Allyson Salisbury— Factors Affecting Urban Tree Wind Resistance to Tropical Cyclones

Ashley Robinson: [00:00:12] Hello and welcome to the ISA Conference Rewind video series. I am Ashley Robinson, Director of Event Services at the International Society of Arboriculture. Today, ISA is proud to bring you a presentation by Allyson Salisbury on factors that affect urban tree wind resistance to tropical cyclones. This presentation was originally given at the 2022 ISA Virtual Conference, so the views seen here are those of the presenters. So, if you're interested in learning about wind resistance, tree risk assessments, and the impact of different species on hurricane damage, I expect you will like this presentation. Now, sit back and enjoy.

Allyson Salisbury: Hello and welcome. I'm Dr. Allyson Salisbury, [00:01:00] and I'm excited to talk to you today about tropical cyclones and tree damage. I'm an environmental scientist and urban ecologist who is very broadly interested in how to help trees grow in places that are a bit difficult growing environments. As an example, this is a photo of me standing in front of a pile of treated sewage sludge. It's next to a highway that would become a new tree planting site. Currently, I'm a research data analyst and writer. I work for two different research teams at the University of Florida and Temple University, though today, the research I'm sharing was done at the University of Florida. I want to begin by acknowledging my many collaborators on this project. This is a very large topic, [00:02:00] and it has absolutely been a group effort to bring this project together.

Hurricanes are a pretty big deal. Hurricane-related damage costs approximately 17 billion dollars per year in the continental US alone. So, you can imagine how much larger that number is moving beyond the continental United States, and while money is really important, this number obviously can't begin to capture the emotional and psychological costs of that people experience when their lives are upended by hurricanes. Hurricanes are a global phenomenon. This map highlights the many regions across our planet that are affected by hurricanes or tropical cyclones.

[00:03:00] As a quick vocabulary sidenote, hurricanes go by many names that a few of it, you'll hear me use today. The phrase tropical cyclone is kind of the most sciency term for this weather phenomenon. Well, the term hurricane is primarily applied to the tropical cyclones that originated in the Atlantic Ocean. The word "hurricane" comes from the Taino word, hurakan, which means evil wind spirit, a rather apt description. In the Pacific Basin, tropical cyclones are referred to as typhoons in English. Typhoon is a rough approximation of the Chinese word, tai fung, which means big wind. So, during this talk, I'll mostly be alternating between tropical cyclone and hurricane, but know that, in this context, I'm using them interchangeably.

[00:04:00] Our project got started last summer. Some of my colleagues have been tasked with creating an updated version of the Tampa Tree Matrix. A screenshot is shown here. This is a pretty nifty online tool. It lists native tree species that are appropriate to plant in Central Florida cities. And at the time we were working with it, the resource provided some pretty basic tree info like height at maturity as well as a set of wind resistance readings. You've perhaps encountered similar types of plant lists in your own city or your own region. This presentation today is a little bit of a behind-the-scenes peek at some of what goes into creating the information that goes in these tree lists. Our team had wanted to expand the

matrix, so that it could include [00:05:00] additional useful information about species such as sunlight preference, soil types, etc. In doing so, we notice that only about 60% of species on this list had wind-resistance ratings. And well, that's not a terrible number, terrible percentage, but well, could we do better since hurricanes hit Florida with a good bit of regularity? As hurricane Ian recently demonstrated earlier this season after it slammed into the Gulf Coast of Florida.

Those wind-resistance ratings I referenced, they come from two seminal papers by Mary Duryea and a research team that was written in 2007. Following a few hurricanes that had hit Florida in the early 2000s, Mary and her team systemically recorded [00:06:00] hurricane damage to Florida and Puerto Rico's urban trees. They also reached out to professional arborists and collected expert opinions about the wind-resistance abilities of common tree species used in the region. Their work led to the wind resistance classification of 145 tree and palm species that are commonly found in Florida and Puerto Rico. So, this is really important work and really was a really cool study - still is really cool study – that improves how we can select trees for hurricane-prone environments. The main drawback of that side of studies, though, is that there's not really a simple or easy or even kind of clear way to incorporate new species into that [00:07:00] classification scheme.

Remember I mentioned that 40% of the Tampa Tree Matrix species were not covered by those by these studies and that wind resistance classification system. And again, those are mostly species just found in Florida. As I mentioned, hurricanes affect quite a large area of our planet. So, we thought that's kind of a problem, or a bit of a bummer. And so, we decided that one way to address this issue would be to develop a wind-resistance prediction model that could assign readings to new species in a more systemic and repeatable way. We would sort of take Duryea's work as our foundation and tweak it so that it could be repeatable and expanded upon. [00:08:00] In this context, when I'm using the phrase model, I'm really referring to a math equation or perhaps a collection of math equations. Generally, we envision our model would look something like the rough equation I've sketched out on the screen. What you would do is you would take information about a species, perhaps such as its wood density, and input that into the equation, and it would produce a wind-resistance rating or an estimate of a rating.

To create this equation, we needed to first figure out what characteristics would be most important to include in the model, and then second find data to generate what's called coefficients, or the unique numbers that sort of make the model work. So, [00:09:00] to get started, we need to find those characteristics that would be good predictors of tree damage during a hurricane. And our hope is that we can prioritize those predictors into our model. And so, that search for predictors is most of what I'll be focusing on in this talk today.

Rather than kind of waiting around for another hurricane to happen and collecting more data, we instead decided to address this question by conducting a comprehensive literature review, which I kind of like to think of as going fishing with a net. To begin with on any good fishing expedition, you have to find a good place to fish. Our search began by using Google Scholar and a pretty broad set of key words. As that process got going, I kind of felt like [00:10:00] searching Google Scholar for only English papers was insufficient. I had wanted to go searching in some other places as well, or go fishing and a few other oceans if you will. Considering that tropical cyclones are, again, global, I thought it was important that we look for tropical cyclone studies and other languages. The rest of our kind of core team agreed, and so, we reached out to our multilingual colleagues for help, and they have been a tremendous asset to

this project. So far, we have conducted searches in Chinese, French, Japanese, Portuguese, and Spanish, in addition to English.

Once we had chosen our metaphorical oceans to go fishing in, we would throw in our metaphorical nets, and with all of the search results [00:11:00] that our nets caught, we started to sift through all of those results and look for papers with methods and analyses that met our criteria. And that's sort of those four points listed on the slide. So, hopefully after a good fishing trip and you've caught some fish, likely the next thing you want to do is to cook and eat and enjoy the fish you've caught. The literature review equivalent would probably be extracting the relevant data out of the papers we had found and analyzing it to help answer our questions. So, for every keeper paper we found, we pulled out information about the study location, the methods, the type of predictors, the type of damage, and the statistical approaches used. So, those are sort of all of our key ingredients, if you will, that we [00:12:00] used to do our data analysis that I'll be sharing next.

So, our initial search turned up over 5,000 papers that were relevant to the topic of tropical cyclones and forests. And from these papers, we found a total of 64 Keepers, 55 were in English, 2 in Chinese, 5 Japanese, and 1 in Spanish. Of that collection, 13 took place in urban settings, while the rest we classified as rural studies. So, our study in urban forest included both trees very obviously in the built environment and trees that were found in more natural or remnant areas that were embedded within an urban setting. Pragmatically speaking, most papers sort of [00:13:00] self-identify as urban forest studies, and that's mostly what we use to classify our urban versus our rural studies.

So, this map shows the location of the studies that we kept. The blue squiggly lines represent the paths of every hurricane or tropical cyclone that's made landfall since 1970. And you can see from our map that most of our studies come from North America and the Caribbean, though we did manage to capture several studies from the Eastern Hemisphere as well. When we compare the general types of characteristics that are studied in urban and rural settings, you can see there are some similarities and differences. For example, [00:14:00] topographic settings can be an important predictor in rural forests but kind of an irrelevant predictor in urban settings. Instead in cities, we expect something like infrastructure, like buildings or utility lines, to have a much greater impact on trees. Management practices are probably the most consistently different category of predictors between our rural and urban forests. Typically, urban trees are going to be much more intensively managed for the purposes of safety and aesthetics. Meanwhile, in rural settings, our forests are going to be, if when they are managed, they're managed either for ecological purposes or for the production of timber.

This bar chart shows the frequency of different types of damage that we found in the studies we collected. [00:15:00] On the left side are rural studies, and on the right are urban, in purple. You'll notice that there are quite a few categories, there are many ways to assess and evaluate tree damage following a hurricane, and that are different categories, kind of vary in the frequency in which they're observed. So, for each study, we classified the predictor analyzed as having a positive and negative variable or non-significant effect on damage. A variable could also be classified as kind of generally significant if it was a categorical predictor and analyzed using what's called a contingency table methodology. So, this set of charts shows the type of predictor along the vertical axis. [00:16:00] So, that's predictors such as topography, soil type, pruning, or management history. And then each column represents the potential relationship with damage. So, again that's significant, positive, negative, variable, or nonsignificant. A darker color means that the same type of relationship was observed in more than one study. So, for

example, we have a predictor again for rural trees, such as topography, where several studies observed - some studies observed a significant difference between trees found in different topographic locations while other studies observed no difference. And so, that's the kind of data we collected.

[00:17:00] So, this version of the graph focuses only on one type of predictor, which is trunk diameter, or DBH, as we commonly call it. So DBH is one of our most commonly evaluated predictors. Here, each row of data is the type of damage that was measured. So, I shared this graph to kind of highlight how even when we have a predictor that's been very widely studied and we can split the type of data by damage. You know, that's things like did the tree fail because it's stem broke, because branches broke, because it flipped over, or the tree was just dead when researchers found it, there's still a bit of discrepancy in the observations among different types of studies.

So, if we look at mortality, [00:18:00] for example, we have studies that observed that bigger trees were more likely to die during a hurricane, and we have other studies that observed no relationship between the size of the tree and the likelihood of damage. So, I'm not going to dive into all the detail and nuance of the results in this talk, because there's a lot of them. But what I want you to kind of take away from this today is that drawing generalizations about any single predictor variable is pretty difficult again. Here, I've highlighted stand density, which again, highlights how multiple studies have observed positive, negative, variable, and no impacts between the density of trees and a stand and the likelihood of any sort of damage. [00:19:00] Part of this probably reflects differences in methodology and site-specific conditions that vary from study to study. Again, these are all observational studies, so they are people observing damage after a natural disaster has occurred, these are not designed as experiments and that makes comparison challenging. A lot of these discrepancies probably also reflect the ways many of these variables interact with each other and create confounding effects. So, I think that's an important lesson for us to learn as we think about building a model to predict damage.

I have to confess I was a little disappointed to not have any like "aha" moments after we synthesized all of this data together. Though that being said, I think there's a lot of valuable information to get pulled out of the state of set. [00:20:00] We just kind of haven't gotten that far into diving into the deep details of these collections of study, sort of tease that out yet. Nevertheless, after going through the urban studies, we do think there are some findings that are relevant and hopefully useful for managers. For starters, we kind of found two management-related recommendations that are relevant prior to tree planting. First, the observational literature definitely agrees that tree species vary in their ability to resist hurricane damage. We at least know what some of these hurricane species are species that are generally wind resistant. You maybe kind of have that awareness in your own community as well, just from observing tree conditions [00:21:00] after major storms. And when we do know which species are more likely to resist wind damage, those are species that we can prioritize planting in high-risk locations, such as near buildings. We can save those less wind-resistant species for naturalized areas where tree fall is going to cause less damage to infrastructure and property and people, and where tree fall is a part of the natural cycle of forests.

Second, what was a little interesting is that we found that there's very little consensus about the role that buildings and other trees play in serving as wind breakage to buffer trees from wind damage. There were some sort of, there have been hypotheses about [00:22:00] the ability of like planting trees in particular locations in order to limit wind damage. But that hasn't really been born out by the literature quite yet or so far and what we have to work with. So, rather than trying to figure out the optimal place

to put a tree in order to buffer it from wind, instead, we recommend that to continue focusing on planting trees and places that are just generally well-suited for a given species and are going to minimize stress as the tree grows. This way, we can grow healthy trees that are providing many benefits to their local ecosystem and community, and are perhaps healthier. Well-structured trees are hopefully going to be more wind resistant anyways.

So, we also found some recommendations [00:23:00] for existing trees in your urban forest. Some urban studies have suggested that tree pruning can help to reduce topical cyclone damage. This can involve removing dead, weak, or damaged branches prior to the storm. And additionally, there's some experimental evidence that suggests that by reducing the kind of overall size or the leaf area of a crown can help to decrease the likelihood of failure during extreme wind events. So, that's good news. This is a preventive step that we can take to help limit the likelihood of damage. Additionally, there have been several studies that demonstrate that risk assessment protocols, like the TRAQ protocol, have the ability to identify trees that are at high risk of damage during a hurricane. [00:24:00] While something like TRAQ and other kind of risk assessment protocols were not explicitly designed for hurricanes, they nevertheless can identify trees that are just generally likely to fail, are at high risk of failure, and that those high-risk trees do indeed tend to fail during hurricane and other high wind events. And I think that's a really cool and great tool that we have at our disposal. You can imagine that if you're a town or city and you're responsible for a lot of street trees in a region that often gets hit by hurricanes, or even occasionally gets hit by a hurricane, and also not hard to imagine that you probably have a really tight urban forestry budget and it's difficult to have all of your trees on a regular pruning cycle, [00:25:00] but if you're able to get risk assessment ratings for all of your trees and you know where your low wind-resistant species are, you could prioritize those trees for pruning and more frequent inspection, because you know that those are the most likely to cause a problem. And in this way, you can take preventative steps, again reduce the likelihood of those trees felling during a disaster. Hopefully, that means saving some time and money during a crisis.

I do want to acknowledge that our literature review approach and attempts to synthesize those factors do have some drawbacks. Like I mentioned, the studies we used have very different methodologies and take place in many different types of environments. [00:26:00] Consequently, comparing them is challenging and has its limits. Also, we focused our search on wind damage, though flooding and saltwater intrusion are also sources of tree mortality during a hurricane, we're treating that as a little beyond the scope of our study, but they can still be important factors. And in general, the other challenge with this type of research is identifying the exact cause of tree failure, especially in urban settings, can be quite challenging. And so, that also makes finding the relationships between particular predictors and damage difficult. And that all being said, we're not quite finished yet.

As I mentioned earlier, our other main goal is to create a model that can help us estimate hurricane wind resistance, [00:27:00] and we are making progress towards that goal as well. During our literature review fishing expedition, we also set aside papers that contain data on the rates of damage caused to different species. And so far, we've collected over 50 papers with relevant data. And this is some of the information that's going to go into that predictive model I mentioned earlier. Our next step is tracking down those species characteristics to use in the model and finding the kind of explicit data for some of those variables I mentioned earlier. The trick or challenge for us is going to be finding characteristics that we feel confident will have predictive capability but are also readily available information. And that's the journey [00:28:00] we've been on trying to understand when resistance and hurricanes. I think this work

is important, because it helps to give us tools to normalize planning and preparing the urban forest for natural disasters before they happen. A lot of attention and money on goes through its cleanup and recovery of natural disasters, and obviously, that's really important. But I'm excited for our research, because it should be providing an additional tool that shows that mitigation is possible and can be incorporated into our urban forest management practices.

So, with that thank you so much for your attention. Please feel free to reach out to learn more about our research.