Give Me the Numbers: How trees and urban forests really affect stormwater runoff

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Q&A

How is leaf area calculated?

_Eric Kuehler_: There are great regression equations built into the model. If you are wanting more local information, I am sure you can go to your local land-grant university that has an arboretum and has probably over the years done some of this type of work to get more information as far as leaf area by size, class, by diameter, by height, things like that.

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Can you clarify the 639 versus 3.9 ft.³ of runoff from impervious area versus trees? Is that 3.9 ft.³ from canopy with an impervious understory or canopy over natural understory?

_Aarin Teague_: Great question. The 3.9 is from canopy with an impervious understory. So that is an estimate that was calculated using the curve number of 70, which is from the urban tree area.

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Are the gallons infiltrated per storm event? And the follow-up question is: how do you calculate annual infiltration capacity?

_Eric Kuehler_: In that particular study, it wasn’t per storm event. They were just using a methodology for infiltration that is typical for soil infiltration. It had nothing to do with storm events, but it did show that soil under tree canopy cover infiltrated more than soils outside. They have the capacity to infiltrate more. So it wasn’t per storm event. Obviously, more research is needed for that.
Aarin Teague: There are many variables that play into estimating annual infiltration capacity and there is not a set preferred method. There are many different ways of estimating annual infiltration capacity, ranging from simplistic averaging methods to detailed analysis of time series that track soil moisture and weather parameters in conjunction with detailed soils data. What type of analysis you choose should depend on the application of the information. The most simplistic is to subtract the annual runoff from annual precipitation, where annual runoff is a product of the annual average rainfall, the runoff coefficient (dependent on the drainage catchment characteristics), and the fraction of annual rainfall events that produce runoff (generally around 90%). However, be cautious because this is a very simplistic, back of the envelope method. Where greater precision is needed, defer to a more detailed methodology.

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How do you achieve the method of averaging to allow for the extremes we are seeing in storms this past decade?

Aarin Teague: If I understand this question correctly, the question is when you are looking at the types of the storms, for instance the 85th percentile storm that results from the record, it will always be changing when you have new, large events. And with a new, larger storm coming every year, that 85th percentile storm that might have been 1.5 inches last year might become 1.7 inches this year. Within most regulatory entities, they set it to a particular rainfall record. And then they have to update that every now and then. From a design perspective, how do you change the method? You really use the same method, but you might add a safety factor or oversize that BMP or the design as a whole in order to account for changing rainfall regime.

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Are there any drainage districts that will accept this data?

Eric Kuehler: I don't know if I have an answer to that. Every municipality, every government entity is different. These are the numbers. This is the research. This is what we have currently. Some of those government entities will accept these numbers and some won't. I don't know of any right off the top of my head that are accepting them.

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Could you define initial abstraction and pour point?

Aarin Teague: Initial abstraction is the amount of rainfall that is captured prior to run off. So if you think about a tree system, this is the amount of rainfall captured in the canopy and that will go through stemflow before the underlying area is saturated and runs off. And then pour point is just a term that we use for the end of where you are measuring. So it is the end the point of a watershed.
What is the best way to describe the infiltration quantity in year 1 and year 2, etc.?

*Eric Kuehler:* So this particular research that has looked at infiltration looked at root mass. And obviously, a newly planted tree isn’t going to have a lot of root mass. You are not going to have a lot of root mass until the tree is much larger. So I don’t know if I can specifically give a number. More research is needed, obviously. But I guess I would say that newly planted trees aren’t going to provide a lot of the benefit that larger, more mature trees will provide.

Can you comment on temperature benefits of trees intercepting rain versus pavement intercepting rain?

*Aarin Teague:* That is a great question. So the question is: what is the difference between the rainfall being captured by tree canopy and it being in the shade versus it just falling on the pavement and then running off, absorbing that energy? The end result is the difference between the heated runoff from the sidewalk reaching the stream versus the cooler runoff from the tree canopy. This is very important when you have temperature sensitive species such as trout, where the heat itself can be a pollutant. And there are very specific guidelines on how to implement trees to provide that shade and that capture, as well as the depth of required infiltration to cool off the runoff as it moves through that BMP, particularly with bio retention. So there is some fairly good guidance out there that you can look at.

How well do you think these studies are reflected in the various tools in i-Tree and are the values similar per millimeter per day?

*Eric Kuehler:* Yeah, actually, i-Tree Eco and Hydro use that 0.2 mm per square meter of leaf area. And that accounts for the avoided runoff reports that Eco provides and for the Hydro reports. They are using that static storage number of 0.2 mm. Right now, I am not familiar with anyone using the dynamic storage numbers, but perhaps in the future, that will be included in some way. Not being a stormwater engineer, I would know how to begin to start calculating that.

Can you explain more about how to use and apply the curve numbers?

*Aarin Teague:* Fantastic question. The best guidance that I can give is to Google SCS TR 55. The NRCS has published a manual with standard parameters of how to use them, guidelines on use and an example for how to apply it. The curve number methodology is a standard engineering technology where basically you identify the land
cover type – or in the case of the WERF examples, what kind of WERF BMP you have – the curve number, and then you go through a set of calculations to identify what your initial abstraction is and combine that with your precipitation information. And it will allow you to calculate your flows and runoffs. I would really recommend going straight to the source with the NRCS manual.

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Were there any studies done for palms?

Eric Kuehler: I didn’t look for any studies for palms. Palm trees typically – well, they are not a tree – but they typically have a very small percentage of leaf area. It has a small leaf area index. So I would expect that there probably isn’t a lot of benefit, unless you just have a forest of palm trees.

Aarin Teague: I have not seen any specific guidance for palm trees. But I will say that you could go and look at some of the more esoteric research studies that were done on palm plantations and be able to derive your curve number from that and make your estimates with an appropriate area calculation. But as far as straightforward studies or parameterizations, I have not seen it.

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Do trees and shrubs have essentially the same capture rate?

Eric Kuehler: I would say no. Typically, shrubs have less leaf area. And I guess it depends on what your definition of shrub is. But am thinking of the densely compacted shrubs that typically have leaf area just on the outside of the crown. It doesn’t have a lot of leaf area underneath that initial layer of leaves. So my inclination is to say no.

Aarin Teague: From an engineering point of view, trees are going to be taller, wider, have a larger diameter than most shrubs, depending on the species. So you would expect trees to have a higher capture rate. Just remember that not all locations would be appropriate for trees, so if you don’t have anything else, shrubs would be a fantastic fall back. So don’t be afraid to use them when you cannot use trees.

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What is the catchment area for a street tree and how could that be included?

Aarin Teague: From a design point of view, it is going to depend on how the tree well or how the runoff is funneled to the street tree. So you can do a lot of creative things to make sure that you have the infiltration. At most, we are probably looking at a catchment area of 1/10 or 1/2 of 1 acre at most. And it’s all going to depend on the design parameters. So you could do some interesting things to play with the type of media that the tree is in, the pervious service on top, and the depth that is given for the street tree. It’s all about playing your numbers.
Do the i-Tree studies take into account the dormant season for deciduous trees when there is no leaf surface area?

*Eric Kuehler:* Yes, they do. And so when you enter a project, that is built into the modeling. And it does take into account dormant season for both Eco and Hydro.

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Can you address caring for the trees that are planted for stormwater projects? Do they need standard care, ordinary watering regime, for example? Or are they more stressed by being planted in such technical materials?

*Aarin Teague:* One of the awesome things about putting the trees in any vegetation within the stormwater features is that it is getting runoff directed straight towards it. But in that runoff, it is going to carry lots of nutrients from the surface. So we are putting all the things that the tree needs for growth right towards it. Now, that requires that the tree be given enough space and be designed appropriately within its BMP. So if you make it in a very tight, small parking island and don't give it enough room for growth or it's not designed properly so that the runoff doesn't actually reach that, then it's going to be quite stressed. But for most bioretention media, and most runoff regimes, it is going to be fine. During the establishment period, you are going to need to give it supplemental watering to get it started. But after the appropriate establishment period, you should be able to taper that off.

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Beside the WERF and federal agencies, are there any national, professional stormwater organizations that have endorsed any of the studies?

*Aarin Teague:* The Center for Watershed Protection has published a compendium of analyses where it references many of the studies and has an entire database of other supporting documentation for use of trees in urban stormwater management. In fact, they have done a survey of the many municipalities throughout the nation to compare how different municipalities and regulatory agencies deal with trees.

*Eric Kuehler:* I was just thinking about professional organizations and the Center for Watershed Protection is a nonprofit. But as far as a SCE or anyone like that, I am not familiar with anyone endorsing these numbers. You know, this is all so new. We are all kind of working our way through this.

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Did any studies include subsoil systems such as structural soils or Silva cells?
Eric Kuehler: Yes. In that eco-hydrology study, we looked at a study out of Chicago. Bryant Scharenbroch did some work at the Morton Arboretum that looked at these systems. And there is more out there out of North Carolina. There is some work being done in these types of systems that I am familiar with.

Aarin Teague: Many of the structural soils are proprietary devices or proprietary materials. So much of the research that is being done on them is conducted by the entity that holds the intellectual property for them. So they will publish with their sales materials their own internal studies. So you can look at how the materials perform under a very strict testing regime and be able to use that information and design if you need to.

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How do we get people to adopt trees as a stormwater reduction strategy?

Eric Kuehler: I guess this is the first start, just providing the sets of numbers.

Aarin Teague: From a design perspective, people love trees. Some of the recent studies identified a 6% increase in property values associated with just having the view of a mature tree from your front yard. So I think that it is something that the market is going to drive. People will gravitate toward treed areas because they like the shade, but they will want to buy houses and invest their money and time in areas that have trees. If we can bring together that increase in market value with the stormwater benefits in the different credit schemes so that both the regulatory side and the development side can see a benefit to the bottom line, I think that it will naturally gravitate towards that.

Eric Kuehler: I think emphasizing the triple bottom line so that the trees are providing not only stormwater but other co-benefits: energy conservation, increased property values, air pollution removal, things like that. It all fits into the triple bottom line component.

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