Growing Trees in Stormwater Basins in Dry Summer Climates

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[00:00:00] [visual: Conference Rewind logo]

Kathy Brennan: [00:00:02] [visual: conference rewind logo and video of speaker] Hi, I'm Kathy Brennan, director of Educational Products and Services with the International Society of Arboriculture. I'm really excited to bring to you today. Our Conference Rewind video series. Today's presentation is “Growing Trees in Stormwater Basins in Dry Summer Climates” by Igor Lacan. This presentation was originally given at the ISA 2020 Virtual Conference.

Of course the viewpoints are those of the presenter. If you're interested at all in green storm water infrastructure, then I'm sure you'll really enjoy this presentation. So now sit back, relax and enjoy.

Igor Lacan: [00:00:37] [visual: screen shows PowerPoint presentation and video of speaker off to the side. Presenters email is ilacan@ucanr.com] Hello, and welcome to this presentation on the “Growing Trees in Stormwater Basins in Dry Summer Climates”.

I'm your presenter, Igor Lacan. I'm with the University of California cooperative extension in the San Francisco Bay area. And as we get started, I have three questions for you. So [00:01:00] when you think about green storm water infrastructure, and I'll introduce these terms in a moment. But when you think about these facilities, what tree species are growing? What tree species are using in these facilities? And how did you decide on them? Are you getting good growth out of these trees? And how do you monitor that? Do you have some way of actually comparing them to your street trees or other trees? And finally how do you monitor them? Do you actually go out and remeasure them. Are they part of your street tree inventory? Do you have a separate system in which you keep these trees?

Just a few questions to think about as we go through this and I'll try to address some of these a little later, but if you want to pause, of course, this is video on-demand. You can pause at any time and think about these questions a little bit.

And as we go through, I'll show you some graphs. Again if you need to pause the presentation, feel free to pause so you can have a bit more time to look at the graphs. But so after this introduction, let's talk about the [00:02:00] presentation.

What are we talking about? Well we're talking about green storm water infrastructure. And on this slide, you can see a good example of that on the left hand side, right here. This is a typical example, and we'll talk more about what this involves, but we have more and more of these facilities and they're often replacing our standard green strip the way these used to be constructed in the past.

And the question I've tried to answer is, do the conditions in these green storm water infrastructure facilities support tree growth, especially in climates that have a dry summer? So in the Mediterranean type climate of the Western United States.

And so we'll start with a brief introduction to these facilities. And then we'll talk about a study I carried out over the last five years looking at green infrastructure in Northern California. So five cities in San Francisco Bay area, as well as in Portland, Oregon, and what the [00:03:00] results can tell us about how we can best grow trees in these facilities. Again, in situations where we don't get any rain or very little rain during the summer.

And that's in contrast to the Eastern United States and a lot of other places in the world where there is year round precipitation. We'll talk about the results, we'll talk about some of the implications for monitoring those trees, and I hope to spur some discussion, virtually of course, on how, what your experience has been and how your stormwater trees have been doing.

So let's start with what these facilities are. There are many names for them. Green streets, storm water facilities, green stormwater infrastructure of GSI or bioswales. And I will use these terms interchangeably. I'll frequently use the term bioswale just because it's easiest to say, but in fact, it's an older term that people don't like anymore.

But in all cases you do are looking at some kind of a facility that is set up to [00:04:00] infiltrate surface runoff, and you can see some of these inlets through which that surface runoff enters the facility can see it here and the terms again, that are used vary, and so to the designs of these bioswales. In fact, pretty much, every one is a little bit different, but at the bottom of it all really is this idea of trying to infiltrate surface runoff.

And I was in one of these facilities in the city of Burlingham when I was approached by eight policemen. I explained what I was doing and the guy sort of stopped me and said, “oh, so it's a ditch”. [indistinguishable]. It's a bioswales, stormwater [indistinguishable]. The guy goes again, “it's a ditch”. And I learned it's best not to argue with the policemen. So I agreed. Yeah, it is a ditch. It's a fairly expensive ditch. That's constructed in very specific way.

Again, infiltrates surface runoff. And it's filled with a specific substrate, which we'll talk about in a [00:05:00] minute. And then it has some kind of an under drain system, typically not always. And this brings us to the first thing that we really need to consider when we're talking about these facilities. The first question is: when you're looking at an idealized drawing like this, ask yourself what is missing, what is left out on idealized drawing like this? And the first thing that's missing is the issue of the surroundings. So some of these facilities are completely aligned with concrete. So they're really like kind of a bathtub. Now they will have a drain typically, but if you have a completely concrete lab facility that does potentially limit what kind of trees you can grow in them.

The other thing that's often not discussed is what the surrounding soil is like. Do you have regular nice soil or do you have maybe more typical compacted urban soil? Or do you actually have concrete because maybe you have the basements on one side, or maybe you have some kind of infrastructure subway on the other side. And again, that [00:06:00] will limit the kinds of trees you can put in.

So if you don't know. Please ask your engineers, they will tell you what's around the facility when, when they approach and they say, well, what kind of trees should we grow?

The reasonable question is “what are the surroundings like?” So that's the first thing to keep in mind. The second thing to keep in mind is that these facilities are not filled with soil. They're filled with a specific substrate that's meant to quickly infiltrate water. Now we'll talk a lot more about this because it's one of these critical things we have to consider, but just for now, keep in mind: this is not soil. This is a sandy substrate very often. It starts out as 50/50 sand and compost. Sometimes it's 60% sand, 40% compost by volume. But in any case it will be very sandy. It is no regular soil.

The third thing to keep in mind is we are talking about Mediterranean climate. So climate is that have a [00:07:00] drive summer season. Well, one thing to really kind of think about is how long is your actual dry summer period. These are rainfall graphs from the National Weather Service. I highly recommend these. You can get them for any even slightly larger city. And what they show you is in this sort of olive green color, they show you the average rain accumulation over a period of a year, starting in January and moving in through December. And anytime that that curve flattens out, it means you're not getting any rain in those months.

And so if you look at places in California, like Oakland or Los Angeles, you can see that the curve flattens out during the summer months. So on average, we'll have something like three months where we get no rain in Oakland and even a little bit longer in Los Angeles. Whereas in Portland, and Portlanders would say that they have reasonably dry summers, but actually there isn't a single month where it doesn't rain at least a little bit on average. Now that's the average [00:08:00] part. The other thing you'll get from this graph is the actual rain accumulation in any one year.

And I would strongly encourage you to look through these graphs. You can just click through, let's say the last 10 years, and you'll see that sometimes things really go very dry. This is I'm showing you the situation in 2018, and this is this pale green is the actual rainfall. And you can see that in Oklahoma, we had like six months right here, the space green flatline with no rainfall. In fact, we had longer period of no rainfall than Los Angeles that year.

And even Portland in fact had a few months, something like almost two months with no rain. So you want to have a pretty good idea of what this dry period is actually like, because that will dictate how much irrigation you need to provide.

And this is one of those things that, pretty much comes out of this study, is that you will need to supply water to these facilities [00:09:00] during the summer. I know that sounds funny to people in the Eastern United States even sounds funny to the folks in Portland, but those of us who are in California or in the Southwestern us, this is something we pretty much have to do. And this question just is: for how long. So this is what I would suggest you consult the, the National Weather Service graphs.

So with that set up, let's talk about the study itself. This was the study I conducted starting in 2015 on tree growth, chemistry of that substrate, and the moisture in green stormwater infrastructure and the bioswales.

And I was trying to answer the question of whether trees should even be included in bioswales and a lot of arborists at that time, five years ago said, no, not really. And they showed me for example, this example, this is from Fort on all the tree. That's really struggling. And eventually these trees were taken out well, I will tip my hand right away.

[00:10:00] What I found was that there were no bioswales specific problems. There were some tree species that just didn't do well, no matter where you put them. And this was one example. But that wasn't a specific problem because they were in a bioswale.

So how did I set up the study? Well, I found a bunch of bioswales and I did this in five different cities in the San Francisco Bay area. And then I also did it in Portland, Oregon. And I found a bunch of these bioswale storm water facilities, you can see one of these basins here in the back. You can see the inlets. And then I found a matching control tree, and this is just a regular street tree in the front. I measured the trees. I rated their condition. I sampled the soil, both the substrate and the bioswale and the soil, just the regular stricter soil. And I installed a soil moisture monitoring system, and this consisted of a bunch of moisture probes. And you can see them here that are connected to this data logger that just recorded moisture continuously.

[00:11:00] So when I show you the moisture data, I'll show you some probes that are located in the. bioswale itself. And then I'll show you some probes that are located in the neighboring street trees. And the whole thing was buried underground to deter vandalism. And so overall I had surveyed 93 bioswales and put these soil mature instruments into 15 of those bioswales and it's interesting to sort of consider what I found.

Well, I found 23 tree species being grown as bioswale trees. And again, the vast majority of them were successful. Now I will say that most of these tree species are found in Portland. In the San Francisco Bay area. I found only about five tree species that were commonly used, but they all worked well. Also, they were native oaks and some red maples.

We did have a few bits of equipment failure, probably not a major concern to practitioners, but the researchers were [00:12:00] maybe trying to do some of this work. Yeah. I expect that some of your equipment will eventually fail because the conditions are off.

Now, when it comes to treecondition, I didn't find any bioswale specific problems for bioswales specific mortality. I had a couple of trees that got run over by car, but that's not exactly specific to storm water infrastructure. And then I've had a couple of tree species that just got sick because they get sick. No because they were in a bioswale.

As far as growth, it was comparable. So it was roughly similar on the, between the trees in the bioswales and the street trees. There were not super fast growing, but they were reasonable and some species did better than other species. But again, perhaps not because they weren't a bioswale. It's simply that some of these species do better in our climates or grow faster in other climates than other species.

So let's look at some of these things in detail, this issue of tree condition and tree growth [00:13:00]. Here is an example of mortality. This was in Portland, Oregon, and you can't see the choke cherries because they all got black knot and disease and they were all removed. We can see these sort of sad, [indistinguishable], and this was the case, whether they were in these. Street tree basins or whether they were in bioswales, which are across the street. They all got sick, they all got removed. It didn't have anything to do with the bioswale. It was simply the issue with this tree species.

So when we looked at the growth rates, on the left-hand side of the screen are the street trees on the right hand side, are your bioswales or green storm water infrastructure facility trees. And you can see, I tried to match the colors. So you've got your Red Maples in the storm water footprint in the street tree. And red maple in the stormwater facility and the growth rates are about the same. They're just under one centimeter of that triangle diameter per year. So it's this trunk diameter [00:14:00] increase per year. This is above what we would expect now. What's interesting is that we had some oaks planted in these facilities as well.

And these are native oaks here to the Bay area coastline, [indistinguishable] and these grew a bit faster. These grew at about one and a half centimeter of triangular diameter per year. And not unimportantly, I think these are drought tolerant trees and we’ll talk about why that might be important a little later. But this is, I think connected the fact that these drought on trees actually grouped better than some of the Maples, which are very tough trees, but perhaps not as ideally adapted to our climate.

Looking at Portland, well, similar results. It's, uh, slightly higher growth rates. So a little bit higher growth rates, a little bit above one centimeter per year in trunk diameter. You have some [indistinguishable]….

… and these all grew fine. And then you have a big downwards, and this is that leprechaun Ash. It was simply a batch of trees that did not succeed. So it wasn't that they were in the bioswale. It was just a batch of trees that were not performing well, but otherwise, similar growth between street trees and the trees in storm water facilities.

So that's good. So then let's talk about what kind of conditions we might want to have in those stormwater facilities to support this growth. And I carry out chemical lab tests and I monitored solar moisture. So when it comes to soil nutrient tests, they all showed that the [00:16:00] nutrient levels are roughly the same in these facilities. Even though they have a completely artificial substrate, right. But the nutrient levels are just about the same between the stormwater facilities and the control soil that the street trees are growing.

So let's just run through this very quickly and you'll see, I'm showing you on the left-hand side is graph you have Portland. And on the right-hand side is the San Francisco Bay area. The street tree soil is in green or planned Bay area. And then the storm water facilities are in blue, again, Portland and Bay area. And you can see right away, for example, for the pH it's about what we would expect. It's a little above seven, of course, in the San Francisco Bay area we have calcium doinated soils. But again, there's not much difference. In fact, the bioswale soil mix seems to be a little bit lower than our native soil pH, but it's all in this very narrow range that's perfectly reasonable as [00:17:00] far as the tree growth goes.

When it comes to soil salinity, this is electrical conductivity again for the one on the left San Francisco Bay area on the right, street tree bioswale. And you can see that they're all roughly the same. And they're all far below that value of two. That's the …[indistinguishable] or millimeters per centimeter.

That's the value of which we start to worry about plants in the soil. And I'll talk a little bit more about self salinity when it comes to monitoring. But in essence, we didn't have any elevated salinity in any of these facilities.

Plant nutrients. I could show you a whole bunch of them, but I'm just showing you the phosphorus, because I think it's perhaps the most interesting one and there's a little bit of a things to consider here. But again, we are far above some level where we would consider phosphorus to be deficient.

Again, Portland on the left, San Francisco Bay area and the right. Street tree [00:18:00] soils in green and bioswales soils in blue. Again, they're all roughly the same. You'll notice that the Portland values seem to be a little bit higher. That's probably an artifact of the method we use, and this is potentially important. If you are going to test soils for nutrients, I would strongly suggest that you call the lab, explain what you're doing and tell them where you are, because this will matter. So for example, our souls that are a little bit [indistinguishable] in that are a little bit calcium, heavy D the lab will need to use this Olson method for phosphorus, and this is not going to be directly comparable to them. The methods they use in the Eastern us for soils that are more acidic or more iron dominated. This is quite important. You won't be able to compare values. Yeah. If you switch these methods mid stream. So work with the soil lab, as you set up your monitoring program and just make sure that they're aware of your [00:19:00] setting and of your climate.

And so the final thing, and perhaps the most interesting thing is the organic matter percentage. Now this is again, 4% organic matter by Lawson ignition. So it's a specific lab value that we're getting. And the first thing to notice is that we are well within some kind of normal range, which would be somewhere between 3% and 6% or 7% of soil organic matter.

These are mineral soils, so this is just regular soil. That's where we would expect to be there a little bit higher in Portland than there are in the Bay area, which is not that surprising. But what's really interesting is that the bioswales field retain some level of soil organic matter. It's low, but it's not you know, off chart, low. It's within the normal range. This is important because there was a lot of concern that this mix of sand and compost would eventually just kind [00:20:00] of turn to sand, but that doesn't seem to be happening. The plants probably are still putting in some of the organic carbon and are maintaining that carbon pool in the soil. Which is really quite great news.

We'll talk a little bit at the end about organic matter and perhaps the need one for that matter, but I did not see any massive loss of organic matter during these five years, which is really quite good news. So then, if these things are similar, if the nutrient illustrations are similar, if the organic matter is similar pH, salinity, what is different?

Well, what is different is the soil texture. This is a picture looking down into a bioswale substrate and you can see two things right away. You can see the sand. I mean, you can practically feel those gritty sand particles. But you can also see all of those tree roots. These are red maple roots.

The trees roots at least, are doing great in the [00:21:00]. Even though, again, the texture is very sandy. So when we had the soils analyzed, these are average values for the sense of area, the native soil is actually quite sandy. So the at least, where my cities are Berkeley, all Seritos San Carlos Burlingame and San Jose. We have about 60% sand on average. But in the bioswale, we had on average 85% sand. So on the soil texture triangle, this will be firmly in the sand soil texture class.

So whereas native. So it would be something like a sandy loam, perhaps. The one thing that's very different is the ability of this bioswale substrate to retain moisture.

It has very little ability to retain moisture. These are what are called moisture release curves, and these are made in the lab. So I'm pretty confident of them. And there's a couple of things to notice here. The [00:22:00] blue is the bioswale substrates. The green is the native soil, and these are averages with the standard errors shown as well.

We're starting here, this is the field capacity. So this is how much water depths, substrate, or soil can hold before water starts draining away, you can see that it's quite low. We're looking at about 13% of water by volume and it goes down to under 10%. And so this blue bar shows you the available water.

So this is the water that has gotten to that soil or in this case, the substrate is going to retain; there's very, very little. In fact, even though our native soil is quite sandy, it actually has about twice the available water for the plants that the GSI substrate has. That's the first thing to notice. And you'll see, when I show you measurements from the field, you will see how quickly that water declines after a rain event. And [00:23:00] this is why the, the bioswale substrate does not hold very much water.

The other thing to notice are these actual numbers. So these are lab numbers. So we can trust that these are pretty correct. When I show you the field numbers, they will be a lot higher. So now it is possible to have soil water be above field capacity right after irrigation event. Right? Because water is actually draining through that soil, but you will see that the numbers I'm showing you from the field are still a little high.

And that's because that's an artifact of the soil moisture probe being calibrated for a sort of generic soil and not for this very sandy substrate. What you would want to do when we look at the field members is you want to mentally adjust them down, but the pattern still holds. So the patterns would still holding, it would just adjust the numbers.

So let's look at those field results. I'm showing you just one of these bioswales because it's the graphs pretty much all look the [00:24:00] same. This is [indistinguishable]. And remember there were three soil moisture probes, one of them, and in this case, the orange probe is in the control soil - that's in the street tree basin. Whereas the other two probes are in the bioswale. One of them, the blue probe is at about two feet under the surface and the grey probe is that about one foot under the substrate surface. And you can see a couple of things right away. You can see that in the summer, the baseline soil moisture levels are quite low. Now obviously there's more soil moisture, the deeper layer of the bioswale than it is right at the surface, which is what we would expect. But these shallow layers as well as the control soil, the moisture level is quite low. Now you can also see that in the winter you don't have any prolonged periods of water logging. We don't see that. We see these rain events where all of the off the street tree and the [00:25:00] bicycle tree, all of the soil moisture goes up immediately after a rain, but it comes down very quickly within typically less than 10 hours we're back to that sort of a baseline. You can also see that if you have large irrigation events during the summer, you can really push the soil moisture up. These are just some of the large irrigation events, but even regular irrigation will be enough to keep your tree alive and I'll show you that in the next slide.

So if we zoom in now, I'm going to use a different bioswale. But we're going to zoom into just a two week period. And this is in Burlingame bioswale so again, these are both the San Francisco Bay area. So this is a two week period, you can tell when the irrigation starts. It starts at 05:30 a.m. in the morning, Monday through Friday. You can see in this case, you are looking at the control, soil is in orange. The deep probe in the bioswale is in blue and the shallow probe is in grey.

[00:26:00] And you can see how that daily irrigation event pushes the soil moisture up and that the plant that deletes it and then the next day segregation, and then again, the plant depletes it again, irrigation, and so on. And then after Friday's irrigation, you just see the steady decline over the weekend until the Monday irrigation event and so on.

So the bottom line is: yes, irrigation can work, but you really have to make sure that it does work. Because again, as soon as you stop irrigating and you see this big decline, they can't quite see that yet in the deeper layer. There is some water attention, but again, without irrigation, this would just keep going down and down and that.

So this is the fourth thing to sort of keep in mind, which is really the lessons from five years of these soil moisture monitoring curves. Do we have water logging in winter, which was the main concern of a lot of arborists. And the answer is no, I have not seen [00:27:00] any evidence of water logging in winter. It takes a few between a few hours and we will be within a couple of hours and a few hours for the soil moisture level to return to a sort of a baseline in these stormwater facilities, but it hasn't been a problem.

Water, one water movement is pretty much straight down and you can see that by the position of these sensors. So if you are irrigating, you will be irrigating, make sure that your irrigation bubblers or your emitters are somewhere where they can actually reach the tree roots rather than somewhere off to the side. There's not very much lateral water movement in the same substrate. So that's something to consider. If you're a researcher, it's something to consider where you place your sensors. Because again, water doesn't move very, very much laterally.

Not very much water storage. We talked about that. And then if you go up there with a solid moisture probe and you just stick the probe in there and you [00:28:00] read the soil moisture content, remember that, then the number you're getting is more of a relative reading because you probably haven't calibrated your specific sensor for that sandy soil. Now, if you go out after a rain event or after an irrigation event and your record the number and you come back maybe 23 hours later, just before the next irrigation and you record that number, that difference is real. So that's soil moisture monitoring is useful, just remember that any one, a number might be more of a relative indication rather than an absolute number.

And then if you are a researcher considering doing that, I've lost a few beta loggers over the years, they were placed in watertight boxes and I buried them in the soils to prevent vandalism. I didn't have any vandalism, but I did have a few failed loggers. So they get kind of wet and kind of rusty. And eventually they just gave up. Something to think about, if you're a researcher [00:29:00].

Now some of you are thinking, okay, well, what if I can't do irrigation? Can I still have trees in these stormwater facilities as well?

Let's talk about Portland because Portland in a lot of places does not have irrigation in their storm water facilities. And yes, it is possible to grow trees, beautiful stormwater trees in Portland. But again, they do get water in the summer, just not very much, but they do get it.

And similar to the San Francisco Bay area, look at this decline where you don't have rainfall for a little while you do get the declines in soil moisture. So yes, it's possible to do it, but you need a climate where you get at least some rain during the summer.

Now for a sidebar, if you're still concerned about your irrigation system, one thing to consider is the actual substrate.

Do we have to use [00:30:00] this super fast, draining sand compost, substrate? Well if you saw Howard Stem’s presentation last year at the ISA meeting, he showed quite convincingly that no, actually this artificial substrate is not the only way to go. There are native soils that can meet infiltration requirements, because remember your stormwater engineers are pretty much only concerned with that one number, which is the speed of water infiltration.

They don't want the water to pond in these stormwater facilities. They want the water infiltrating into saturate. That's why they love this sand compost 50/50, or 60/40 substrate because they know it's going to infiltrate like crazy. But it doesn't store very much water, which is our concern. If we're trying to grow trees.

So the question for some time has been: Are there actual soils, real soils that would meet infiltration requirements, but allow [00:31:00] us to have a little bit more of that available water? So if something goes wrong or irrigation, or if we don't have irrigation at all, we still might be able to keep trees alive.

And the answer is yes, absolutely. Now you will have to have a discussion with your engineers. And one of the magic terms is ‘alternative soil specification’. Just to remember that magic term, ‘alternative soil specification’, and you will have to prove probably that whichever soil you've chosen has the capacity to infiltrate stormwater fast enough. The problem you're going to run into is that, and here's some infiltration values shown here. The problem you're going to run into is that the modeling software that the engineers use tends to underestimate soil water infiltration rates. So in this case, these are loam soils. The model infiltration rates were somewhere on the order of one inch per hour, and the engineers do not like that.

But the measured [00:32:00] infiltration rates were in excess of five in some cases, eight inches of water per hour. That's fast. So bottom line. It is possible. And again, these are slides from Howard Stem from last year's ISA conference in Knoxville. It is possible to use native soil to meet infiltration requirements, but you will probably have to prove that extra the engineers by actually conducting the filtration test.

It is not necessary to use the artificial bioswale meets the 60/40 percent to compost mix. That infiltrates way faster than what the engineers actually required. It's just that everybody loves that mix because the soils suppliers are to make it, the engineers know it's going to infiltrate.Everybody's happy.

But if you are concerned about the ability of this mix to support trees, will I sort of have two messages. One is with irrigation, it seems to do perfectly fine. [00:33:00] At least that's been my experience in my little study in California and Portland. But if you're still concerned, yeah, it is possible to use native soils.

You will just have to prove to the engineers that you're getting fast enough irrigation. Just to be clear, not all native soils are going to be suitable. Some are certainly not going to work. But a lot of these loamy soils seemed to do okay. And the burden will be on you to prove that to the engineers.

So let's sort of wrap this up with some of the considerations: how to monitor trees in green storm water infrastructure. There's a lot of things you can monitor. Don't get overwhelmed, but do keep an eye out for what's happening. That's my sort of first message. The way I will do this is I would start by recording tree growth and condition because at the end of the day, that's what we're going to care about.

And then looking at soil moisture. And then perhaps after a few years look and see where your roots are going. And this is, we [00:34:00] talked about this at the very beginning. Are you getting root session outside of the facility? So when it comes to tree growth, how would you do this? Well you would measure the tree diameter at standard height. So about four and a half feet. And you will do this yearly.

You would assess conditions and you can use any number of methods. I like the Jerry Bond method that described in his book, *Urban Tree Health*. There's basically these four parameters. But whichever method you use, just remember to mark the trees labeled and somehow, so you can keep track of what tree you're actually coming back to all the time. And just in your system, whatever it is, just have a provision for what you're doing.

If the tree gets struck by a car and this is removed and the nutrients planted have some way of actually noting that.

So that’s pre growth and condition. The next thing would be soil moisture. I don't know that you have to do this routinely for every single bioswale, but I think it would be useful to do it at least three times.

So [00:35:00] certainly after you planted the tree, then after the first rains and you would do this to make sure that your bioswale, is actually, you know, infiltrating the water. I've seen situations where trees were planted at the very edge of one of these facilities and they're essentially outside of that wetted area. So they never actually get wet. They depends 100% on the irrigation system.

[break in audio and visual] You definitely want to check that. And then finally you want to come around mid-summer and make sure that your irrigation system is actually working. You can use any serious soil moisture system, capacitance, probe, TDR probe, or even a tensiometer, or you can just do the sample and feel. And if you don't know how to do that, USDA has an excellent guide on how to feel soil moisture with your hand. And [00:36:00] you would simply use sand soils category. So not these clay play lawns. You would go to the next page, which says sand, and that's what you would use.

The third set of things you could monitor is the soil chemistry, so plant nutrients. I don't think this is repeatedly useful. Definitely not the standard MPK stone trends, unless you've got symptoms of nutrient deficiency, I wouldn't worry about that. Clump activity or soil salinity may be useful to monitor, especially if you're using recycled water irrigates out in these facilities. And I know this is going to be the case in some places in Southwest. If you're using the second water, remember you're applying recycled water to a sandy substrate, which has very little capacity to buffer that salinity.

So you definitely want to sample the soil and read the salinity at least twice a year. After draining season, so sometime in the late spring and then right before the rainy seasons, [00:37:00] so sometime in the late fall. What is going to likely happen is you will see an increase in salinity during the summer, and then hopefully with enough rain during winter, you will see a decrease. If that's all you see year to year and you're kind of staying constant, you're probably okay.

On the other hand, if you are seeing year over year, increase in soil salinty, then you need to consider how you're going to leech that salinity out of the soil. But again, this is probably mostly going to be a concern for those if you are using recycled water? And by the way, if you are, I'd love to hear from you because I think that's a really interesting situation.

The final thing you can monitor is soil organic matter. Now, I'm not sure if it's another one of those things that I don't think is routinely useful, but if your bioswale soil keeps settling. Then I think this is something to go out and measure again. You would sample the substrate, then send it off to the lab. The soil vendors will tell you how much your substrate is going to settle. It will settle. There is some percentage and they will [00:38:00] specify that that's fine. But if the substrate keeps settling, you may be losing that organic matter.

One of the reasons why organic matter is important is because it helps retain that little bit of soil that this substrate is retaining. So here's the example of sandy soil, essentially with soil organic matter 1%, 2% or 3%. And you can see how with, you know, increasing a portion of soil organic matter, you are increasing the available soil moisture because that soil can hold a bit more moisture.

So to start losing organic matter, you're going to decrease the ability of that soil to hold moisture. So not great, but again, that's not what I've seen in five years. So I don't think we have to worry about this by default. That's something to think about. So let's just conclude by admitting that stormwater trees can succeed in stormwater facilities in Mediterranean climates. We have done [00:39:00] this for at least a couple of decades now with great success.

And the only thing to kind of keep in mind here is that where bioswales have problems. Those problems are often caused by improper installation. I think because the engineering was faulty or because during installation, they did it during a really wet period when the substrate was waterlogged and its substrate was compressed, and the problem start there. So just, this is the usual landscape installation best management practices. So as long as those are followed, we're probably okay.

As far as species though. Some species might be unsuitable though, frankly, I have not seen any that were flat out unsuitable. What I have seen is that those species that are tolerant of summer drought, seem to do a little bit better. Those native Oaks, which this was a little surprising to me. I thought they would maybe not like this super sandy [00:40:00] situation, but they did. They did have irrigation. Remember it to sort of keep them alive during summer, but they seem to grow by quite well. Chemistry is okay. And of course, soil moisture is absolutely critical.

Just to finish this up. If you're ever talking about this, engineers remind them that vegetation is part of the green stormwater infrastructure. That's the green part. So if the vegetation is all dead because their irrigation system malfunctioned or dates and never bothered to put one in, then this is not a bioswale. This is just a sand field basin and it's their problem as well.

And if we're trying to come on for things, again, we're starting with trees then with soil, and then perhaps later on with the growth, the roots, and again, some through remind the engineers, the irrigation system really will be critical in a lot of our really dry situations.

If you're trying to monitor, here's a few guidelines and you can, as I mentioned, just falls to the [00:41:00] presentation and read this yourself. You would measure some of these things in the field, mainly the soil conductivity and soil moisture, you would perhaps send off to the lab for soil organic matter.

And again, potentially saw salinity and that's probably all you need to do. Now. You need more information on how to actually monitor trees. They are three publications that just came out from the US forest service that I would strongly recommend. And these are the publication by Lara Roman and Natalie van Doorn.

These are the two urban tree monitoring guides. *Urban Tree Monitoring Field Guide* is the short version. The *Urban Tree Monitoring Resource Guide* is a longer version. I recommend you got to look at both of them. And then if you need a good overview or good encapsulation of what trees do within the green storm water infrastructure framework, the recent publication *Urban Forest System and Green Storm Water Infrastructure*, highly recommended.

They are free. They're online downloadable, and they're very helpful, [00:42:00] especially if you're trying to talk to engineers or trying to talk to planners about why trees matter within this context. And then if you need soil references, there's a few of mine. My favorite preferences certainly Bryant Scharenbroch's website.

Absolutely excellent. Jim Urban's book, Watson and Himelick's book. Handreck and Black's book specifically on growing media and then Larry Costello's book on the antibiotic disorders, excellent books. And of course, Kim Coder's info leaflets. And that's it for me. Thank you very much for joining me. My contact information is here.

And I wish to thank the entities that funded this project and it's two of them be. University of California Institute for water resources and then the USDA forest service that funded this project on recommendation of the national, urban, and community forestry advisory council. So thank you all. And thank you again for joining me.

I'm happy to take any questions [00:43:00] or email. That's my contact information below. Thank you very much.