University of Minnesota Nutrient Management Podcast Episode "Agricultural drainage and nutrient management"

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Paul McDivitt:	Welcome back to University of Minnesota Extension's Nutrient Management Podcast. I'm your host, Paul McDivitt, communication specialist here at U of M Extension. Today on the podcast we're talking about ag drainage and nutrient management. We have five members of Extension's Nutrient Management Team: Dan Kaiser, Jeff Vetsch, Lindsay Pease, Brad Carlson, and Fabian Fernandez to cover the basics and beyond. Welcome. Why don't you each give us a quick introduction?
Jeff Vetsch:	Hi I'm Jeff Vetsch, I'm a sole specialist or neutral management person at the Southern Research and Outreach in Waseca.
Dan Kaiser:	Daniel Kaiser, I'm a nutrient management specialist with U of M Extension house at the Saint Paul campus.
Brad Carlson:	Brad Carlson, Extension educator work out of the Extension Regional Office in Mankato.
Lindsay Pease:	Lindsay Pease, nutrient and water management specialist at the Northwest Research and Outreach Center in Crookston.
F. Fernandez:	And I am Fabian Fernandez, the nutrient management specialist here in the Saint Paul Campus and I work primarily on nitrogen management in corn cropping systems for crop production and water quality.
Paul McDivitt:	All right. First of all, can you explain what happens when we drain soils?
Brad Carlson:	Yeah, so if you think about the soil as being actually a matrix of, you've got your soil particles of course, which you can think of like tiny little rocks, but they're the mineral part of the soil. But then you've got the area in between the soil, which we would call pore space, and then of course there is the soil water, which is also part of the soil and of course there's organic matter also. When we fill the pore space completely with water, instead of having air in there, we of course are eliminating oxygen, which is necessary for plant growth, root growth and microbial activity, certain types of microbial activity and so forth.

Brad Carlson: What we're accomplishing with drainage then is trying to pull the water back out of the pore space to the point where we've reintroduced air into the system. If you think about the drain tile as being a pore itself, which it really is, it's just one really great big one, you're just simply flowing the water by gravity when it becomes saturated and is no longer held to the soil particles by gravity, or water tension, I should say. And it's just simply dripping, if you will, into the drain tile and then of course running through the tile system, the drainage system, based on the slope that we established on the tile and so forth. We think about our drainage systems, their design of the drainage systems in terms of a drainage coefficient. It's important to remember though that because we'll continue to move water into the drainage system just simply based on it's being at a point of saturation or above field capacity, which is having all your pore space fault, the amount of water going through the drain tile is sort of fixed.

Brad Carlson: The drainage coefficient relates to the amount of water we can take away in 24 hours. And so if we think about frequently in western Minnesota, we would design to a quarter inch drainage coefficient that's going to drain a quarter of an inch of water spread over an acre or whatever you want in 24 hours. As we moved towards the eastern side of the state, it's more common to be up to a half inch drainage coefficient. But the important thing to remember about that is that's the speed that we're moving the water out at, not the amount of water that we're actually moving that for the most part, as long as the soil is drained, we're going to drain the same amount of water out of the soil profile is just simply a factor of how fast it's going to go and that's really determined by the saturated hydraulic conductivity of the soil and then how deep and how far apart we put the tile lines as well as, of course, it's impacted by the outlet in the capacity of the outlet to take the water out away from the field.

Lindsay Pease: I think it's important to think about really there's sometimes a lot of questions about drainage over draining the soil, but really you're just bringing it down to field capacity where the plant starts to take up the water. You're only removing a small part that's gravity drainage and its not overdrawing the soil so you're not taking water away from the plant and I think that's an important distinction to make.

F. Fernandez: Basically an easy way to understand it is if you have a sponge and it's in a glass of water and it's floating in that water, that water has no place to go, the sponge is full of water or maybe a glass with very tiny holes, that's what the soil without tile drain will be like. It will drain slowly and first all the free water will drain and then the water in the sponge will start to drain to a certain point and then whatever is left after, when you squeeze the sponge, that water will be the field capacity water that is still in the soil. So the tile drain, what it drains is basically the free water that is in that system, not what is held by the soil.

Paul McDivitt: What are the impacts of drainage on crop production and water quality?

Brad Carlson: Well of course probably the biggest factor we think about these days is nitrates. Nitrate is negatively charged as are the clay particles in the soil, so nitrate is not held in the soil and so for that reason it will move with the water. So there's been obviously a lot of focus on nitrates and water, both surface and groundwater, and the extension which we're taking water away from the fields through our drainage systems there's going to be some nitrate in that. There's been a lot of attention drawn as to why their drainage systems are actually causing the problem. They certainly, it can't be denied, they're a conduit of the problem. Whether they actually are responsible for it, I don't believe that they are, It's more of a factor of the environmental conditions in the field. But to that extent, if we don't manage nitrogen properly in our fields, if we apply too much or use practices such as the wrong type at the wrong time and so forth, we can lead to having higher losses in nitrate through the drain tile.

Lindsay Pease: And from a phosphorous standpoint, there's been a long term belief that the phosphorous, once it's in the soil profile, it stays in the soil profile. And I think it's a good time when you're talking about drainage to really think about the fact that actually there is a little bit of phosphorus that's always leaving and it's soluble form that's gonna leave with drainage water. And you know, we knew that this was happening even back in the 1970s but it was kind of an amount that was considered to be negligible. And now why kind of all of a sudden you're starting to hear these water quality concerns with phosphorus and freshwater systems is because we're finding out that that amount of phosphorous that's leaving through the tile that we thought was negligible is actually enough to promote growth of algae in freshwater systems, so all of our fresh water lakes in Minnesota can be at risk if you have high phosphorus losses.

Brad Carlson: We've had research plots at Waseca, and Jeff has been directly involved with those, got established in the mid 1970s, monitored phosphorus and nitrate. Not a lot of focus on the phosphorous, those numbers exist but we've done an extensive amount of looking at the nitrate. And so what we tend to see with the water flow out of those drainage plots is obviously a lot of that happens prior to planting, so obviously it's wet and saturated in the springtime and we see most of the drainage coming through the drain tile at that time of the year. Consequently, a lot of the nitrate losses from that time of year when the crop start growing and using water out of the profile, then we see the amount of water flowing through the drain tile really going down significantly, diminishing, to the point where it doesn't exist in a lot of years.

Brad Carlson: And we also, if you look at the dynamics of nitrate loss through the drain tile, a large percentage of that then of course mirrors the loss of water. But the thing we have to recognize is in most cases that's not nitrogen that was applied for the coming years crop. So to some extent there's going to be nitrogen that might've been left over from the previous year's crop that's going to be lost and then in addition to that, we recognize that significant amounts of nitrogen are mineralized from soil organic matter, and that happens by microbial action as long as the soils are warm and they have moisture and air, you're going to have that effect.

Brad Carlson: And so we typically will black layer corn around Labor Day, but we don't cool soil temperatures down to 50 degrees until more or less about the 25th of October. So that's about six weeks of time where the soils are warm enough to see significant mineralization of nitrate in the fall with no living plant out there to take it up. And so a lot of the data from Waseca indicates that a large portion of the nitrogen that we moved through the drainage systems was actually some of this accumulated mineralized nitrate that came from previous year. And for that reason, there's not a lot we can do to impact that with nitrogen management.

Brad Carlson: There's not a lot that we can do to impact that, and we'll maybe talk a little later about some of the strategies we can do to deal with nitrates in water, but a lot of whatever it is that we're going to do, it doesn't have a whole lot of effect on that nitrate.

F. Fernandez: Yeah, and your question was about the crop production aspects. I think nobody can argue against the fact that when you drain the soils in soils like in Minnesota, it's probably one of the most productive things you can do to soils that need that drainage. We do have issues with nutrients that we started to discuss right now, but in reality the other option is not very much of an option for these soils because the ability of us to produce crops in these soils really linked to that drainage. I mean we started doing tile drains since the 1800's in Minnesota and there is a reason for that and it's exactly that we're able to produce crops because of that.

F. Fernandez: One thing that is interesting that we haven't really touched on is the fact that with drainage we not only impacted the ability for nitrates to move faster out of the soil and phosphorus to a certain degree. But also in terms of carbon and carbon storage, we introduce oxygen and so that reduces the amount of organic carbon in the soil over time. And we have a study, actually, where we are comparing draining and drain conditions and that's one of the things that we noticed is that there is typically more carbon in the sites where there is no drainage than the sites where we have drained the soils and so that impacts the ability of the soil to do a lot of other biological functions potentially and maybe even some of the physical properties of the soil over the long-term. But really and truly I don't think we have looked at that in great depth to truly understand what are the of the changes that happened because of that drainage.

Jeff Vetsch: One of the key impacts or factors that the production increase by using drainage or ag drainage is that we're getting the oxygen in the soil and we're enhancing root growth. With enhancing that root growth, we're also increasing the uptake and utilization of nutrients that are already in the soil and that's critical and that's really key and that's every nutrient having a better root system is going to make nutrient uptake more efficient and that's going to increase production as well.

Brad Carlson: If you look at the some of the history of drainage, particularly in the more near term, the amount of drainage being installed really took off starting in the mid 1990s of course that correlates to when the climate started to get a lot wetter. But it also correlates to when yield monitors first showed up in combines and through anecdotal experience when you talk to farmers, they'd look at what happened with the yield monitor in places where there was good drainage when they went over the tile and they saw what the yields were and they saw what it was when they got farther away from the tile and it didn't take much to do the math, that my yield was suffering by 20, 30, 40 bushels an acre.

Brad Carlson: You could start multiplying that times the crop price and then start calculating out the number of years and all of a sudden it was an easy salt of the banker. They could walk in with the yield map and just say, "Hey look, see this". This is how fast this is going to pay for themself and loans were instantaneous 'cause it was very clear on how well that paid.

Paul McDivitt: How does drainage affect nutrient management?

F. Fernandez: Well, in terms of the nutrient management we've been discussing some of these things kind of along with crop production. But one of the things that again is very important to recognize with tile drainage is that while we increase the potential for nutrients to leach out of the field, without tile drainage the biggest concern is that then we lose nitrogen through denitrification.

F. Fernandez: And we have seen years actually in this particular study where we have looked at a drain and drain conditions where we need more nitrogen pretty much every year. There've been very few exceptions where pretty much every year we need more nitrogen in the drain soil, then the drain system to optimize the yields. And so that's telling me right there that if we don't drain the soils, yes we are now losing nitrogen through leaching but we are losing actually more nitrogen through denitrification. Or the other option is that the crops are not able to develop as well as Jeff mentioned when we drained the soils, the crops are able to develop a better root system and take advantage of everything that is in there. And so whether it is that we are losing more nitrogen through denitrification or that we are hindering the plant from really taking advantage of what is in there,. We have a plant that is less effective, we end up actually needing more nitrogen to get to the same level of yield we would in the drain system and so not draining soils is not really the solution to manage nitrogen.

Brad Carlson: I thought it was interesting, Jeff you could comment cause this was your project, but they've currently got a study on their drainage plots there at the Southern Research and Outreach Center that's investigating the use of cover crops and there was one of the trials I know, it required a higher amount of nitrogen to achieve optimum yields yet that particular treatment actually had lower losses through the drainage tile. And so that's really the effect that you guys were talking about was that actually if we optimize crop growth work, we're positively impacting water quality because you're not leaving nitrogen behind then further to be lost.

Jeff Vetsch: Yeah, we were using a cereal rye prior to corn planting and cereal rye was a good scavenger of leftover nitrogen following the soybean crop, but that left less nitrogen available and the synchrony of that end release from the cover crop back to that subsequent corn crop, maybe was not ideal and it resulted in taking a little bit higher end rate to produce the same yield. But at the same time it was very effective at minimizing the amount of nitrogen or nitrate nitrogen that left the profile and at the tile drains in that early spring period prior to that corn crop. Having enough demand for it to utilize it in the production.

Brad Carlson: The only other thing I'd say about drainage and its impact on nitrogen management particularly is just frankly that good drainage opens up the window in our heavier soils in southern Minnesota where there trafficable that allows us a wider application window, gives us more flexibility for how we're gonna manage nutrients and when we're going to apply it and so forth. And so from that standpoint it does give us better tools at our disposal than undrained soils. That can be very difficult if we have to come in in-season and do a split application or can be very difficult to be sure that you're going to get your nitrogen applied in a timely manner. If it's for instance, before planting and so forth, you may be waiting to plant in order to get your nitrogen applied cause you don't know that it's going to be too wet after that to come back and so forth. It just adds a lot of flexibility to the management system.

Lindsay Pease: Yeah and the one other aspect that we haven't talked about yet really is the temperature of the soil too. When you've drained the soil and you've got the air in there instead of water, it actually warms the soil up faster, which is also really important thing up here in Minnesota, so that's another factor. You may actually be able to get into your fields a little bit sooner, not just because of less moisture, but because they're a little bit warmer as well.

Paul McDivitt: How can we minimize nutrient loss through drainage systems?

F. Fernandez: So there are several things that can be used and I would say that they all have their good things and their not-so-good things. We were talking earlier about cover crops for instance and we noticed that, with cover crops, you can capture a lot of that residual nitrogen or in the case of what Brad was mentioning earlier, some of the mineralized nitrogen, mineralization that happens after the crop reaches physiological maturity. If you have a cover crop, you can basically utilize a lot of that nitrogen, dig it out of the system into the cover crop so that you don't lose it. We've seen that, especially in some of these last few years where we have had really wet falls where you measure soil nitrogen before physiological majority of the crop and the soul is basically bone dry, there is hardly any nitrogen in there and very little water as well. And then we started getting mineralization and then with these large rain events that we are seeing in the fall, we started to get some of that nitrogen flushing out of the system. If you have a cover crop you're very effective at potentially capturing some of that.

F. Fernandez: That's the good thing, the challenge is that sometimes depending, especially on when you terminate the cover crop, you can actually, that could result in having to add additional nitrogen to assist them in order to produce the cash crop and so that's one of the issues. There are other options like manage drainage, I couldn't think of the word.

Lindsay Pease: Control drainage

F. Fernandez: Control drainage, thank you, control drainage where it's a way to try to do the best of two worlds. Take the excess water early in the spring, when you need drier conditions and warmer soils for planting, and then maintaining a lot of that water in the system. So basically closing the title so that you don't drain the whole water that's in that profile so that it's available for the crop later in the season. And by doing that, you can also potentially reduce the amount of nutrient loss because simply you're just draining for a very short time early in the spring and then before harvest if there is a need for that, and then you maintain most of that water in the system. So that helps keep that water in the system instead of draining it out. So those are some of the others, and there are others that my colleagues I'm sure will talk about.

Dan Kaiser: I think looking at it mean really I think Fabian hit the key there is if you don't have water movement, you don't have loss. But the problem is with the rainfall events we have, I mean I don't think we can necessarily count on that. And getting back to one of Lindsey's points with phosphorus side, we just finished up a study looking at different volumes of water moving through the upper surface of the profile, and you see essentially the concentration coming through really wasn't varying based on the volume. So really our concentration was dictated more by the soil test itself. So if you look at our risk assessment for phosphorous, I think it's relatively easy because we start getting to more ranges above the optimum level.

Dan Kaiser: I mean we know that that risk tends to increase greatly and you look at that point, I mean really you're risking really a negative return on investment at that point too, so there's economic implications to that as well. With nitrogen, I mean we know that same thing can happen, but it's harder to judge what that optimum rate within the field would be. So you know, in an ideal world, the best way is looking at as Fabian was saying some of those control drainage situations, if you could limit the water moving off site, you really significantly limit the risk for loss.

Brad Carlson: Really there's, and we've already kind of mentioned this but not really organized it this way, there's three suites of ways that we can reduce nutrient movement into drainage water. There's nitrogen management, nutrient management, and so that gets into the whole four R's and following best management practices. There's vegetation changes, particularly the cover crop one that we've been talking about, and then there's engineering practices. So that would include the control drainage, it would include saturated buffers, it would include running water through bioreactors as well as potentially constructed wetlands that might be strategically located in a landscape. And so there's really that four groups.

Brad Carlson: The thing I like talking about or focusing on when we do a lot of our education is that the cheapest thing you can do to keep nutrients out of the water is following nutrient best management practices because those are designed not just for an environmental performance, but they're also designed to be most profitable for the farmers. So theoretically if you're doing that kind of stuff, that's the first easy step you can do. Some of the other things, I think the vegetation stuff is still a bit of a developing science and then of course the engineering practices, probably the biggest problem we have with those is initial costs, you know, most of those practices, now some of them control drainage may not be quite so expensive. The thing you got to remember about control drainage though is that the research shows it doesn't reduce the amount of nitrate in the water, it just simply reduces the amount of water running out and so you have less nitrogen running into surface water but it's accomplished just by reducing the amount of drainage.

Brad Carlson: Some of the other practices though, a lot of the data's shown that they will only remove 10% of the nitrate on an annual flux and so forth. Part of the problem with these, so for instance like with saturated buffers and bioreactors is they are designed to not impact the performance of the drainage system in the field, and so they've got a bypass. And of course if we're losing the majority of our nitrogen, the majority of our water in March and April and what right pre-planting in a lot of cases, then that water's falling through the bypass and it's not going through the treatment, so those can be real variable in their performance. I know a lot of the research that was done related to nitrogen management and the impacts on drainage was done at Waseca, I know Jeff, maybe you want to talk a little bit about some of the timing work, the split work, the nitrification inhibitors and some of that kind of stuff that you guys have done through the years.

Jeff Vetsch: Well, yeah, we can certainly talk about the different BMP things and their impact, but I think it's important to remember that the biggest factor by far is cropping system. The difference between row crops like corn and soybeans in nutrient loss, especially if we're talking about nitrogen, versus a perennial crop like Alfalfa or some other perennial, it's just night and day difference and there's none of these other factors that even come close to limiting the amount of nitrate loss in a drainage system compared to that cropping system going from a perennial two-way row crop.

Jeff Vetsch: But once we're in a row crop, then the most important thing is probably rate. Putting on the right rate and getting that rate is fine tuned as we can without limiting production is going to have the greatest impact after rate. There's lots of other things we can do. It can be source of N. Anhydrous ammonia is going to be the best source. We can look at timing as an option, but in some trials we've shown that timing really doesn't change the total amount that's lost all that much. What it does tend to do is change when it's lost. And then placement isn't a big factor when it comes to nitrogen loss unless you're at least in tile drainage water, but those are the key factors. You just always remember that the cropping system is the major one and there's really nothing else that comes close, but doing those other BMPs can give us a little nuggets that just get us better and better, but it's not a perfect solution.

F. Fernandez: And just a couple of things in terms of the nitrogen rate, I think that that's right on that the best management practices when it comes to nitrogen rate, that's the best thing that we can do in terms of the management that we apply, the other things that we do, they don't really make much of a difference. And we see consistently whether it's directly in the water or indirectly by looking at residual nitrates in the soil, that if you apply to about an optimum end rate the amount of residual nitrogen doesn't really change between let's say a check plot where we apply no nitrogen and all of our research plots we have different rates. You look at all those rates up to the optimum and the amount of residual N is about the same, it's a flat line.

F. Fernandez: And we started to see a real increase in the amount of residual once we start applying above that optimum point. And so really trying to target to that optimum is important because of environmental reasons, and also profitability. Going below that is going to reduce yields without really impacting the water quality aspects and I think that's a really, really important thing to keep in mind.

The other thing that I wanted to mention in terms of the control drainage structures is, or of that matter, not having drainage at all is that we do a trade off of problems when we have, especially with these racial events that we're having more frequently. If we don't have a way to move some of that water out of the system, what we are trading off is nitrate in the water versus phosphorous and soil in the water and so which one is a worse evil.

Lindsay Pease: Yeah, and I guess I'll jump in here. I mean I've done a lot of work with control drainage structures when I was in Ohio and hope to do some when I'm in Minnesota too. If you're doing control drainage, if you're interested in that management, what you want to do is you do want to make sure you have enough space. You're not closing your tile system off completely because then you will allow some of that water, some of that rainfall to infiltrate into the soil profile so you're not creating just a situation where you're trading subsurface drainage for surface drainage. And so if you're kind of maintaining that, you know at least a foot below the ground surface, we've seen that really you're minimizing your risk of surface runoff. The other thing I just want to add is if you have a lift station, you're really already doing control drainage because that, lift is only pumping when you need the drainage and so if you turn off your lift station during the growing season, then you can simulate control drainage really pretty easily and cheaply because you'd be saving money on electricity.

Brad Carlson: I just want to say one last thing because I want to just reiterate something that Fabian said and that just simply is that I think a lot of people think that we can improve water quality by lowering nitrogen rates maybe to a sub optimum level and the research shows pretty clearly we don't really see a reduction in the amount of nitrate running through the tile line when we go through, when we lower the rates below the optimum productivity, it's really not that significant. And so from that standpoint, that's not really something that we would look at even beyond the fact that it's certainly not profitable for the farmer, it really doesn't produce a lot of environmental results either. So that's not really something we think about as being part of our toolkit.

Paul McDivitt: All right. That about does it for the podcast this week, we'd like to thank the Minnesota Agricultural Fertilizer Research and Education Council, AFREC, for supporting this podcast. For the latest information on nutrient management, you can follow us on Facebook and Twitter at U-M-N-nutrient-M-G-M-T where you can also send us your questions for future podcast episodes. Thanks for listening.

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