Introducing a Definition of Urban Ecosystem Altering Trees:

A Case Study in Overstocking of Selected Species

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Abstract

This analysis introduces the definition of a new classification of tree species that can cause problems to urban forest health. The term Urban Ecosystem Altering Tree will be defined as non-native species that are planted well in excess of established biodiversity goals. While not invasive by nature, these species are overstocked by human actions to the point where they directly impact the ability of an urban forest ecosystem to function at optimal levels. This overstocking has a direct impact on the ability of urban forests to be resilient in the face of pests, and can lower the ability of urban forests to produce ecosystem services. This article suggests a simple definition for species that have this impact on urban forests, presents a demonstration of an example species, and produces recommended solutions to improve the sustainability of urban forests. By examining the impact of crape myrtles (*Lagerstroemia indica*) on Jacksonville, Florida's urban forest, an understanding of this term shall be developed and contribute to recognition of this challenge to urban forests. Multiple urban forestry texts will be analyzed to develop an understanding of the threat that these species can cause and to develop recommendations for appropriate remedies. By analyzing the development and impacts of UEAT species, this paper seeks to introduce the classification of UEAT species to the realm of urban forestry and propose appropriate solutions for this scenario.

I. Introduction and Definitions

Introduction

Urban forestry is a rapidly growing field, and as it continues to grow, practitioners and researchers alike are just beginning to understand many of the complexities that it entails. One example of these complexities is the debate over native versus introduced species and at what level is planting non-native species acceptable (Sjöman et al., 2016). Many communities have already passed resolutions to only plant native trees in response to this debate; yet others have no formal policy, showing a clear diversity in approach to this problem (Almas & Conway, 2016). This debate has become polarizing in many communities, as several non-native tree species have already become an ingrained part of a sense of community in many places, leading to some urban foresters simply avoiding the subject (Selge et al., 2011). However, as the importance of urban forestry continues to grow in the era of climate change, this issue must be addressed to ensure that urban forests provide ecosystem services at a sustainable level to help protect clean air and water for the future inhabitants of urban communities.

Crape myrtles (*Lagerstroemia indica*) present an excellent example of a non-native species that has been introduced and planted at a widespread level but does not present the typical challenges and traits of an invasive plant. This delineation is essential to this case study as the goal is not to argue over whether or not to remove invasive species, but instead to focus on improving urban forestry practices to maximize ecosystem services and protect biodiversity. Due to the widespread nature of the planting of this species, this analysis argues that they have a fundamental impact on the functioning of urban

ecosystems by reducing biodiversity, decreasing urban forest resilience, and replacing native tree species that would be more appropriate in many locations. Thus, it is argued in this case study that crape myrtles and other similar tree species that are planted in overwhelming excess of recommended biodiversity standards present a unique challenge, not as an invasive species, but instead as by what might be termed "Urban Ecosystem Altering Trees" (UEATs). By analyzing the abundance of this species and the results of such widespread overplanting, it will become clear that these UEATs present a significant risk to the urban forests of the future.

In order to demonstrate the challenges presented by UEATs, the role of crape myrtles within urban forests will be analyzed in the context of Jacksonville, Florida's urban forest. Jacksonville is currently facing the UEAT threat, with over 24% of the city's street tree population classified as the crape myrtle species (Arborpro, 2019)[1]. In addition, Jacksonville presents a unique environment to study this aspect of urban forestry due to its unique land size of over 800 square miles and the consolidated structure of government where the city and county governments are the same entity (*History of Jacksonville, Florida* 2021). This combination presents an excellent opportunity to analyze what happens when a single species is planted at such an extreme scale and over a broad area without any prior constraints. By analyzing the role of this species in Jacksonville, it will become clear that UEAT is a necessary classification to recognize species that pose threats to the health of an urban forest but do not meet the criteria for classification as an invasive species.

Definitions

One of the key phrases used often throughout this analysis that has not been previously defined is Urban Ecosystem Altering Trees or UEATs. Throughout this analysis, this term will be used to define species that pose a threat to the health of urban forest ecosystems due to the extreme overstocking of

[1] While crape myrtle commonly refers to the genus (*Lagerstroemia*), this text will use the title crape myrtle to refer to common crape myrtle (*Lagerstroemia indica)*, which includes non-cultivar species and hybrids of the various subspecies.

their population within specific ecosystems. It should be noted that these species have little to no recognized invasive potential of their own (i.e. their propagation is not excessive to the point that they escape to natural areas), but instead have become so widespread due to excessive plantings conducted by humans that they challenge the ability of urban forests to provide ecosystem services sustainably. The primary difference between invasive species' and UEATs is that instead of more traditional natural vectors (such as birds) that increase the spread of invasive species, UEATs are spread primarily by the human vector (Cain et al., 2000). Species that fall within this category share three primary characteristics. First, they account for so much of the urban forest that a mass die-off event of this individual species would create a massive loss to urban tree canopy levels. Second, they are often planted in a space better suited to a tree that would better enhance the urban forest due to the larger canopy or native status of the alternative species. Finally, they are non-native to the region, but do not present the biological potential to be classified as a truly invasive species. By this definition, the overstocked species of the 20th century (*Ulmus americana and Fraxinus spp.*) are not classified as UEATs, but it is important to note that overstocking is a problem for both native and non-native species. This classification would best define species that present a significant challenge to urban forest ecosystems but do not require extensive removal and control efforts. In this analysis, this definition will be expanded on and used to demonstrate the hazard that crape myrtles currently pose to Jacksonville, Florida's urban forest.

Study Objectives

While Jacksonville has a unique government, urban forest management program, and geography, many of the challenges that its urban forest faces are common challenges the urban forestry field encounters that can be applied elsewhere in the United States. This case study will demonstrate that one of these challenges is overstocking of ornamental tree species to the extent that they now pose

a threat to the resilience of an urban forest. By analyzing this specific example, urban foresters elsewhere may understand what constitutes a UEAT, how to prevent the spread of one, and how to respond to this spread. In this case, the species that has been overstocked so extensively in Jacksonville is the crape myrtle (*Lagerstroemia indica)*, which now comprises 24% of the city's street trees (Arborpro, 2019). While this analysis will focus on street trees, it is also important to note that this single species has been inventoried at 23.6% of the city's park trees, also well exceeding recommended biodiversity goals (Plan-it Geo, 2021). The fact that both inventories calculate a similar level for this species population indicates that this species is stocked at this level across a variety of land uses throughout Jacksonville, indicating that the species does compose about 24% of the city's total urban forest. This is well in excess of the 10-20-30 recommendation provided as a guideline in modern urban forestry texts (Miller et al., 2015, p. 334). While this guideline has been established for several decades in response to the Dutch Elm Disease (DED) and Emerald Ash Borer (EAB) threats of the 20th century, it has not been implemented in many locations. When implemented, urban foresters often fail to address the full scope of the problem. In order to respond to this challenge, this case study will develop a plan to respond to this challenge in Jacksonville that could present an outline for other cities with similar challenges to follow suit. By examining the development of crape myrtles as a UEAT in Jacksonville and recommendations to respond to it, this case study can help advise management elsewhere.

Methodology

In order to define this challenge and establish an outline of how to correct it, this case study will take a three-step approach that centers around the overstocking of crape myrtles in Jacksonville. First, the history of tree plantings in Jacksonville will be analyzed and compared with other cities to establish a clear pattern of overstocking that can be understood in the context of many North American cities.

Next, the problems caused by this practice will be examined to define the threat posed to the health of urban forests throughout the world. Finally, an outline of how Jacksonville could respond to this issue will be provided that could be used to develop plans for responding to similar issues in other cities. While circumstances will differ by specific location and time, this analysis intends to create recognition for a modern challenge to urban forest management.

II. Background and History

History

Urban foresters in the United States are painfully aware of the problems that overstocking a single species can present, as these challenges have plagued urban forests for the past century. At the turn of the 20th century, American Elms (*Ulmus americana*) were planted as one of the most common street trees throughout the country, but their population was decimated by Dutch Elm Disease (Ferrini et al., 2019, p.252). In response, urban foresters began planting different species of Ash trees (*Fraxinus spp.*) as the predominant street tree, until an infestation of Emerald Ash Borer attacked this species, once again drastically reducing Urban Tree Canopy (UTC) levels all across the country (Ferrini et al., 2019, p. 252). Locally, Laurel Oak (*Quercus Laurifolia*) became the predominant shade tree in Jacksonville during the national and local suburban boom of the 1950s, with many now testing the boundaries of their average 50-70 year life span and is currently causing a significant loss to Jacksonville's urban forest (Gilman et al., 2021). Clearly, urban foresters and developers have a pattern focusing on a small selection of available tree species for streetscape plantings throughout the United States. Much of this challenge could have been avoided had biodiversity received greater emphasis previously, but the lessons learned from these experiences have presented an excellent opportunity for urban foresters to improve their practices and prevent similar scenarios from happening again in the

future. By recognizing UEAT species as a specific concern to urban forests with practical approaches to manage them, these scenarios can be avoided in the future.

Just as bad of a threat as these invasions of biotic stressors is the introduction of invasive tree species through urban plantings. Often, a new ornamental tree has been imported and planted extensively. Researchers and foresters then realize that this tree poses a risk to native ecosystems as an invasive species (Frank, 2019). This was seen with the Chinese Tallow tree (*Triadica sebifera*), which was imported to Florida for its fall color and is now a highly invasive species in the region (*Triadica sebifera* 2021). In addition, research has also indicated that many of the invasive insect species that harm trees (i.e., EAB), are introduced through urban areas where non-native trees are imported (Branco et al., 2019). While non-native trees are sometimes imported to fill a role where existing native trees in cultivation are not meeting residents' goals (such as flowering in a specific color or presenting more fall color), these patterns show an apparent problem that is caused by the importation of these trees. This demonstrates the necessity for caution any time a tree is imported, but even more so demonstrates the importance of caution in species selection so that any one species is not planted at excessive levels before realizing that it poses a risk for invasion.

Similar in history to crape myrtles but in a different region is the history of Bradford pear (*Pyrus calleryana* 'Bradford'), which had a very similar development as a UEAT throughout the Eastern and Midwestern portions of the United States. These trees were introduced during the early 20th century and quickly became extremely popular due to their ornamental value (*Bradford Pear* 2020). While the Bradford pear itself is sterile when pollinating with other trees of the same cultivar, they can become highly invasive when they are able to pollinate with other variants of the same species (Shaughnessy et al., 2020). While there has been little indication of this development occurring in crape myrtle populations, the widely known case study of this Bradford pear species presents an example of

what can and often does occur when a non-native species is planted at such a high level to be classified as a UEAT. Should a new hybrid develop or should pollination patterns change, the results of overstocking of these non-native species becomes catastrophic to not just urban ecosystems, but also to their natural counterparts.

While crape myrtles are well established enough in the landscape that most professionals and researchers don't consider them to be invasive, they do share some common traits with invasive tree species. For instance, the crape myrtle was imported for its flowering traits and has been planted widely before much research was conducted on its invasiveness, similar to the history of the spread of Chinese tallow trees mentioned previously (Kirk-Ballard, 2020). Fortunately, it is generally agreed that this species does not pose much genetic potential for true invasiveness due to the lower natural propagation levels (Frank, 2019). However, if this species had greater natural propagation levels or should a hybrid with greater invasive potential develop, the results of overstocking this species could be catastrophic to natural areas (Almas & Conway, 2016). In addition, it appears that in Jacksonville, and much of the southeast, they are now the predominantly overstocked species in urban forests. The confluence of these two challenges presents crape myrtle as an excellent example of the negative influence that a seemingly positive tree species can have when planted at such a grand scale that it fundamentally changes the ecology of an urban forest. In the next section, this modern challenge that the crape myrtle presents will be analyzed more thoroughly to define further how this historical trend is being demonstrated today with this species.

Modern Problem

Urban forest biodiversity research has generally found that an acceptable rule for urban forest composition is 10% of any one species, 20% of any one genus, and 30% of any family of trees (Miller et al., 2015, p. 334). Crape myrtles have been planted well in excess of this number throughout

Jacksonville and other areas of the United States. For example, New Orleans, Louisiana, has had crape myrtles calculated as 28.6% of their urban forest (City of New Orleans 2021). In Jacksonville, crape myrtles currently represent approximately 24% of the publicly maintained aspects of the urban forest, nearly two and a half times the recommended limit for any one species (Arborpro, 2019, p.11). This presents some significant threats to Jacksonville's urban forest.

First and foremost, an ecosystem where a quarter of the tree population is the same species will not function as it properly should. In these scenarios, biodiversity is reduced to the point that the urban forest's resiliency is drastically reduced, native plants that provide crucial food and habitat for wildlife are being replaced (in this case, almost entirely by human choice), and ecosystem services are not being provided at their maximum potential. These topics will be explored further in the ecological factors section. However, it is essential to recognize early just how important these factors are to the definition and understanding of what comprises a UEAT and how these species impact urban ecology.

Public Perceptions

Much of the overstocking that has been conducted historically, including in the case of crape myrtles, is due to public perceptions of individual species that view them as highly favorable based on specific traits. In this case, crape myrtles are extremely popular with many people due to their hardiness levels and the attractive flowers they display for a lengthy bloom season each summer (Knox, 2016). In addition, because of their small mature size, they are seen as a low maintenance tree, presenting another reason why they are so popular with many homeowners (Gilman, 2007). Unfortunately, the spread of this tree as a popular ornamental has been accompanied by misinformation about proper tree care, and topping has become a major phenomenon among crape myrtles throughout the southeastern United States (*Crape Myrtle Pruning* 2021). This has been attributed to the belief that this practice increases the volume of blooms or that it is a healthy way to keep the tree at a manageable size, but

arboricultural standards are quite clear that this practice is very damaging to the health of trees (Lilly, 2010, p.121). The combination of these two factors has led to a troubling history for urban forests throughout the southern United States, where whole streets are lined with crape myrtles that are topped down to stubs of their potential annually.

In addition, Jacksonville's history with crape myrtles provides greater insight on how the overstocking problem has become so rampant. In the 1990s, one of the goals of Mayor John Delaney's administration was that they wanted Jacksonville to be known as the "City of Crape Myrtles" and established several programs to give away thousands of crape myrtle trees every year (Jacksonville Tree Commission, 2020, p. 3). This certainly had the support of the local electric agency, JEA, as well, since crape myrtles are of such low risk to the electrical grid (Jacksonville Tree Commission, 2020, p.3). While the number of crape myrtles planted and still surviving through these programs is unknown, the local government's clear and unwavering support thus far for planting crape myrtles must have been a factor in the decisions made by citizens to plant so many over the past several decades. While these programs are no longer being implemented, their impacts are still felt on Jacksonville’s urban forest.

III. Ecological Factors

Land

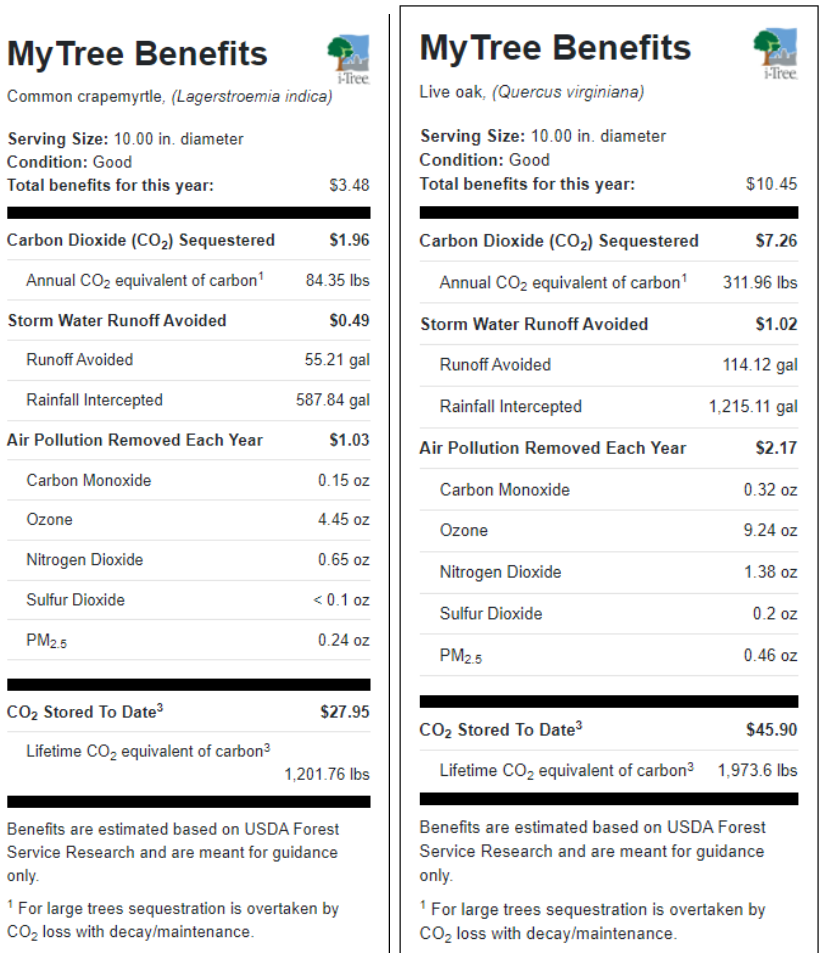
While pest outbreaks and potential invasion by overstocked species are always the first concern that an urban forester has, often the first primary symptom of UEAT overstocking is a functional loss of ecosystem services. Research has indicated that, when possible, either large or native trees should be selected for planting sites over smaller or non-native species (McPherson, 2003, p.19). In the case of native versus non-native, this preference for native species is based on the ecosystem services provided to native wildlife that depend on the food sources provided by native plants or on the entire tree for

their habitat. Thus, when a non-native species is planted in a site suitable for a native species, that is a case where potential food or habitat for native wildlife is being lost. With the continuous deforestation and habitat fragmentation occurring across the United States, ensuring that any opportunity to assist native wildlife is not lost should be a significant concern for any urban forester.

Just as vital, if not more so, is the importance of planting large trees wherever possible within an urban forest. Some estimates place the ecosystem services of large mature trees at nearly triple that of their smaller stature counterparts (McPherson, 2003, p.20). To illustrate this difference, i-Tree "MyTree" calculator was used to calculate the annual benefits of two trees planted directly adjacent to each other (*MyTree* 2021)[2]. Each had the same DBH value entered with the same condition rating of "good" to generate an appropriate comparison of potential ecosystem services compared between a small species and a large species, all else being equal. This calculator tool generated annual CO2 storage and stormwater runoff avoided values for the live oak at 312 Ibs and 114 gallons respectively (*MyTree* 2021). For the crape myrtle, each of these values was only 84 Ibs and 55 gallons respectively (*MyTree* 2021). This is a clear discrepancy between these two species and demonstrates just how much environmental benefit is lost every time a crape myrtle is planted in a location where a larger tree would be suitable. In addition, note that these values are only for similarly sized species; considering the extended lifespan of larger species, such as the live oak, the environmental benefits lost over a lifetime when a crape myrtle is planted in a space where a larger tree would be suitable become much greater. Considering the potential amount of ecosystem services lost with every location where a crape myrtle was planted but another species was more suitable, the immensity of a large-scale overstocking as is present in Jacksonville becomes clear. In this way, crape myrtles truly do present themselves as an Urban Ecosystem Altering Tree due to the number of potential ecosystem services lost and the potential

[2] This tool was developed using the values produced through several of McPherson's studies, including the one cited above. This research was expanded to provide individual species values and provides an estimate of all environmental benefits of a specific tree, as seen in the images below.

habitat for the wildlife of urban ecosystems. Each of these aspects has significant impacts on the potential of urban ecosystems to function at a sustainable level, given the other stressors already occurring to these ecosystems.



MyTree Benefits

Common crapemyrtle, *(Lagerstroemia indica)*

Serving Size: 10.00 in. diameter
Condition: Good
Total benefits for this year: $3.48

Carbon Dioxide (CO_2) Sequestered	**$1.96**
Annual CO_2 equivalent of carbon[1]	84.35 lbs
Storm Water Runoff Avoided	**$0.49**
Runoff Avoided	55.21 gal
Rainfall Intercepted	587.84 gal
Air Pollution Removed Each Year	**$1.03**
Carbon Monoxide	0.15 oz
Ozone	4.45 oz
Nitrogen Dioxide	0.65 oz
Sulfur Dioxide	< 0.1 oz
$PM_{2.5}$	0.24 oz
CO_2 Stored To Date[3]	**$27.95**
Lifetime CO_2 equivalent of carbon[3]	1,201.76 lbs

Benefits are estimated based on USDA Forest Service Research and are meant for guidance only.

[1] For large trees sequestration is overtaken by CO_2 loss with decay/maintenance.

MyTree Benefits

Live oak, *(Quercus virginiana)*

Serving Size: 10.00 in. diameter
Condition: Good
Total benefits for this year: $10.45

Carbon Dioxide (CO_2) Sequestered	**$7.26**
Annual CO_2 equivalent of carbon[1]	311.96 lbs
Storm Water Runoff Avoided	**$1.02**
Runoff Avoided	114.12 gal
Rainfall Intercepted	1,215.11 gal
Air Pollution Removed Each Year	**$2.17**
Carbon Monoxide	0.32 oz
Ozone	9.24 oz
Nitrogen Dioxide	1.38 oz
Sulfur Dioxide	0.2 oz
$PM_{2.5}$	0.46 oz
CO_2 Stored To Date[3]	**$45.90**
Lifetime CO_2 equivalent of carbon[3]	1,973.6 lbs

Benefits are estimated based on USDA Forest Service Research and are meant for guidance only.

[1] For large trees sequestration is overtaken by CO_2 loss with decay/maintenance.

Image 1: A side-by-side comparison of environmental benefits of a crape myrtle vs. a similar sized live oak.

Vegetation

In addition to the above problems posed by overplanted species, the introduction of a new species that is not native to the region it is planted in always carries with it some potential of invasive species outbreaks. While there is very little literature currently suggesting the development of invasive

spread by crape myrtle trees, distribution maps reveal 339 records of escaped individuals throughout the southeastern United States, with some escapes recognized in counties neighboring Jacksonville (Crapemyrtle (Lagerstroemia Indica) - EDDMapS Distribution, 2021). While the potential for escape has been seen as low up to this point, should climate or genetic conditions change, there would be a considerably greater risk for further invasion of natural areas. Since there is always the potential for invasive spread when non-native species' are planted, great precaution should be taken when considering their planting. Research has indicated that large-scale overstocking (such as this overstocking of crape myrtle that is being studied) can certainly contribute to greater invasive spread of a species, presenting even more reason to limit these overstocking actions (Loeb, 2012). By limiting the human vector of this species' spread, their dispersal through urban and natural areas can be minimized.

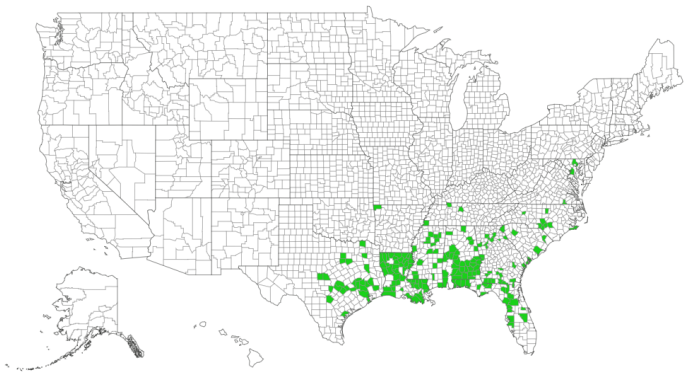


Image 2: A map indicating all documented locations where crape myrtle has been identified as growing in the wild.

As explained previously, the overstocking of a single species in urban areas can also contribute to mass die-off events in urban forests when presented with a pest or disease outbreak. As seen in the case of Dutch Elm Disease and Emerald Ash Borer, overstocking of American elm (*Ulmus americana)* and Ash trees (*Fraxinus spp.)* has led to significant decreases in urban forest health when they were faced with their respective pests (Berland & Elliott, 2014). Raupp and Gonthier find that this pattern of

replacing one species facing catastrophic loss with excessive levels of another (such as in the case of replacing American Elm with Ash trees) "predisposes cities to catastrophic loss" (Ferrini et al., 2019, p.252). While Crape myrtles currently do not have a significant pest outbreak threatening them, history has shown that outbreaks can occur at any time due to the interconnected nature of globalized society. In addition, there have been several first observations of new pests reported among crape myrtles, including bacterial leaf spot, gray mold, and apple-knot nematode (Babu et al., 2014, Afroz et al., 2016, Gu & He, 2015). Finally, Branco et al. explain clearly that most invasive pests are introduced through urban horticulture practices, often when importing trees from different areas of the world (2019). While the impacts of this specific aspect are likely avoided in the case of crape myrtle (as most being planted in North America are now grown in North American nurseries), it does provide plenty of reason to shift tree selections from non-native species' to native species that do not carry this risk (*PlantANT* 2021). By reducing the overstocking of UEAT species, urban foresters can help to avoid these risks to natural and urban ecosystems.

Wildlife

The most prominent impact crape myrtle overstocking has on wildlife is the loss of native habitat and food sources that are key to the survival of existing wildlife. As animal species evolve in a pattern similar to that of plants, it can take several generations for changes in food and habitat sources to be effectively utilized by wildlife (Schell et al., 2021). In natural areas, the introduction of non-native species through escape can also lead to the out-competition of native plants that are essential to native wildlife (Corona et al., 2011). In addition, in urban areas, the selection of non-native species, such as crape myrtles, can lead to the loss of this habitat for native wildlife that has otherwise been able to adapt to urbanization (Schell et al., 2021). As this wildlife is essential to the functioning of an ecosystem (such as through pollination), any efforts to preserve native wildlife should be

encouraged. Thus, while in small amounts the planting of non-native species may have minimal effect on wildlife, major overstocking of non-native species can highly alter the functionality of urban ecosystems by reducing food sources and habitat for wildlife.

Biological Processes

While heavily stressed by human impacts and facing much different challenges than natural areas do, urban ecosystems are critical to human survival and function in many similar ways to their more natural counterparts. Native plants are critical to the natural food chain that occurs in natural and urban ecosystems, so preserving their inclusion in both types of ecosystems is critical to the functionality of that ecosystem (Corona et al., 2011). While preserving an urban forest composed entirely of native plants is likely impossible, efforts to preserve their survival as much as possible will lead to healthier urban forests. In addition, biodiversity is key to the long-term health of urban ecosystems, as biodiversity can significantly enhance the resiliency of such an ecosystem. With the constant stresses of development and pollution, urban forests are often easily susceptible to pests outbreaks on overall canopy levels, so having a wide diversity of species can reduce the impact of such outbreaks. Finally, preserving habitat for animals residing in urban ecosystems is crucial to ensuring that they can remain a part of that ecosystem. Just as they rely on plants for their habitat, these plants in turn rely on insects and animals to sustain their populations through pollination and seed dispersal (Cain et al., 2000). By protecting native biodiversity within urban forests, urban foresters can maximize the ability of urban ecosystems to function at their optimal level, given the stresses they already encounter.

IV. Social, Cultural, Economic, and Ethical Aspects

Social Aspects

Unfortunately, many of the challenges to correcting this historical overstocking problem lay within the realm of social and cultural aspects. Since urban forestry focuses on bringing people and trees together, it is essential for urban foresters to recognize the human aspects of this realm of forestry and work with the community to improve the urban forest they are managing (Little & Leon, 2021). Especially in this case, social aspects play a significant role due to the immense popularity of crape myrtle trees (Knox, 2016). With how popular crape myrtles (and most other UEATs) are with the general public, convincing citizens of the importance of reducing their impact on urban forests will be quite a challenge. This challenge must be approached directly, with quantified and verifiable research that indicates the need for biodiversity. Having good data is only half the solution, though; if programs to lessen the amount of UEAT stockings are to be effective, urban foresters must implement robust educational programs to disperse this information to residents of their municipality (Ferrini et al., 2019, p.214-216). One significant aspect of this information to share is increasing public knowledge of the benefits provided by shade trees and supporting this knowledge with concrete data about the economic, cultural, and environmental values they provide. In the case of crape myrtles, this direct comparison of a smaller tree species to the immense value provided by canopy trees would be highly beneficial to persuasive arguments to limiting the planting of UEAT species. By tying urban forestry efforts to economic and cultural values, not only will urban foresters be able to gain support for specific projects like the reduction of UEAT overstocking, but they can also gain greater support for their work in general.

Cultural Aspects

In addition to the challenges presented by crape myrtles as a UEAT species, they present another great challenge to urban forest canopies due to a culture of topping the trees. This practice is often seen with a reduction of nearly all of the tree's canopy, reducing the environmental benefits associated with tree canopy to nearly negligible levels. With this practice occurring annually on many of the trees that undergo this pruning practice, the specimens being topped are essentially unable to produce ecosystem services at all as most of their energy is going straight to survival. For examples of such the topping that is common in Jacksonville, see appendix E. Of course, such a drastic reduction in canopy is highly detrimental to the health of a tree, and this practice can dramatically reduce the lifespan of a crape myrtle, further reducing the potential environmental benefits produced by individual specimens that have faced this practice. With sufficient canopy levels being so vital to the future of urban forestry, any such cultural aspects that produce a significant loss in canopy annually should be promptly addressed. By reducing the overstocking of this species, the impact of topping culture can be significantly reduced.


Images 3 and 4: topped crape myrtles at different points in their life-span with the image on the left showing a newly planted tree that has been topped and the image on the right showing a repeatedly topped specimen.

Economic Aspects

The first major economic aspect to consider before reducing the usage of crape myrtles (or any other UEAT) as part of an urban forest is ensuring that there would not be a negative economic impact associated with the reduced usage. As prices for crape myrtle trees are similar to the prices for other tree species, reducing the usage of this one species would not increase the cost associated with tree planting practices (*PlantANT* 2021). In addition, reducing the overstocking of this species would incur a net gain economically, as the increased biodiversity and Urban Tree Canopy (UTC) levels would increase the economic benefits produced by Jacksonville's urban forest (Mohamad et al., 2013). As explained previously, much of the problem associated with the overstocking of this small tree species is that they reduce potential planting areas for other trees that have greater canopy levels. With this greater canopy, the environmental benefits increase, thus increasing the economic value of the trees in planting areas where more appropriate trees are planted (McPherson, 2003). By reducing this overstocking, not only would communities keep the cost of planting projects similar to current levels, but they would also greatly enhance the economic value of their urban forests. By reducing UEAT species overstocking, urban foresters improve the sustainability of the urban forest they manage and provide greater economic benefits to their community.

Ethical Aspects

As sustainability has become such an important environmental ethics concern, ensuring that urban forests are resilient over several decades is a major concern for their ethical management. Thus, any actions taken by urban foresters to increase resilience to pests and increase the amount of UTC to ensure healthy cities in the face of climate change are the ethical choice for urban forest management.

By reducing the plantings of UEATs, urban foresters can increase this resiliency and ensure that maximum canopy-producing trees are planted wherever possible. Reducing the plantings of crape myrtles is consistent with this effort and would thus be the most ethical option for urban foresters to ensure greater resilience of urban forests (Ferrini et al., 2019, p.93). In addition, by working towards improving and protecting ecosystem functionality, urban foresters are taking an ethical approach towards protecting the ability of animals to continue surviving, even in highly altered urban ecosystems (Douglas et al., 2010, p.5). By working to actively improve the health of an urban forest, urban foresters that reduce overstocking of UEATs, such as crape myrtles in Jacksonville, are taking the ethical management approach.

V. Management

Historic

Historically, the issue of UEAT species, and specifically, crape myrtle overstocking has been essentially ignored in Jacksonville and is the same in many of the urban forests impacted by similar scenarios. This is primarily due to the lack of a vigorous urban forestry effort in Jacksonville. In 2015, the City of Jacksonville government faced a lawsuit for misuse of tree mitigation fund money (due to lack of planting efforts), which led to the eventual development of what is essentially an entirely new urban forestry team of what is now four full-time staff members (Ross, 2018). Before this lawsuit, there was only one urban forester for the whole city of more than 850 square miles, which of course, meant a minimal urban forestry effort focused only on removing hazardous trees (Little & Leon, 2021). Due to this historical lack of staff, the city's urban forestry team could not devote time to recognize potential future challenges, such as this end result of overstocking crape myrtles. This lack of ability to recognize the problem has led to the continued excessive planting of this species, leading to the present condition

where this one species makes up nearly 25% of Jacksonville's urban forest. This, of course, has created the current challenge, where planting practices of previous decades have to be corrected.

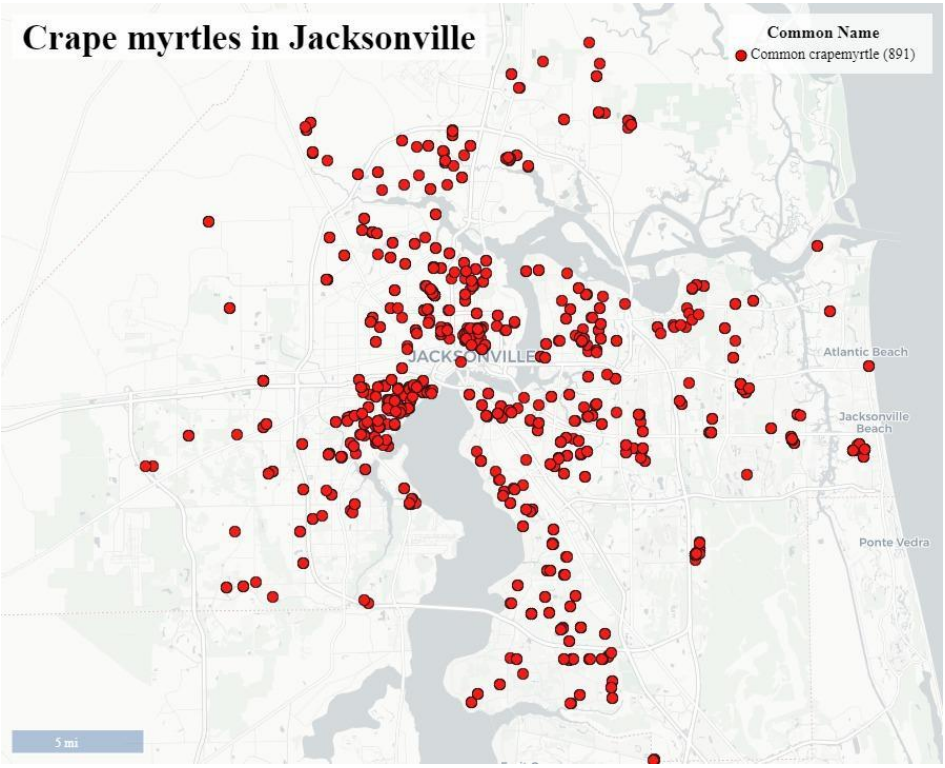


Image 5: A map of crape myrtles planted on all City of Jacksonville tree planting projects since 2016.

Current

Due to the increase in staff explained previously and continuing education efforts of this staff, the problem of UEATs can now be recognized by Jacksonville's urban forestry staff, allowing them to correct this historical trend. The staff has quickly recognized the importance of reducing the planting of non-native and particularly UEAT species, with them now no longer being offered through the city's award-winning "630-City" tree-planting program, where individual residents can request for trees to be planted in the right of way adjacent to their home (City of Jacksonville 2021b). Even with this quick informal action, little formal action has been taken. Potential formal steps could include removing them from the city's approved tree planting list or formalizing the policy of reducing these plantings on the

urban forestry team's website (City of Jacksonville 2021a). This lack of formal action is likely due to the expected public response to removing such a popular species, as was revealed in the social aspects section. In order to avoid this backlash, city staff should utilize academic research to support the argument against continuing the planting of overstocked species. By presenting this research on the subject of UEATs to gain the support of the city's tree commission, city staff may be able to take further definitive action to reduce the planting of crape myrtle trees and prevent further spread of potential future UEAT species.

VI. Time, Space, and Landscape Aspects

Time

The process to offset decades of inaction on UEAT species is likely to take several years at a minimum. Due to the increasing tree planting efforts being conducted by the city, continued efforts by city staff and local nonprofit groups may be able to offset this practice quicker than it took for the situation to reach the current conditions. By focusing on planting native trees at the current scope of their planting projects, positive results could be attainable within just several years if appropriately managed. The gathering of support and policy would be the first step towards these actions though, as such a significant shift in policy would need support at a level higher than the urban forestry staff. In this case, having the full support of the city's tree commission, as documented by a resolution, would grant staff the ability to fully implement such a policy with less fear of political repercussions. The process of gaining this support would likely take several months to one year. This would include time to conduct further research, prepare presentations, and share their findings with the tree commission to garner support. Once this support is gained, the policy of ending plantings of UEATs by city staff can be formalized and allow staff to increase native biodiversity to the point where the urban forest is best served and is thus better serving the Jacksonville community.

Space

Due to the consolidated form of government where Duval County and the City of Jacksonville share the same government, efforts to reduce the planting of crape myrtle would necessarily be countywide. As there is only one urban forestry team for this consolidated city and county government, any policy changes reflected to correct this historic overplanting trend would be implemented at this countywide scale and would thus be fairly simple to track and manage. While policy changes are important to correct this error, caution must be taken to ensure that actions to counteract it are not too ambitious. Instead of conducting a removal of crape myrtles and other overstocked UEATs, as is often the approach for invasive species, a simple shift to avoid planting them is the more proper response. The damage done by entirely removing the species from an urban forest would be greater than the damage done by having them remain present, with their population gradually decreasing. Instead, they should be replaced gradually with a diverse palette of more appropriate species that better serve the urban forest. In addition, the logistical challenges of an approach including removal would be too costly and time-consuming to prove efficient. While new policies regarding new tree plantings would cover a large area, there would be little to no logistical problems to solve as there is no removal effort being recommended.

Landscape

Whether over one year or fifty years, dramatic alterations of an urban forest are generally seen negatively impacting a city's landscape. Even if the change is gradual and sure to positively impact the urban forest's health over the long term, urban foresters can certainly expect to receive public criticism over the response (Ferrini et al., 2019, p.214). In this case especially, there is sure to be a major public response due to the attractive flowering of crape myrtle trees and their widespread popularity. Even with this expected negative response though, this change to Jacksonville's landscape is entirely

necessary to ensure the health of the urban forest for future generations and to ensure that ecosystem services can be provided at a sustainable level.

Even with the public outcry over the decrease in population of such a popular flowering tree, the landscape can retain its appeal due to the many flowering trees already native to the region. For instance, Magnolias (*Magnolia grandiflora*), Fringe trees (*Chionanthus virginicus*), and Eastern Redbuds (*Cercis canadensis*) all produce excellent flowers, are native to Florida, and are not currently planted at such a high level in Jacksonville's urban forest that they pose the risk of being considered overstocked and presenting similar challenges to those created by the overplanting of crape myrtle (*Native Florida Trees,* 2021). With a greater diversity of species, there will be greater diversity in flowers, fall color, and general structure of trees, ending up creating an overall more attractive landscape. While urban foresters should not focus their time on aesthetics, spending some time on this aspect can bolster greater support for efforts to reduce UEAT plantings.

In addition to being potentially more aesthetically pleasing, the landscape of Jacksonville would be far more resilient than it currently is. As mentioned previously, crape myrtles are currently not considered susceptible to major pest outbreaks. However, caution should always be taken to ensure an urban forest is as resilient to them as possible due to the continuously evolving and spreading nature of urban forest pests. This means ensuring biodiversity as much as possible, and at the very least, ensuring that there is not such an extreme overstocking as is presented in the case of crape myrtle trees in Jacksonville or other UEAT species elsewhere. By taking clear and definitive actions to reduce this overstocking, Jacksonville's urban foresters can take specific and measurable steps to further enhance the biodiversity and resiliency of the landscape. Biodiversity will help to reduce susceptibility to any future invasions of invasive pests that would threaten the overall health of Jacksonville's urban forest

and thus protect canopy levels as much as possible to ensure trees are providing ecosystem services at their maximum potential.

Finally, by shifting focus to planting native species of a broad variety, urban foresters can highlight the already existing beauty of northeast Florida's natural vegetation. While many local production forests focus on the timber-producing yellow pines of the southeastern United States, the native habitats of northeast Florida range from swampy bogs to high and dry mesic flatwoods, and have a variety of native hardwoods typically associated with more temperate regions further north (*Habitats* 2021). This creates native biodiversity that includes numerous oak species (*Quercus spp.*), hickories (*Carya spp.*), and pines (*Pinus spp.*), all native to the same region. This creates a natural landscape rich in biodiversity (and thus resiliency) and beauty that needs little assistance from introduced species to meet a wide array of interests. Thus, actions taken to plant less introduced species, such as crape myrtles, and increase the usage of native species that already thrive throughout the region would be an excellent way to help restore residents' cultural connection to the land they live on.

VII. Recommendations

Education

First and foremost, to reduce the threat of UEAT species, urban foresters should develop a robust educational program. Not only should this program focus on the threat of a single UEAT, but instead, this program should be oriented around the positive aspects of biodiversity. This will help frame the message positively, which can help increase the public's receptiveness and increase public support for urban forestry efforts (Benedict & McMahon, 2006, p. 225-226). In addition, approaching the subject with a central focus around preserving and increasing biodiversity may help resolve the immediate issue with a specific species and increase awareness of the development of UEAT species.

By increasing this awareness, urban foresters can hopefully reduce the likelihood of such overstocking occurring in the future with similar species.

Since urban forestry is such an emerging field, educational opportunities should be welcomed whenever possible and to the fullest extent possible (Benedict & McMahon, 2006, p.215). Thus, urban foresters should take educational opportunities not only to focus on this one particular issue that they are facing but instead should use these opportunities to provide the public with more information about the science surrounding the field. In this case, using educational opportunities to share with the public how appropriate levels of species selection are recommended based on scientific data is a great way to not only gather further support for the practices of reducing UEAT plantings, but can add some legitimacy to the field in the public eye as well. Thus, these efforts to increase education about UEATs would work towards resolving the present and similar situations and increase support for further urban forestry efforts.

Phase-Out Efforts

After education has been approached thoroughly and some public support has been gained, urban foresters should begin to phase out plantings of UEAT species. In the case of Jacksonville's crape myrtles, these efforts should begin after urban foresters have shared their concerns with the city's Tree Commission, to gather support from the city's official urban forestry advisory board. This commission's support is crucial to future actions as this board has oversight over tree planting projects and could present a challenge to complete phasing out efforts if they are not thoroughly informed of the reasoning behind such steps before they are undertaken. By actively seeking their support and encouragement, urban foresters may be able to gain approval and assistance in efforts to reduce UEAT levels within the city. Previous actions to reduce the planting of a similarly problematic species (date palms) were greatly aided by the passing of a resolution by the city's Tree Commission, prohibiting their planting

within city right of way areas (City of Jacksonville 2021b). Seeking a similar resolution may greatly enhance the efforts of Jacksonville's urban forestry staff to reduce the plantings of crape myrtles. By actively engaging the Tree Commission and seeking such a resolution, urban forester actions to reduce the overstocking of crape myrtles would be more effective.

After support is gained, the efforts to phase out UEAT overstocking are relatively simple: stop planting the problem species. This includes any public planting project where urban foresters are supervising tree plantings. While this may seem a drastic approach, urban foresters must set an example of best practices within the city they serve. If a UEAT species has been recognized as posing a challenge to the health of an urban forest, urban foresters should set the precedent of minimizing their plantings to best set an example for community members. While this approach may seem impractical due to the high difficulty of entirely stopping plantings of a single species that is generally very hardy in an area, this full-scale approach appears to be the only effective measure to reduce plantings of species selected for reduction. This is based on an understanding of how urban foresters have attempted to end the planting of invasive species, where complete elimination of their planting was truly necessary. While not necessary to completely eradicate UEAT species, taking a similar approach towards plantings can dramatically reduce their presence (Hulme et al., 2017). Thankfully, UEATs are not of such a severe threat that they require any removal efforts, as is often employed in the case of invasive species. Since these species do not spread by natural vectors other than humans, simply reducing the human vector for their propagation will help to reduce the spread of UEATs, including crape myrtles. Phase-out efforts by city governments will almost certainly be insufficient to stop the human vector of UEAT spread, but it will set the necessary example to begin a reduction in population.

Unfortunately, even simple efforts to reduce UEAT plantings will be highly controversial and will face political challenges to even just a simple measure such as stopping the planting of the specific

species. In the example of Jacksonville's crape myrtle population, heavy pushback can certainly be expected due to the immense popularity of crape myrtles, as outlined in the social aspects section (under section IV). By taking the steps outlined above to ensure education is shared with important political agents before taking action, urban foresters can help reduce some of the expected pushback. In the case of extensive pushback, urban foresters would hopefully at least have the support of the Tree Commission. This model can easily be applied to other communities where UEATs are beginning to pose a threat as any phase-out efforts of such a prominent tree is likely to result in controversy and should thus be approached with great care.

In addition to the political challenges that will accompany efforts to phase out UEAT species, there are likely to be practical challenges to implementing such a practice. In many cases, UEAT species are also very hardy in the local climate in which they are planted. For instance, crape myrtles are very hardy in Jacksonville, where they are very well suited to the local climate (Knox, 2016). With this hardiness level and adaptability, it can be hard to select other species appropriate to many sites that are most suitable to these very hardy UEAT species. In response to this challenge, a better approach for strengthening urban forests is to continue with the phase-out efforts needed to reduce the overstocking of the UEAT species, but take a more holistic approach to planting. This approach should emphasize modifying a site slightly to make it more welcoming to a variety of other tree species, instead of just planting one tree species in every site that presents a challenge to the establishment of most tree species. This effort to enhance sites to a greater variety of species will require strong arboricultural knowledge by city staff, but this enhanced planning can significantly improve the strength of an urban forest.

Monitoring

As every organism evolves over time, so does every ecosystem. Urban forests are no different, with new invasive species, diseases, or insects being introduced regularly that fundamentally alter the urban forest ecosystem. The same is true for UEATs. Thus, simply phasing out crape myrtles (or any other UEAT) is insufficient to protect urban forests from the threat of new tree species being overstocked at these harmful levels. Instead, continued monitoring programs should be established to ensure that the UEAT species posing a threat has its population controlled over the long term and ensures that no single new species fills the hole left by reducing the UEAT.

In order to effectively prevent another future overstocking of a potential UEAT, each new species to be planted should be researched heavily by the city's urban forestry staff. In addition to the typical research on the invasive potential regularly conducted when beginning the planting of new species, this research should also center around what the urban foresters expect the public reaction to this new species will be. For instance, questions should include how popular they think the species will be based on characteristics such as flowering or attractive foliage, as these traits can contribute to the overstocking of a specific species (Lilly, 2010, p. 86). After conducting extensive research on a new species they would like to plant, Jacksonville's urban foresters should develop an introductory number of this species to plant to allow for continued monitoring of the species success in the local climate and to watch for any potential cause for concern. The staff should then prepare and present their findings to the city's Tree Commission to formalize approval before planting the new species regularly. While many of these steps may appear redundant or overcautious, this is an excellent opportunity to ensure that the urban forest remains healthy to sustainably provide ecosystem services.

In addition, one urban forester from the city should be tasked with regularly analyzing species distribution maps. These maps can be found at https://www.eddmaps.org/distribution/ and show all

locations where specific plant species have been found to have escaped into wild ecosystems (*Crapemyrtle (Lagerstroemia indica)* 2021). By monitoring these maps for each non-native species that the city is planting, the urban forester can ensure that the non-native species being planted are at low risk of invasive spread. While this approach is generally more beneficial to preventing the planting of invasive species, the continued monitoring of these maps can also offer more insight on the other potential impacts of UEATs beyond their direct impacts on just the urban ecosystem. For instance, in the case of crape myrtles, while their impact is primarily on the functioning of urban ecosystems (as this paper has highlighted), they have also been found in native habitats in 339 locations throughout the United States. By highlighting the spread of UEATs into natural areas, urban foresters can gain more support for the removal of these species from approved tree planting lists that many communities have adopted. Thus, efforts to monitor the spread of new non-native species accomplishes multiple purposes and helps to preserve native habitats in addition to the highly altered ecosystems of urban areas.

Community Approach

While the above steps are essential to slowing the spread of a UEAT and ensuring that urban forestry staff is setting an appropriate example for the community, these measures will be insufficient to reduce the abundance of such heavily overstocked species successfully. Instead, community input and support should be gathered to ensure that any efforts to reduce such overstocking are implemented across the whole community instead of just within public lands. While the efforts of urban foresters are important and can set an important example just by their actions alone, reducing the overstocking of a UEAT on public lands alone is insufficient when considering the fact that the majority of land in cities is on private land. Thus, urban foresters should work to establish greater community connections so that they can inform private landowners of the consequences of continued UEAT planting and how their help can improve the whole urban forest.

One group that would be especially important to establish connections with is land developers. As Jacksonville and many other cities require developers to plant trees after construction, it is crucial for urban foresters to work with developers to a greater extent to ensure that the right tree is being planted for each place during development (Lilly, 2010, p.220-221). By developing this relationship and encouraging the planting of other trees better suited to enhance Jacksonville's urban forest, city staff can help to reduce the overstocking of crape myrtles at one of the primary sources that have contributed to their levels historically. Especially since private lands typically don't have the same level of constraints that right of way areas have for tree plantings, this provides a unique opportunity to increase the planting of larger shade trees in areas where these selections are more appropriate. Just like tree protection during construction requires working with developers very early in the development process, so should urban forest biodiversity protection begin at this stage (Lilly, 2010, p.220). By working with developers early on in the planning stage, they will be more likely to consider other options for trees that are better suited to specific locations and can significantly reduce the overstocking level of crape myrtles.

Of course, just as important is sharing this information on crape myrtles and other UEAT species with private residents of the city. As outlined above, a thorough educational effort will be needed to ensure that Jacksonville residents are aware of the ecological challenge presented by these species. By implementing this educational effort, urban foresters will not only be able to impact the species selection decisions of many individual residents, but hopefully, as more residents learn about the impacts of such heavy overstocking, they will share this information with their neighbors. By increasing this outreach, not only will urban foresters be directly working towards the lessening of crape myrtle overstocking, but they will also be creating a community network to decrease the

occurrence of similar plantings in the future. These same efforts should be applied across any municipalities facing a similar UEAT scenario and beginning to reduce their overstocking.

Conclusions

The Problem

Forests need biodiversity to thrive and function properly. They need a wide variety of plant and animal species working apart for each of their individual survival for the ecosystem as a whole community to survive (Ferrini et al., 2019, p. 123). Urban forests are no different. They need a wide variety of species to ensure that the massive loss of no one species is catastrophic to tree canopy levels as a whole. They need biodiversity to ensure that native wildlife already facing habitat loss doesn't also lose access to the native plants it needs for food and shelter. People need urban forest biodiversity to ensure that ecosystem services are provided at their maximum level for all members of a community to enjoy the environmental benefits of trees. Thus, any threat to an urban forest's biodiversity is also a threat to that urban forest's resiliency, sustainability, and ability to positively provide services for all people and wildlife of that community.

Urban Ecosystem Altering Trees are a direct threat to urban forest biodiversity. They are stocked in such heavy numbers that they often take the place of native and larger trees that either provide greater ecosystem services to the people of an urban ecosystem or the wildlife that share that ecosystem. These tree species are stocked in such heavy numbers that a massive disease or pest outbreak similar to that of DED or EAB would eliminate much of an urban forest's canopy level. The primary and defining factor that separates UEATs from invasive species is that the natural vector creating their spread is almost entirely human action. These species typically don't highly alter native areas as humans are not planting them in those areas. Thus, they are not as severe a threat to these

native ecosystems as truly invasive species are, creating their defining trait. However, their severe overstocking clearly impacts the urban ecosystem, where urban forests are not being protected and producing their maximum amount of potential benefits for the other inhabitants of that unique ecosystem type.

Jacksonville's current plight of crape myrtle overstocking presents a clear example of what a UEAT is and the harm it can cause to the health of an urban forest ecosystem. This species has been planted to such an extent that it composes over 24% of the city's street trees and over 8% of the city's tree canopy (Arborpro, 2019, p.12). Any mass die-off event similar to DED or EAB that could develop at any time would thus have a dramatic impact on the city's tree canopy levels. In addition, due to the small size of this species and its non-native status, it provides lessened ecosystem services than other, more appropriate species in any of the locations where it is planted, as greater canopy and native status are associated with greater production of ecosystem services for people and animals (Ferrini et al., 2019, p.55) This means that even without such a massive loss, crape myrtles are already having a significant impact on the health of Jacksonville's urban forest ecosystem. Thus, the overstocking of crape myrtles in Jacksonville presents a clear example of what a UEAT is and how the species can negatively impact the health of an urban forest. By focusing on the case study of this species in this location, this paper has demonstrated how UEAT species can be defined and presents an example of how they can be addressed, even in the complex and often political arena of urban forestry.

The Cause

The primary cause of the UEAT problem is overstocking by humans. Just like plant pathogens and invasive species are spread by some sort of natural vector, humans are the vector of spread in the case of UEATs. Historically, this has been seen with the overstocking of American Elm (*Ulmus americana*) or Ash trees (*Fraxinus spp.*) throughout the United States, where these native species were

planted at such high rates that the canopy levels of entire urban forests were decimated by single pests. In Jacksonville specifically, Laurel oaks (*Quercus laurifolia*) were planted at such a high rate over several decades that most current tree removals are from this species (Little & Leon, 2021). Since the 1990s, crape myrtles have been planted so often by the residents and government of Jacksonville that they now account for 24% of the trees in the city. This certainly presents a clear example of how widespread this human vector of planting a single species in excess of recommended standards can dramatically change an urban forest's composition. This monocultural urban forest composition often leads to future mass die-off events such as DED or EAB.

While the cause of the spread of UEATs is quite clearly by the human vector, a critical first step in combating UEAT overstocking is to recognize why the species is planted so overwhelmingly in the first place. In the case of Jacksonville's crape myrtles, there are a few major causes that would lead to it being planted so actively: the species is quite hardy in the region, the species has attractive flowers, and it doesn't grow so large that it creates the perception of a hazard (Gilman, 2007). While each of these factors separately would certainly be an attractive feature to consider when selecting a species, the combination of all three has certainly led to the immense popularity of this species. This popularity creates the UEAT problem in this circumstance as residents have been planting this species in such high numbers that it has reached the point it is at today. While each UEAT will have specific factors like these leading to the overstocking of that species, it remains consistent that the number one cause of UEAT overstocking is the human vector.

Proposed Solutions

Of course, the immense popularity of any species planted at such a high level to be considered a UEAT will present some roadblocks to solving the problem. In the case of Jacksonville's crape myrtle population, it is highly expected that there will be a lot of controversy over efforts to reduce the

abundance of this species. That is why the first and foremost recommendation to resolving UEAT threats is to create robust and continuous educational programs to inform the public about the ecological impacts of the species. By beginning with education and using this method throughout phasing out efforts, urban foresters can hopefully increase and retain public support for their efforts. Similarly, community involvement will be essential due to the high amount of urban forest trees that are privately owned and maintained. Developing these educational programs can help develop this community involvement and help implement actions on private property to reduce the severeness of the situation.

Most important to phasing out efforts is phasing the species out of active planting projects. Since UEAT species, such as the crape myrtle, don't typically pose the same potential to impact natural areas as invasive tree species do, it is not recommended to introduce a removal program for existing trees of these species. Instead, simply removing the species from approved tree species planting lists should suffice for these efforts to reduce the impact of this overstocking. While this step is large and will face significant pushback, it is necessary that urban foresters set an example of what their community approach to urban forestry should be.

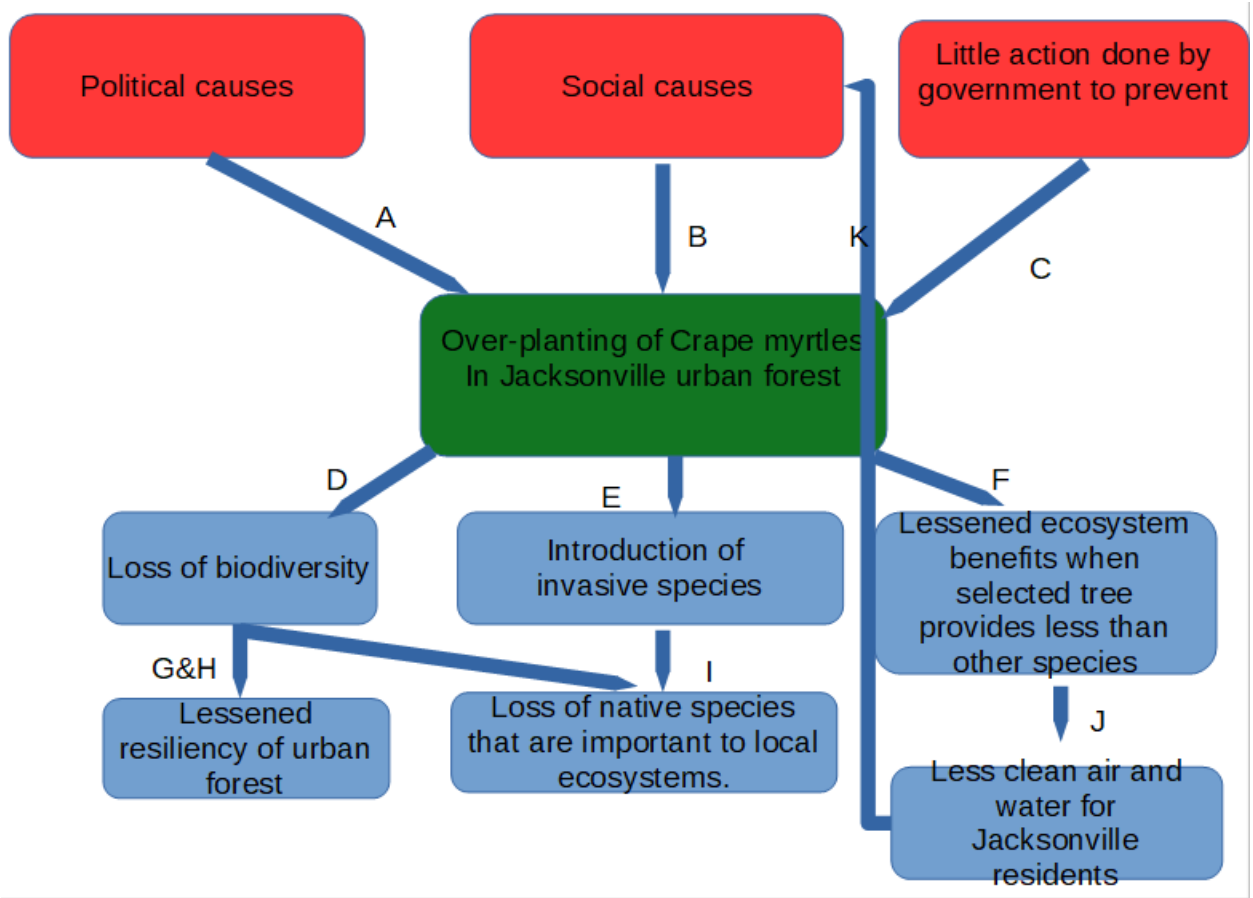
It is recommended that urban foresters continue to monitor the population of any UEATs affecting their city and any other species being planted to avoid future occurrences of this issue. While taking the previously described actions may be sufficient to reduce the overstocking of crape myrtles in Jacksonville or similar UEATs elsewhere, it is also necessary to continue working to avoid similar situations in the future. As these scenarios can develop at any time and always pose a threat to an urban forest's resiliency, continued monitoring is necessary.

Concluding Summary

An Urban Ecosystem Altering Tree is defined as any species that is spread primarily by human vectors but planted at such a high rate that it fundamentally alters the ability of urban ecosystems to function properly. These species reduce the ecosystem functionality of an urban forest by reducing resiliency, impairing habitat for native wildlife, and replacing tree species better suited to planting locations that would provide greater ecosystem services. These UEAT species are likely to be highly popular with the general public of a region and will thus be controversial to remove from planting efforts. Even with the challenges of reducing the overstocking of these species, these efforts should be undertaken to reduce the threat that they pose to the health of an urban forest.

Jacksonville, Florida's urban forest currently presents an excellent example of a UEAT species actively altering the function of the urban ecosystem. Crape myrtles in this city have been planted to well in excess of recommended urban forestry guidelines and present an excellent example of what defines UEAT species. By examining the history, causes, and solutions to this UEAT, an outline of how to reduce and avoid this problem has been created. Following these steps is crucial to ensuring that urban forests can remain healthy and produce ecosystem services at their maximum potential.

Appendix A: Diagram of Interactions



Explanations of Pathways

A-Political causes shaped the over-planting of specific tree species over the last century. By exerting influence, politicians and local groups were able to influence which trees were planted in such high quantities as to be considered overstocked.

B- Many stakeholders plant crape myrtles too often, leading to the modern problem of them being overstocked.

C- Due to the small size of the Jacksonville urban forestry team historically, there was no action taken to prevent overstocking of crape myrtles.

D- With the overstocking of crape myrtles, there has been a loss of biodiversity in Jacksonville's urban forest.

E- Practice of unabated overstocking can lead to the introduction of invasive species.

F- Crape myrtles provide less ecosystem services than some other species of trees that could be planted in place of the crape myrtles. By overstocking crape myrtles, these ecosystem services are lacking.

G- A loss of biodiversity causes an urban forest to be less resilient.

H- A loss of biodiversity can also lead to a loss of native species that are vital to their local ecosystems.

I- Introduction of invasive species can also lead to the loss of native species.

J- The lessened ecosystem services provide fewer benefits to Jacksonville residents.

K- The loss of ecosystem services negatively affects the local residents by doing less to combat the adverse effects of climate change.

Appendix B: Matrix Showing Proposed Results of Improved Planting Practices

System	Indicator	Effect
Ecological Value	Wildlife habitat	Planting more native trees and fewer exotics can lead to better availability of habitat for native wildlife.
	Ecosystem services	Planting more appropriate (larger) trees when possible can provide for greater amounts of ecosystem services.
	Biodiversity	Increased biodiversity can increase the strength and resiliency of an urban forest.
Social Value	Aesthetics	Increased diversity among planted trees can provide better aesthetic values.
	Human health	When a more appropriate tree is planted, greater benefits for human health can be provided.
	Education	Increasing education about specific species can decrease tree injuries, such as topping.
Economic Value	Ecosystem services	More appropriate tree selection can provide better air and water filtering benefits.
	Increased benefit/cost ratio	Planting longer living and larger trees can provide increased benefits while keeping costs at relatively the same level.

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