USDA Forest Service

URBAN FOREST CONNECTIONS

webinar series

The Effect of Urban Tree Canopy on Microclimate and Heat Islands

Wednesday, January 13, 2016 | *1:00 – 2:15pm ET*

TRANSCRIPT

Dana Coelho: So, today to jump right in, our topic is the effect of urban tree canopy on microclimate and heat islands. We will hear from two speakers, Austin Troy and Sara Davis. If you have questions during the presentation today, feel free to type them into the group chat at the bottom of your screen. We will have a question and answer session for all speakers at the end of the webinar that I will be moderating.

Our first speaker Austin Troy, addresses issues at the intersection of urban planning and environmental sustainability through spatial analysis. He is professor and chair of the University of Colorado Denver department of planning and design. He is the author of "The Very Hungry City," a book that looks at how cities consume energy and is a long-term research partner in the Baltimore ecosystem study, one of the national science foundations to long-term ecological research projects. Thanks a lot, Austin, for joining us today and I will turn it over to you to get started.

Austin Troy: Thank you very much, Dana, and thanks everyone for attending this webinar. For the next 20 minutes I will be talking about some research that I've been working on with some of my graduate students at University of Colorado Denver about urban tree canopy and its benefit for microclimate and shading. And basically there are three parts to it that will be highlighted; I want to give a quick mention to my co-authors here Bob Taylor and Mehdi Heris who were instrumental in putting together this research and most of the legwork, getting the technical work together for this. Let me see if I can control this thing. Let's start by asking why do we care about urban heat? And I'm guessing most of you on the line are pretty aware of the urban heat and may not know exactly what it means and what the benefits are of moderating urban heat. We do know with climate change that there are all sorts of bad things that we anticipate happening related to heat in cities having to do with increased heat related illnesses, a higher energy build, increased water usage for landscaping and evaporative demand on water and so forth. I won't go too far because I assume you're

pretty familiar. I will point out that heat related deaths are a real thing and when heat waves do strike them out we do see a lot of the vulnerable populations affected by them and the urban heat is relevant to that.

Without getting too much into what urban heat island effect is I will quickly mention that it's the condition where we see the central urban parts of cities being hotter than their surroundings, particularly with respect to nighttime temperatures and what we see is all the hard surfaces in downtown and the less vegetated areas within the cores of cities absorb a tremendous amount of heat and we radiate it at night and relative to their cooler natural surroundings where we see vegetation so we see the heat island effect that his signature and most prevalent or most discernible at night when we see a higher temperature in the nighttime temperatures in the urban core relative to the surroundings. Trees are really important element within the urban matrix in terms of regulating urban heat. The trees operate in several different ways, and vegetation in general operate in several different ways to moderate and mitigate the urban heat island effect. One way is through evapotranspiration. Trees are like a water pump and they take water it from the grounds up through their leaves and in the course of doing that you get a heat transfer that helps dissipate heat through the evaporative process. And that effect can be quite significant especially when you have species that transpire a lot and you have to weigh that against water usage in arid climates and we will talk about that in a second.

Another mechanism we see by which trees moderate urban microclimate is through direct shade. And obviously, trees intercept light and create shady areas underneath. And this has a very large impact on urban heat but particularly when that shade is against buildings. Trees have higher emittance levels which means they are able to emit heat much better than other types of services and their efficient emitters of heat. Overall they are very effective way of moderating urban heat in cities. The project we have been working on was funded from the Forest Service for several years now and is looking at urban microclimate and urban heat at several scales. We've been looking at the urban scale, the scale that is traditionally looked at for urban heat studies so the citywide or metro wide scale. We are also looking at the individual building level scale. And we have some relative findings on both of those scales. The research questions we're dealing with today are three. The first one is how does the heat island effect differ in a humid temperate city, and in this case and Baltimore, versus a semi-arid city and in this case Denver? And much less has been done this study the heat island effect in the latter category. Most of it tends to be more highly vegetated, humid areas so it's very interesting to look at the difference and see there is a big difference. Secondly, how does the spatial pattern of tree canopy mediate trees influence on urban heat? In other words is there an optimal pattern, spatial pattern for planting trees to mitigate heat or can you just put trees around with no regard to the actual pattern of how they are planted? Or does planting them in a certain pattern decrease heat more effectively? And thirdly, what is the role of direct shading? And we are in the process of doing some work looking at the effect of shading on energy consumption but due to some data constraints right now all I can present is some research and findings we

have about how much shade is hitting buildings and the method we come up for calculating that and looking at the difference in both Denver and Baltimore.

We will start with the first question, the heat island in Denver versus Baltimore. And what we see is there's relatively comparable amounts of tree canopy in the two cities. 31 km² versus 48 .31 km² versus 48 km² but not an order of magnitude difference. And these are some satellite imagery of the surface temperatures 434 daytime and one for nighttime in Baltimore. And here's the surface temperature nighttime and a time for Denver. And what we can see in both cases the nighttime temperatures seems to really cool down at night in the surroundings but the blue area that you see on the bottom right is Baltimore County. In that cooler areas that you see in nighttime in Denver here is this annexed part of Denver where the airport is where DIA is. Mostly prairie until you get to the airport and then there's a lot of hard surfaces. This is a close appear of daytime surface temperature. And what is interesting as you see these cool areas and let me see if I can control my mouse here. My pointer does not seem to be working here. But anyway in the center you will see there are some bluish areas in what is a pretty urbanized part of town but it has a lot of tree canopy. And here's the nighttime temperature. And again what we can see if it's further out its cooler at night but there's a lot of cool patches in the middle of Denver. Here's a close-up. We are looking at the intersection of interstates 25 and 70. And it's a very industrialized area and if we overlay a heat map there with the temperatures we will see by all these buildings, these big industrial buildings. You will see it's quite hot there. It's quite hot there during the day. At nighttime it's interesting and we see the hot spots along the interstate because there are these massive amounts of concrete and they absorb a tremendous amount of heat and we radiate at night. So you get a lot of heat along those intersections. Here's a close-up of a residential neighborhood. You can see tree canopy and see the polygons for trees. And you will see the coolest areas are the areas with trees.

This is a trend line showing a bunch of different things. The building area in the video – vertical access and the distance from the center of the city along the horizontal access. And the average patch area radius by the radius of the circles and the temperatures.

And then here in Denver what we see is a very different looking trend. Baltimore has a very clear classic trend in its downward sloping, but Denver not so much. And the reason for that, and we will see this here but here's another transect, Denver on the left in Baltimore on the right. Baltimore has a classic downward sloping transect where it gets cooler as it gets to the outskirts not so with Denver. Denver was more of a flat line. This I think is really telling and the reason why this is, Baltimore is a city surrounded by woods and agriculture and a lot of growing things. At the plant lots of trees. And as a result the outskirts cool down much faster at night. Due to the high eminence relative to the city. In semi-arid locations trees are not there but urbanization means more trees and Denver was a prairie before was a city means we urbanized it and when we urbanized it we brought in a lot of trees. Now that we have tons of trees, the heat trapping effects of the city are counteracted essentially by the larger preponderance of trees in the city center relative to the outskirts. So really, you get a

canceling effect where the nighttime difference between the outskirts temperature and the core temperatures are not that different. The exception is downtown where there is a lot of building area relative to trees and also the airport. The question number two. Spatial patterns of trees and urban heat mitigation. This one is fast and I'll go through it quickly. What we found, basically we wanted to look at landscape ecology metrics that are used to enter habitat patches for wildlife studies.

So we characterized the shape of tree patches in our city using foley and things like patch edge length, patch edge area ratio, patch circularity and envelope ratio, minimum bounding geometry, patch density, average patch area and so forth. We controlled for building area, parking area, and total canopy patch area and the questions we wanted to know is after controlling the land coverage including controlling for the amount of trees and total amount of trees does the shape of the tree patches make a difference in moderating heat? And the results were that we got a good model with about 80% of variance in surface temperature and we have a strong positive correlation between temperature and building pavement area and a negative correlation, which we expected with tree canopy area. But then we got these interesting tree canopy effect for each additional 10% of the grid cell occupied by trees, we see a drop of about .3°C so about foley vegetated grid cells about 2.8° cooler with cells without trees. And it does not matter – doesn't matter how the trees are range? And so the following special patch metrics are significant. The average area patches. The average area so if you take all of the patches within a grid cell and you average the area of those patches, so larger the average area of patches the lower the temperature.

The envelope ratio, and that's describing compactness; it describes how well your shape fits into an envelope. The higher the envelope ratio, that lowered the temperature. The higher the number of patches, the higher the temperature. Again it's not making the temperature higher, it's just saying that your trees are already cooling things down but they're not cooling things down as much as they are spread out in a bunch of small patches. The edge length of patches, which is highly correlated with the last one which is the edge to area ratio also are related to higher temperatures. If you have more edginess and less core area you're typically get less of a cooling effect from the trees. You will still get a cooling effect but not quite a strong. We also asked questions [indiscernible] is very critical threshold for patch size in terms of trees as impact on heat. What we found is about 5000 m² is where you hit the sweet spot. Basically a 5000 m² tree patch is where you get the most return on investment for heat mitigation and after that it levels off. The interesting finding is that if you want to have a bunch of optimally sized patches, 5000 m² in this one case in Baltimore appears to be the best size for fighting heat. Obviously this needs more validation and this is one study. We need to do this again and again to make sure how it varies from place to place and it's very preliminary but it's pretty interesting. So still a lot to determine on this but basically trees reduce urban heat significantly. The way trees are arranged can boost or detract from the effect.

After adjusting for the total tree area, canopy trees have the most effect when arranged in areas of large average patch sizes are relatively compact and shaped. Their effect is somewhat reduced by being spread out, having lots of edges, and so forth. And there appears to be a threshold at 5,000 m².

Final question. We did a lot of work on coming up with ways to do map automation of our data so we could look at high-resolution shade maps and look at how shade from trees intersects with buildings. One of the things you have to take into account is when the shade is hitting so we looked at a bunch of different ways of averaging shade over 12 hours, over the hardest four hours of the day, how to six hours of the day and we tried a bunch of different approaches. And then what we would do is we would overlap that with buildings. And look for intersections of shade and buildings. And one other thing we did as well, I don't think I have it in here is we also experimented with a three-dimensional approach using a software called Rhino-grasshopper and we simulated three-dimensional buildings and simulated the shade hitting the walls of the building and we found that it's actually somewhat different particularly with taller buildings. And that will be our next stage is to really quantify that. We just have done that for sample areas right now and we have established the methodology for how to do that but what's really interesting is we found that Denver and Baltimore have very different profiles for the amount of shade hitting buildings. So the total tree shade, the area of shade is given in this graph here, for Denver and Baltimore. And as we can see there is more overall shade in Baltimore because they're more trees but in the next slide here if you look at roof tree intersection the amount of trees shade hitting buildings is way higher in Denver, which we found really interesting. And I think that's because this is a planted environment where we planted trees specifically around houses and they are not natural, we don't get them happening in these big natural clumping like you do in Baltimore where you have big for forested parks and then you also get tree deserts where there are no trees at all. Denver has a more even tree canopy and as a result you get more tree shade and I thought that was really interesting.

So the conclusion for this whole thing, the heat island effect is very different in Eastern and Western United States. Western cities tend to have more trees relative to natural surroundings then do Eastern cities. When you make a city in the west, you bring the trees. And that has an effect on heat island. The spatial pattern of tree canopy has a big impact on heat mitigation. Big patches with more core area are better for heat mitigation and scattered, isolated trees up to a certain size, and so forth. But here's the interesting thing: more concentrated forest comes at the cost of less direct building shade, which requires distribution of trees. What I think is happening, the pattern metrics we're looking at were really focusing more on evaporative transference of cooling and you get more effectiveness from cooling from having the big patches, but you lose some of the effectiveness of having the direct shade and by having distributed trees. It's a balancing act and you have to figure out which one is best for you. So tree shade varies between Denver and Baltimore, the final point, and there's way more tree shade on buildings in Denver which is because in Baltimore trees happen naturally and are left over from natural forested areas in the past. The next thing we want to do is relate this energy consumption data and I think that will be very interesting. That is all I

have and I'm happy to take questions. I don't know if we do them now or later. Thank you very much.

Dana Coelho: Thank you, Austin. That was great and we will do questions for both speakers at the end of the webinar. But we do have some questions for you, the audience right now, now that we have had a chance to settle and we will take a few minutes to learn about who has joined the webinar today. We will post a few questions on the screen and ask that you respond to these fairly quickly so that we can get back into our next presentation. So I will pop those up in the first question is where do you work? I will give you a few seconds to fill this poll out. Great attendance by the way. And we will close this question in three, two, and one.

Our next question for you is what is your profession? And this poll will close in three, two, one. Question three, where are you from? Nice diversity is showing up there, and we will close this poll in three, two, one. And our last question, how many participants are with you at your location? One is just you. And this question will close in three, two, one. Thank you very much for the feedback.

Our next speaker this afternoon is Sara Davis. She is the rockstar urban forestry program manager for the city and County of Denver Colorado. Working here for the past nine years she has provided leadership for the city's tree planting campaign and investments in measuring urban forest. She serves as a county government representative on the National Urban and Community Forestry Advisory Council and as President-Elect of the Rocky Mountain Chapter of the International Society of Arboriculture. Thank you for joining us today, Sara, and take it away.

Sara Davis: Thank you. Thank you, Dana. I wanted to illustrate with this screenshot Austin's point that Denver is that little purple start out there in the mass of tan, short grass prairie versus Baltimore's firmly located in the massive green forest. If you dial in a little bit closer you are going to see our little municipality and it does have that ring of tan low-water vegetation around the city with the metro area being the pocket of green at the center of the screen. Austin's research is pretty new. So I'm going to mostly talk about some information that we had provided to us in the past from a previous assessment that we are building on now. So we are very proud of our trees here in the Metro Denver area. It's taken us a long time to get up to Denver school of having tree canopy cover of 18%. And I noticed a lot of you from back east on this call, I would imagine that you took a deep breath there were more vegetated areas have a goal of 40% canopy cover and were very realistic about what we can obtain with what we have available. We have several datasets we have been pulling from. Of different types in the data points on all these relate to one another. So hopefully moving forward with some of Austin's help and his students we'll be able to consistently move into the future with data that is comparable at different checkpoints moving forward. We had a

canopy assessment done in 2013 by the Forest Service and the University of California at Davis, my alma mater. And one of the things I that was important to include in the canopy assessment was the idea of urban heat. What you're seeing now is our 39 municipality metro region; next to that is the index to heat. You can see where the red of most of our heat occurs. So from that assessment we were given the standard output of the environmental services that our trees provide to our citizens. And from there we really started thinking about, wow, we have this heat layer now and what does that mean? How can we use this moving forward to plan where we are going to target our efforts of planting and preserving trees. On this map you can see that the darkest green neighborhoods are the neighborhoods that have the most available planting spaces. So we were looking at that and matching it with those red and yellow blobs where we have the most heat. So if we can get the most bang from our buck by focusing our planting on those areas. It just so happens that most of the red I also pointed out earlier tends to be around our large interstate transit corridors; and it's also running through our industrial corridor along the South Platte River through the center of town. So from the heat, the heat layer it's really easy for us to get engaged with our environmental health department who is responsible for writing our climate action and climate adaptation plan.

So in 2013, the year that we started to have discussions about what climate resiliency means to us and how are we going to create an action plan that really has depth and does something to contribute to the resiliency of our city. And we went to the exercise of identifying the vulnerabilities within our city and finding tactics that we could use to address those. So within that action adaptation plan, you will see that we have these EMS activities. So Denver is the only city in North America that has metrics for all of our city departments under the ISO 14,001. Our environmental management system is a way to hold departments accountable for working on these environmental goals. We abetted into our adaptation plan, that we would first have an assessment for the metro area. Then we would work on inventory of all of the trees within the city and County of Denver. Those in our park system as well as those that we maintain in our public rights of way. And then lastly we wanted to take that information and look at the lens of diversity. What should we be telling people to plant knowing that we are going to have an altered climate in the future? For Denver, the climate models are showing that will definitely be hotter here in 30 years, but in northern Colorado we have a little bit of a conflict. It may be drier or it may be wetter. We are not sure yet. That faces a really interesting question that how do we as urban foresters put together a pallet of trees that will be able to survive now with our colder climate in a hotter future where there may be less now? So how do we establish things in a colder environment also thrive in a warmer environment? So we were working along on our and our adaptation plan on strategies and then all of a sudden this happened. We found emerald ash borer in an adjacent county which forced us to step away from our strategic planning around addressing heat and diversity into damage control. What we are able to do with our assessment is quickly say these are the benefits we have now and we think 15% of our tree population is ash, so we reduced our benefits by 15% and start having those conversations with our budget management office.

So of course they say it sounds like we have a big issue that we will potentially have to deal with really soon and how much is this all going to cost? We really had no idea. We had this a very broad canopy assessment with some big assumptions to it but we didn't really know exactly where all of our right-of-way trees were, what species they were, what condition they were in, or if it even made sense for us to treat or save those trees? So from those discussions, with the money people, we ended up with some positive results. In 2014 budget proposal, for 2015, we came back with a pretty sizable expansion. We were able to bring on inventory staff as well as contract some inventory work over a two-year period. As well as inventory all of our park trees that we maintain, start a five-year public awareness campaign, and then start getting ahead so that when emerald ash borer started taking a toll on front range we would have our debris produced ahead of time and also proactively planting throughout our park system. So in that one budget for that two through five year separate project that expansion ended up being two point $2.25 million. And now that we have our inventory in place and we know what we are dealing with we been able to go back to budget management and say the trees we have with 76,000 trees in the park system that we actively maintain. And we have about 218,000 street trees that are the property of the city and County of Denver but are maintained by the adjacent landowners. So now that we have that metric in place, we can help out discussion for the 2016 budget.

From that, we ended up with an expansion of 10 new forestry staff members, as well as starting proactive treatment of trees of ash in the public right-of-way. As well as aggressive proactive planting and we want to have trees in the ground growing starting to take the place of those ash that we may lose in the future so that we don't have a devastating loss in environmental services as well as doing a fun outreach program to educate the public about what they can do to save their private property trees. So now that we are out of that crisis planning mode, we ended up with almost $3 million budget expansion for the year of 2016. Now that were out of crisis planning mode, now we can get back to analysis mode again. So we know we have about three quarters of $1 million each year moving forward to prompt right-of-way trees and how will we do that strategically? What other information can we look at? Do we want to look at property value versus canopy cover? Do we want to look at average household income? Versus the neighborhood canopy? And bring that heat layer back in? Where do we focus our treatment dollars for ash? Do we want to focus on neighborhoods that are lower income that can't afford to preserve their trees? Or do we want to come up with some other type of system? And now that we have often in our region working with us it will be very exciting to see how we can match all of our data up and make some great strategic plans. So moving forward, working with University of Colorado at Denver, and Austin's students, we're looking at water.

Water is really important to the West. It does not fall from the sky here at the rate that it does in other parts of the country. We on average get about 14 inches of precipitation annually and most of that is in snow. So we are looking to do a project where we create a water budget for the trees in the city and then what would that water budget look like as we change the species of those trees in the city? Is there a trade-off if we have more trees is consuming more water are we saving more in energy or are there

different trade-offs? Also, we are working with the Trust for Public Lands on their Climate Smart Cities Initiative and we are looking to do more research there around urban green infrastructure and we will also be looking at using more of our downtown core right-of-way space as green amenity. The public really has spoken up and said the number one amenity they want to see more of in our urban core is trees. So for the first time in many years, the development community is starting to listen to us and to the citizens saying we want cooler, shadier, more beautiful spaces to live in. We are also updating our 50 year strategic plan, which we call the game plan, for the Parks and Recreation Department. And this heat idea and environmental ecosystems and services are going to play a much larger role in that game plan that was last visited about 20 years ago. So it's very exciting and we are on the cusp of some really great partnerships with our research institutions now. I think that is the highlight of what I wanted to cover. I think I am good with opening it up to questions with Austin.

Dana Coelho: Awesome, Sara. Thank you. We have had some questions start to come in. I will read those that have come in and feel free to keep asking questions as we are having a discussion. We have a nice chunk of time for you to guide the conversation. So let's see the first question that came in is probably for Austin. When assessing urban heat who is looking at surface versus ambient heat, and is anyone researching waste heat from the built environment and transportation?

Austin Troy: Good question. We are looking at surface temperature. To do atmospheric temperature you need sensors, we have deployed some sensors, my student, Mehdi, has done some calibration with ambient temperature sensors but I don't have any results from that to show at this point. In terms of anthropogenic heat, that really is a big question. I have not studied that yet. You can see it from looking at the satellite data and where [indiscernible] industries are, but it's not something we directly addressed yet. It's been well-established in the literature that there is a lot of urban heat islands that are due to actual heat generated by conduction and industrial processes, cars things like that.

Sara Davis: I believe that Brian Stone out of Georgia who is working with the trust for Public land climate Smart cities has been doing a little bit of work on waste heat. I've seen in some of his publications but that is the only thing I am aware of.

Dana Coelho: Thanks. Another question here for Sara on the budget figures that you are sharing is: The $1 million for treatments, does that also include removal or is it just for insecticide treatments?

Sara Davis: That's just for the systemic trunk injectable. Our plan is to treat cohorts of trees over a ten-year period to manage our mortality curve so we are not having to

take out so many trees all at once and our staff gets overwhelmed with our code enforcement duties. It's a little inflated. It's about $900,000 just for treatment. Annually.

Dana Coelho: And since Denver has an interest in urban heat islands, how do trees mitigate that effect and have you incorporated a planting approach for the city that accommodates the trees, landscaped underground which usually translates into a larger, healthier canopy?

Sara Davis: Yes. That's one of the exciting things that we have just started to really make headway on. In Denver, our development community is very sensitive to the American with disabilities act so it's very difficult for us to overcome the issue of usable surface versus walkable surface and having those walkable surfaces meet those ADA requirements. So we've been working very closely with public works and community planning and development and development services, to come up with different tree planting pits that can support trees for longer amounts of time and I know cities all across the world have this down and figured out and do it really well. For some reason Denver has really lagged in that. So were finally making headway and we've gotten away from the 5 x 5 pit to 5 x 15 pit. It's a small win but now that the community has come back to us and said that trees in our urban core are a prioritized amenity that's going to help us leverage the conversation even more and to get even more meaningful routing volume.

Dana Coelho: Anything you want to add that Austin?

Austin Troy: No, that was well said.

Dana Coelho: Okay. Another question: Since Denver is in the high plains, are there any data on the cooling effect of grasslands?

Austin Troy: I don't know. That is a good question. There has not been a lot done looking at the kinds of differential between urban tree canopy and grasslands in terms of nighttime temperature differential. Have not seen much written on it. So it's a new topic. I really don't have an answer to that.

Sara Davis: And I'm an urban forester, so once you leave the city I have no idea what is going on.

Dana Coelho: Here's another inside the city question. Are you considering native trees to replace the ash trees you mark?

Sara Davis: We would love to consider native trees to replace the ash trees. The problem is that palette is so small that could actually thrive in town. It's really not feasible. If most of our native trees are going to be conifers which aren't optimal to plant along the streets in Denver primarily because they shape the streets in the wintertime and the snow does not melt. Additionally they tend to use a little bit more water a lot of times. Our other native species are going to be things like choke cherries which aren't suitable to be large trees or cottonwoods which are such heavy water consumers that that is not really a practical option either. So our forest is primarily made up of non-native standard shade trees. If we had native suitable for urban and community situations we would love to use them. It's just that palette does not fit with our community set up.

Dana Coelho: Another question for Denver: Are you focusing any efforts on improving soils as part of the tree planting effort to enhance survivability?

Sara Davis: That's a really good question. When we are working in the urban core, when we are in the more engineered planting spaces we are definitely looking at enhancing the soils because the soil that we have in pits that have failed or were trees have died tend to be very salty from ice melt in those sorts of things. We definitely want to cultivate healthier soils in that area. As for our residential areas we don't do a lot of soil enhancement because those are areas that are adjacent to the property owner maintaining and soils tend to be pretty supportive of the types of trees that we plant now.

Dana Coelho: This one is also for you. Money used to fund these new programs in Denver is 100% of that money city budget or is money coming from a separate trust account where developers pay in when they first remove trees from a development site?

Sara Davis: Interestingly enough, it's a little bit of a combination. All of these expansions are general fund expansions so basic tax dollars coming into the city. Previously when we had a 1 million tree planting campaign, that effort was supported by a donation or sponsorship. So this is the first time I'm aware that we've had general fund dollars to support such a large scale planting. We do have mitigation funds where developers have to remove trees for one reason or another and pay the appraised value. That does stay in a special revenue fund that by ordinance is required to plant trees in public spaces and public rights of way. The bulk of it is general fund with some supplemental coming from special revenue from developers.

Dana Coelho: This one is also a money question. What was the cost of the latest tree inventory that was done for Denver?

Sara Davis: That's a really good question. We are 70% finished with the inventory of the centerline miles in the city and county. I have not personally looked at my labor cost in comparison with my contracted cost. But knowing that it's going to take me about a year and a half for five FTE with benefits and five on-calls, it's going to be most likely, if you looked at the labor costs and everything involved would be, wild guest close to $.5 million, maybe more.

Dana Coelho: This question is around education and the emerald ash borer. Do Denver education efforts include educating the citizens are having their trees treated with the systemic trunk injection that may also be lost and that you won't be able to treat them forever?

Sara Davis: Yes. Being very clear and transparent that the ash are not all going to be here forever and that the city is not going to intervene into perpetuity. We will be very up front as we start to treat and letting people know we are treating your tree for this period of time and we will check back with you in three years and at that point your tree may no longer be a candidate for our treatment as the parameters that tighter and tighter as we move into the future. It will be very clear and very frank. With all of our citizens that have trees in the right-of-way that we treat.

Dana Coelho: Great. This next question is for Austin. Are there known differences between the cooling effects of an assemblage of landscape trees like street trees versus that of an actual forest system within the urban landscape?

Austin Troy: Not from what we can tell from our data. I would imagine that what you consider a natural assemblage which would be canopy over soil and understory plants would be more effective because you have healthier trees and more evapo-transpiration happening and fewer harder surfaces. I would imagine that would be the case, as opposed to a solid canopy of landscape trees over hard surfaces. We could probably figure that out from our data. And a think we would probably find out what I just said, but it's definitely not confirmed yet.

Dana Coelho: Sara, have you developed a plant palette for your new planting plan?

Sara Davis: No, but I will tell you how we will approach it. I just got finalized budget expansion in November so the idea of actually executing something at this scale is something we are still wrapping our heads around. So the way out we approached our

last larger scale project was to use the [indiscernible] species selector, which had high leafy trees with best quality shade and those that were the lowest BBOC emitters and the best in collecting particulate matter. So we looked for the list of super trees and that will do everything for us and then we went through that list that was generated and vetted those. About what we know and what really performed in our region with our wind loads and snow loads and the drought cycles. All of those factors and then we have to pare that to our vendors. What can we actually get from the nurseries? So it's always something that changes from season to season but we really try to do our due diligence and look to the research and find the trees that are going to be the best for our community. We are also in EPA ozone nonattainment, so air quality is very crucial to us. The city sits in a basin so as the wind comes over the Rocky Mountains it bounces and suppresses all of the particulates and air pollution against the city, before the current hops back out over the plane. So you can see our air pollution and it's important for us to make good choices about our trees from the angle as well. We have another partner for that research around [indiscernible] emissions with University of Colorado Boulder, with Dr. Halmeg, and he took that list of trees that we developed for our last planting and ran them through rigorous experiments to determine that yes these are low emitters and they are good trees for air quality in Denver. We try to be really thoughtful when we develop our planting palette.

Dana Coelho: Thank you Sara. Another question for Denver: Do you have partnerships with local electric utilities to support urban heat island mitigation?

Sara Davis: No, we do not. It's a politically charged question. We have brought that up for many years that may be tree planting could be a strategy that are local utility would want to use to offset peak demand but we have chosen to go the route of founding other efficiencies in terms of what actually happens at the power plant. To reduce emissions. So no, not really. We have done some work at looking at conflicts between rooftop solar generation and existing trees versus a newly planted trees. And that sort of thing but that's really the only place that we have dabbled in the world of energy.

Austin Troy: From the research perspective we are in discussion, very preliminary talks, with Xcel Energy and Baltimore Gas and Electric about getting access to repaired data and nothing has been decided yet but we are in discussions and they recognize that there is a value to using trees as a load mitigation strategy during peak times. I think there's interest in it but it's a very hard to get a hold of repaired data and it would be very useful for this kind of research.

Dana Coelho: Thank you for that. Another more general question: Are any cities thinking about heat mitigation policies mandating greening on new developments with green area ratios or using green factors?

Sara Davis: That sounds like a spectacular idea. I'm not sure that I know of any communities that are doing that. The first thing that comes to mind would be mandates around shading parking lots, but I'm not familiar with anyone working on that right now.

Dana Coelho: Another question for Denver, from Southern California. They have a problem with nursery quality being poor because of large container size. Does Denver contract grow it seedlings?

Sara Davis: We currently do not. We have had a nursery for a number of years but it was not cost effective. It's more economical for us to put out a bid and then have vendors deliver trees to us. I would say that the majority of our stock comes in from Eastern Oregon and Washington, through local vendors here. We do have some locally grown trees but a majority are imported. I feel it's most likely because of the cost of water in Colorado. Water is very expensive versus fuel. We tend to ship stock in more so than grown locally.

Dana Coelho: We just put up on the screen the ISA CEU credit code and if you are looking for that and we will continue for about 15 more minutes with discussion and questions, since we have them. For those of you who only had the lunch hour to join we wanted to make sure that information was available to you and you can receive credit from ISA which you can download from the chat pod and I will close this out in a few minutes and I wanted to make sure it was up there if you needed to jet.

Our next question is also for Sarah. You said there was a lot of demand for trees from people in Denver. Is that something the community asked for themselves or did you have to sell trees to the public before they really became interested?

Sara Davis: I will qualify that and it's not demand for trees in Denver, it's more about the urban core. So we just did a survey around the outdoor Denver which is looking at the urban core and adjacent neighborhoods and how do we bring more green space and park amenities to these areas. And as a result of that planning process, there were surveys done of the public and that's where the public in the core area said that the number one amenity that we want more of. So interestingly enough, we in forestry didn't know that that planning process research was going on and it was really positive to hear that that is what the citizens were saying without any prompting from our office. It was very exciting. As for the rest of the city, demand for trees is buckshot. Some neighborhoods have a lot of trees and they want more. And we have to tell them know because they don't fit. There is no more room. And then there are other neighborhoods that it crickets. It’s radio silence. They really aren't engaged. It's hit or miss and it’s positive to hear that feedback from those in our burgeoning downtown core city area.

Dana Coelho: This question is also for Sarah. Did you do a complete tree by tree inventory or a sampling, windshield survey and did you use professionals or volunteers?

Sara Davis: Our inventory for public right-of-way tree inventory is every single tree in the public right-of-way. The majority is being completed by in-house staff that are trained and another portion by contracted consultants. Our park system inventory was completed completely by consultants. We did do a sample inventory back, and I'd have to look at my slides. We did a sample inventory, with volunteers back in 2008, and ran it through the precursor to i-Tree street stratum. Interestingly enough the number from the sample was telling us we had about 255,000 street trees and right now being 70% complete it shows we will have about 218,000 street trees so the old version got is pretty close to having an idea of how many street trees we had. Hopefully, we will have the complete inventory done by June.

All of our data, if you ever want it, is on the Denver Open Data Catalog and search that once when you get to the page, you can put in tree in the search box and get all of our data layers. We are also publishing for our citizens, online in a user-friendly format using the my tree keeper application from the daily resource and ours is DenverCO@mytreekeeper.com and individuals can click on their trees are park trees and click on what they are and we can start keeping information if there slated to be treated or if there's a vacant planting space that a tree is coming soon and we will have all of those resources up and running.

Dana Coelho: Great. This next question is for Austin. Did you include a comparison of conifers and deciduous trees in your data set?

Austin Troy: No, we did not do that. It's something we could do because we know which trees are conifers and which are deciduous and Baltimore, there are very few conifers in Baltimore and there's a larger number in Denver. It's still a pretty small number. Sara, do you know the percentage of conifers?

Sara Davis: I do know that in our street tree inventory there are no conifers in our top 15 species. They must tend to be on private properties. I could not accurately say.

Austin Troy: Yes. You tend to get, I have one in my front yard here, the Colorado blue spruce. But there's not quite enough of them to necessarily make a big difference. I think it's interesting to study because there are some issues around regulation that the conifers will block of sunlight in the winter which could be detrimental and also conifers tend to have higher rate of evapotranspiration and if they tap into ground water they can transpire the water without doing much with it. I think it's important to know the difference and in general the strategies for heat mitigation will be decidedly in the corner of deciduous trees.

Dana Coelho: That goes right into another question that was being asked about what data is available on evapotranspiration rates for different species, leaf areas, canopy density and other variables.

Austin Troy: That is a project we are working on right now in conjunction with Sara Davis and her folks. I have a new PhD student who is working on a project, as Sara mentioned, to create a water budget for the trees in Denver and there's not a lot of good data on many of these species and particularly not in this environment. We do have ranges. There are a few studies that we have been able to take data from where it they use flow meters. We are in the process of trying to put together funding to get some meters so we can calibrate some information locally so the answer is there is not a lot of good hard data on transpiration rates but there are ranges and we can take averages. But we do know in general that certain species use more than others and we have a general sense of how the size and class relates to consumption of water.

Dana Coelho: And [indiscernible] the topic a little bit more, is Denver integrating its tree planting effort with stormwater folks within the city because of this water budget aspect and the stormwater benefits of trees?

Sara Davis: That's another one of those loaded questions about the utilities. Water law in Colorado is very complicated. Water cannot be detained in certain situations for extended periods of time. Some places its 48 hours, and some places it may be even less than that. We are a headwaters state, so the water needs to get to the ground and get moving. So when we are looking at using public right-of-way and trees as vegetated infiltration facilities is very challenging because the water needs to get in them, through them, get into a pipe, and it needs to go out of them. With that in mind our urban drainage authority is putting forward soil mechanisms that we are not happy with, and they're not really happy with because of the high amount of sand. They want in the stabilities and low amounts of organic matter makes it really difficult to keep a tree a life without large amounts of irrigation. It is a definite challenge. We are looking at trees as a basin scale for stormwater management strategies more so than an individual facility strategy. But we would love to be able to use runoff to keep our trees irrigated but we have such complex water law and user water rights that it's very challenging for us to make headway into even getting curb cuts, and it's illegal in Colorado to even have rain barrels unless you own water rights to your property. That is a very long-term discussion that we would have to have.

Dana Coelho: Here's another long-term question. Have long-term resilience plans been established for Denver and if so, to what extent are city forestry plans influenced by them?

Sara Davis: We just drafted our first adaptation plan which would be synonymous with resiliency in Denver and that plan just got finalized and announced and published in 2014. It's a new idea to us. We are trying it out. And the nice thing is our adaptation plan is integrated into our EMS. As we reach those goals within our EMS, then we are having to come up with new goals and strategies to keep our accreditation with the ISO 14,001. We just embarked on that and our climate action plan is a longer-term document and we have sustainability goals going out to 2020. I would have to defer to my colleague in environmental health and office of sustainability about their longer-term and longer-range plans. But we are doing our very best to keep our urban forest in those conversations and a part of those plans.

Austin Troy: And related to that, the water budget study which is talked about which is a Forest Service study, that is meant to be a climate adaptation study in large part. It's meant to look at to what extent could Denver support, how much additional irrigation water would be needed if we had different climate change scenarios here if we had a reduction in precipitation an increase in temperature in an increase in transpiration rates what would happen to the urban forest? And that's in support of resiliency planning for the urban forest in Denver.

Dana Coelho: One last question. When you evaluate which trees you will plant you take into account their wildlife and if it's in conjunction to all the other factors we have talked about?

Sara Davis: I would like to say yes, but the honest truth is not really. If we are going to be planting some of our more natural or naturalized areas than we definitely would but our workgroup does not really get involved with that as much. Should we focus on areas that are irrigated so once we start planting for wildlife in the riparian corridors it's hard for us to establish those trees because the water and irrigation source isn't necessarily there. So we tend to when we are planting for wildlife, they are in channel riparian species and that falls into more of our natural resources group in terms of forestry that is not something firmly in our work plan aside from cleaning up debris when the beaver come through and cut down trees and fall into the water.

Dana Coelho: We did have one more question come in and maybe both of you could address this. It's about what hard science are you aware of that links urban heat and human health?

Austin Troy: There's definitely been a lot of studies on that looking at some epidemiological and public health studies looking at susceptibility to heat stroke and things like that. And heat related illnesses as they relate to urban heat. There’s different heat-related diseases, they’re exacerbated by more heat so that can definitely

make that work. It's a well-established connection. That's why the public health sector is more and more interested in this.

Sara Davis: And that's one of the things that has been a priority for many years for the National Urban and Community Forestry Advisory Council, looking at the linkages between human health and the urban forest and as I'm looking through our research needs and framework from the Council's Ten-Year Action Plan, one of the areas that is a focus for the next 10 years is to promote human health, human and community health through community forestry. So I have a feeling that over the next decade there will continue to be innovation grants and categories that speak to making those correlations between the community forest and human health.

Dana Coelho: Great. It's a nice action-oriented, positive note to wrap up our webinar today with. I would like to thank both of our presenters again for their time and for sharing with us all of their knowledge and experience about this hot topic. And thank all of you for participating and your excellent questions.

As we mentioned a few minutes ago if you are seeking ISA CEU credits, that code is up on the screen. If you are seeking a certificate of participation to submit to any other continuing education program and you have not done so already, please type your full name and email address into the chat and question pod and we'll keep that open another few minutes to do so.

If you have any other follow-up questions, feel free to email us using the link on our webpage. Please feel free to join us on the 10th for the next Urban Forest Connections webinar and the topic will be the *Forest at School: Implications for learning* where we will hear from Dr. William Sullivan at the University of Illinois, one of the premier researchers in the area of human health benefits of nature.

And one last thing before you sign off, please let us know how we are doing. Tell us how you would rate today's webinar and if you have any specific comments or suggestions, please do share those. Thanks again so much for joining us today at urban forest connections and we truly hope you enjoy the rest of your day. Thank you.

[Event Concluded]