like how different are they, I guess, is what I'm trying to get at.

Dan: Marissa, that's a great question. In our system, we're looking at a set of prairies that were all planted at different times in the past, they're all contiguous, they're all adjacent to one another, so they're really all in one place, but we're measuring 13 prairies all separately. And what we see is that the amount of carbon in those soils varies by like 50%, even in basically the same place, right? This is a small area, easily a loop that you can walk around in an hour and a half would go around this entire block of prairie, and in that area, there's a 50% difference in the prairie with the most carbon and the prairie with the least carbon. They're all accumulating at about the same rate, but if they started after being in agriculture at having really low carbon, that rate gets them to a low level. And if they started at a higher level, then they have that same rate, but they end up at a higher level, so they maintain those differences even after being in prairie for decades. They retain those differences in initial conditions.

Marissa: Yeah, that's really cool, yeah, and it just highlights that incredible variability just even in a small place, and the importance of like understanding that when we're thinking about this. The last.

Megan: I was just going to say the legacy of our actions on the land, right? So it's every, we say this a lot at field days, but every choice that's made connected to that parcel or that piece of land, that history shapes it for the future, and so we can make decisions, you know, to help improve that prairie or reconstruct it or connect it or all of these things, but it's still living its legacy, and I just think that's pretty fascinating. No pressure, all the choices that we're making right now, but I mean, it like your choices that you make do matter, and they can have lasting impact on the land, and so it's something that I think we need to be really aware of how connected we are to that choice that we make.

Marissa: Yeah, good point. I did have one other question. You were saying that, you know, your second method of calculating carbon was measuring it, and you can measure and then weigh it and measure, and that will get you, right, is how much that carbon is changing. But if somebody just wanted to know like what is the current stock of carbon, like just measuring that once can give you that estimate, right? So you can sort of get what is my current stock of carbon by doing some measurements. Is that true?

Dan: That's true, and it would, you know, cost about 10 bucks if you find the right lab to send your sample to and you sort of know how to prepare it. If someone is preparing it for you, it might cost a little more than that, but by taking a sample of soil and sending it to a lab, you can know how much carbon is in that soil. If you want to know like how much of that carbon is in forms that are more stable versus forms that are turning over more rapidly, like we talked about before, that's a little more carbon, but it's still measurable. But if you just want to know the total stock, that is an easily measurable thing to do.

Sarah: I would just add that, I mean, there are some tricky parts to that in that, you know, you talked already, Marissa, about there's so much variability. And so even within

a single prairie, you know, you can have a lot of variability. So to get like a precise estimate of the amount of carbon that's being stored, you have to try to account for that variability and sample across that, and then the other thing, too that, you know, we've been talking about is that prairies can build carbon deep in the soil, too. And so again, if you want an accurate assessment of how much carbon is in your soil, you have to also try to sample over depth, so that can add to your 10 bucks, you know. If you really want a precise estimate, you need to sample in multiple places, you know, and over multiple depths.

Marissa: Yeah. Really good point. Thank you.

Megan: Well, as always, we get to this point in the podcast and it's like okay, we could do five more podcasts about this topic, but we've got to move on to our next section.

(Music playing)

LET'S SCIENCE: To The Literature!

Science!

Megan: Okay. This is the part of the podcast where we recommend a book, a blog, or a paper, and, or a website, whatever, just resources where you can learn more. That's the intention. So we're going to start with Sarah, and what are your picks?

Sarah: I cheated and I actually picked three papers to recommend, and they're all related to one another. And actually, one of them lead author is by Marissa. So there are three different studies that are comparing different so-called natural climate solutions, so different management options for trying to promote carbon sequestration and offset emissions. And so there is one analysis that's led by Griscon that was published in 2017 called *Natural Climate Solutions*, and that's looking kind of globally at the potential to use these natural climate solutions for mitigating climate change and offsetting emissions. And then there is a second paper that was led by Joe Fargione, who is based here in the Twin Cities at Nature Conservancy, and it came out in 2018, it's called *Natural Climate Solutions for the United States*. And so this is dialing down and looking specifically at the US and the potential for natural climate solutions to offset emissions. And then our very own Marissa has a study that came out in 2021 is just focused on Minnesota, so it's called *Nature and Climate Solutions for Minnesota*. And the reason that I like these papers is that I think they're a good reality check because they really try to quantify how much carbon can these different, you know, restoring prairie or implementing cover crops or doing conservation tillage or reforesting, like how much do all these different land use change or land management practices store carbon and, you know, thinking about like what the potential is to actually implement these on the landscape, you know, realistically, how much of our greenhouse gas emissions could we offset using these natural, so-called natural climate solutions. And so yeah, I like these papers because they kind of move from the global to the local scale, and they also are trying to, you know, put everything that we talked about into a bigger greenhouse gas emissions context. So those would be my recommendations.

Megan: I like it. Marissa, you're going to have to do a follow-up paper your backyard. The global, US, Minnesota, your house.

Marissa: It was very much a team effort. Sometimes it's convenient having your last name start with A and end up with the front of the alphabet, but yes, that was very much a team effort. But it is, you're right, like that was kind of the goal is the stepping down process to locally, to really figure out what can we do here, you know, in Minnesota to contribute like what is the potential of these things and where should we thinking about putting our energy.

Megan: I like it. Dan, what are your picks?

Dan: My recommendations are a blog, a newspaper article, and a scientific paper. The blog is The Prairie Ecologist by Chris Helzer. I feel like it should probably be mentioned on every episode of this podcast. Chris does an amazing job of talking about all things prairie and also has fantastic photography on his blog. He has a great post that is titled *What We Know About Managing Soil Carbon in Prairies: A Complete But Disappointing Guide*. I feel like it does a really good job of capturing what we know and what we don't know about carbon sequestration in prairie. The second is related to the discussions that we had about grazing. It's a New York Times article by Benjamin Ryan about keeping cattle on the move and carbon in the soil. It touches on some of the complexities of how grazing animals influence carbon sequestration. Some of the hopes and dreams of certain people in the ability of grazing to sequester carbon, and then some of the complexities of the realities of how that plays out on the ground. And then finally, I recommended a paper that was led by an undergraduate that works with me at Carlton College, where we did these direct measurements of carbon sequestration in the Carlton Arboretum. So that's a paper in Ecosystem that just came out in 2021 led by Kate Libby, and it's a great way to see how carbon is measured over a 20-year period and what it looks like in a restored prairie.

Megan: Perfect. Marissa, after all this talk about the climate, climate change, carbon sequestration, and prairies, I just want to go see one. I just want to go spend some time in my friend at the prairie and thank it for all the work that it's doing for us every day that we forget to thank it for. So what do you think? Should we take a hike?

Marissa: Let's take a hike. Where should we go?

Megan: Well, Sarah, where do you want to hike to?

Sarah: I've already mentioned Cedar Creek a couple of times. That's where I did a lot of my research. And Cedar Creek Ecosystem Science Reserve is a research reserve that is located near East Bethel, Minnesota. It's in both Anoka and Isanti Counties, and it's, not all of it is open to the public because it is a research reserve, but there is a public trail, the Fish Lake Nature Trail, and during the summertime, we have bison on part of the reserve, and there's an extension of the trail that goes into the oak savannah, and so the oak savannah is prairie with some trees, right? So and it's, you can see the bison if you're lucky and the bison happen to be near the trail that day, but it's actually a great place to just enjoy oak savannah and prairie and it's also one of the best places to see redheaded woodpeckers in Minnesota, well, anywhere, and besides that natural trail, there's also a lot of public programming that we do at Cedar Creek, and a lot of it is related to prairies and climate change and carbon and so you can find out about both the nature trail and also all the other public programming that goes on at Cedar Creek at

the website, and I assume we can put a link to the website, so yes. It's cedarcreek.umn.edu, but it's a great place to visit and see the really nice oak savannah.

Megan: We did a savannah episode this season, so please check that out. Dan, where are we hiking?

Dan: My pick for a hike is an area that is new to me. I actually just visited it for the first time last year. I started a new project at Spring Lake Park Reserve in Dakota County. This is a restored prairie that also happens to have a bison reintroduction as part of their restoration work. This is a really cool study. They're doing a lot of vegetation monitoring, they're doing a lot of monitoring of other species as well, but the work that my students and I are doing, there is to think about how bison influence soil processes like carbon sequestration in restored prairie. We know a lot about what bison do in native prairie remnants where bison have been reintroduced. We know a lot less about what bison do in restored prairies. And so this is a really cool county level project that is trying to do restored prairie and have bison as part of that restoration, and then also monitor the impacts. There's some great biking trails there, there's some great hiking trails, the bison are often easy to see because they're in a fairly narrow strip of prairie that is planted with access to trails and so it's a place where you can see bison that is maybe the other direction from Cedar Creek from the Twin Cities, but still, still an easy trip.

Megan: I like it. Bison and prairie. All important prairie pieces working together to go hike. Well, we could talk about this stuff all day. We really could because we all love prairie a lot. But as always, you can find all the resources that we talked about today, including our Let's Science and Take a Hike on our website at mndnr.gov/prairiepod. You're not going to want to miss a moment of prairie excitement, so you're going to want to catch us next week next Tuesday on Prairie Tuesday, where we're going to be taking flight and discussing one of Minnesota's, and the world's, iconic butterflies, the monarch. We'll be joined by Dr. Karen Oberhauser, who is arboretum director at the University of Wisconsin Madison, and Dr. Ray Moranz, who's a grazing lands pollinator ecologist with the Xerces Society. Both of whom have been studying monarch butterflies for their entire careers, and they're perfect to fly us through the life of the majestic monarch, their incredible migrating life cycle, and how we can part of the solution and not part of the problem, as my mom would say, when it comes to figuring out how we can help monarchs persist in the prairie forever. All right. This episode was produced by the Minnesota Department of Natural Resources South Region under the Minnesota Prairie Conservation Partnership with partial funding from Minnesota's Nongame Wildlife Program. It was edited and audio engineered by the fantastic Dan Ryder, our web production team is led by the equally fantastic Bobby Booz, and our social media lead is the amazing Kelly Randall. What should we say to sign off? Don't forget to invest in your retirement account? The soil.

Marissa: The soil. (Whispers)

Marissa: We gotta, we don't need to whisper it. We should shout it.

Megan: The soil. (whisper).

Marissa: The soil. (Laughter)

Megan: Prairie soils. (Laughter). I don’t hear them saying it so. (Laughter) We’re left out over here. We’re all in. We’re whispering it and they’re just looking at us.

Marissa: Yeah. Well, thank you both for joining us. I super appreciate it.

Sarah: Thanks. It was great to be with you.

Dan: Yeah. Thanks for having us.

((sounds of birds chirping and wind blowing))