ESTABLISHING CONSENSUS CORE CRITERIA FOR THE PROTECTION OF HERITAGE TREES

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ABSTRACT

Heritage trees are valued based on the important historical, cultural, size and other components that these specimens represent. These trees have been identified around the world and are often legally protected to ensure these aspects are conserved. However, there lacks a standardized set of expert verified criteria that can be applied to any of these programs regardless of geographic location. An initial set of 40 criteria were derived from an analysis of 46 case studies and presented to a panel of heritage tree experts to obtain consensus on the core criteria that should be used by any heritage tree program. A three iteration Delphi method was used to evaluate the aforementioned criteria and allowed additional content to be generated by the panel. The result saw 50 criteria analyzed to produce a set of 16 consensus core criteria that should be used by these programs and an additional 29 situational criteria that can apply on a case-by-case basis. Best practices found in the literature were also evaluated by the panel to serve as complementary aspects when implementing a heritage tree program. This study identified the existence of 16 common values shared among these tree programs and serves as an initial template that should be used by current and proposed heritage tree programs to select ideal candidates. Through this standardized evaluation system, the current patchwork of heritage tree programs now has the potential to become a unified network that should lead to the increased awareness and protection of these trees and the many benefits that they provide.

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INTRODUCTION

1.1 Nature of the Problem

The protection of the world's most unique and exceptional trees has been an important topic dating back to the middle ages when one of the first known references of tree conservation was seen in 1189 Bohemia (Dreslerova, 2017). This case sought to promote the preservation of forests and did so through the implementation of penalties for anyone who damaged such areas (Dreslerova, 2017). Later, specific trees with extraordinary characteristics that set them apart from others in their geographic area and amongst their own species, began to be formally recognized. Such was the case with Alexander von Humboldt during his 1799-1804 expedition in South America, when he identified unique tree specimens as "monuments of nature" due to their exceptional characteristics (Von Humboldt, 1877, p. 501). Since this time, trees from around the world with various attributes (physical, environmental, cultural, historical, etc.) have continued to inspire a sense wonder and awe that has led to the creation of numerous programs that identify these individuals as "Heritage Trees" (aka Exceptional, Champion, Significant, Monumental, etc.) However, with 60 different terms used to identify these trees throughout the literature (Jim, 2017), in addition to numerous types of varying criteria, it is clear that these programs would benefit by implementing a standardized process that utilizes well-defined criteria (Zapponi, Mazza, Farinam Fedrigoli, Mazzocchi & Roversi, 2017). This could allow these programs to more efficiently identify optimal heritage tree candidates, which can lead to the increased protection of these important specimens.

1.2 Heritage Trees and Programs

1.2.1 What Are Heritage Trees?

A heritage tree can be described as "a tree or collection of trees that is acknowledged and valued for the unique characteristics that set it apart from other similar trees" (City of Spokane Urban Forestry Department, 2018, Heritage Tree Program section, para. 2). Programs that recognize these trees are found from local to national scales in countries around the world (Republic of South Africa Department of Water and Forestry, 2003; Rodger, Stokes & Ogilvie, 2003; City of Melbourne, 2012; Village of Glenview, 2013; National Parks Board Singapore, 2017; City of Spokane Urban Forestry Department, 2018; Trees Winnipeg, 2018) and vary depending on the location being examined. Some of these programs educate the public about the importance of these trees (Nebraska Forest Service 2018), while others do this and provide legal protections that prohibit the unnecessary removal of heritage trees (City of Portland, 2016; University of Hawaii, 2018). It is important to note that the criteria used to designate heritage status varies widely among these programs even though they share a common goal of protecting these valued trees.

1.2.2 Current State of Heritage Trees

A tree can be nominated to receive heritage status if it meets one or more of a heritage tree program's stated criteria. This designation can apply to trees on both public and private land for many programs (Village of Glenview, 2013; Arizona State Forestry, 2019; Forests Ontario, 2017b), although in certain cases such as Asia, roadsides, parks, government facilities, educational campuses and religious or other institutional grounds have been identified as the

five most common land use types where these trees can be found (Jim, 1994; Jim, 2004a). Many heritage trees in urban settings (especially mature and larger ones) have been found in older and less densely populated areas that provide a more suitable habitat for these specimens due to reduced pressures from construction and limited space often associated with newer planting sites (Jim, 1994; Jim, 2004a; Jim & Zhang 2013). This was seen in Hong Kong where 40.9% of their heritage trees and 50.4% of their associated species were found in public parks and gardens (Jim & Zhang, 2013). This ideal land use type has not been utilized to the same degree in other locations such as Guangzhou, China where urban parks had the fewest number of heritage trees compared to other land use types and 46% of these trees were found along roadsides (Jim, 2004a). Locations such as this place the future survival of heritage trees in jeopardy as of these trees are removed or succumb to injuries as a result of construction (Jim, 2004a, 2004b).

While the number and species of heritage trees can vary greatly across programs depending on the types of land available, they can also differ due to mortality rates. Heritage tree mortalities have largely been attributed to anthropogenic factors such as roadwork and construction (Jim, 2004b, 2004b) that frequently result in damaged roots, trunks, branches and foliage which can lead to the eventual removal of a heritage tree as it succumbs to these often-terminal injuries (Chen, 2015; Jim, 2017). These anthropogenic factors also indirectly result in the death of heritage trees as an inadequate amount of space is allocated for these often very large trees (Jim, 2017). An example of high mortality rates was seen in Guangzhou, China between 1986 and 1995 when 21.5% of their original heritage trees were lost and another 44% declined (Jim, 2004a). When comparing the same program over a longer time span from 1985-2007, the

number of mortalities increased to 29% (Chen, 2015). This trend of substantial mortality rates was also seen in Hong Kong between 1993 and 2005 when 53 heritage trees were lost and amounted to a total decrease of 14% (Jim, 2004b). While heritage trees will inevitably be removed due to both anthropogenic and natural causes, a successful heritage program should be able to replenish these trees through replanting programs (Jim, 2017). However, there has been a lack of the aforementioned next-generation programs which in turn threatens the viability of heritage tree programs as new trees will not be identified or propagated to replace those that have been removed (Jim & Zhang 2013). Sufficient laws and policies must be put in place in to prevent this from occurring and protect these heritage trees from experiencing a generational gap.

1.2.3 Heritage Tree Best Practices

Once the core criteria for a heritage tree program have been derived, it is important to supplement these with identified best practices to more efficiently protect these trees from experiencing the aforementioned mortality rates. The ability to legally protect heritage trees from unnecessary damage and removal is arguably the first and most crucial step that must be taken after these trees have been added to a heritage tree program. While some programs incorporate legal policies (Zapponi et al., 2017; University of Hawaii, 2018), the level of protection, rates of enforcement and resources allocated can vary based on current policies, management practices, and public support. In Guangzhou, China, their heritage trees have been protected by eleven laws spread across all three levels of government (five federal, one provincial and five municipal) since the 1980s (Jim, 2004a). Ontario, Canada has a province-wide heritage tree program that sees the majority of its legal protections created and enforced

by individual municipalities (Heidenreich, 2016; Forests Ontario, 2017a). Additionally, in Perak, Malaysia there exists a "Tree Preservation Order" issued by the local planning authority to "protect trees in the interests of public amenity" (Ali, Hassan, Hassan & Nayan al., 2016, p. 623). Trees deemed to provide a valuable service to the public can be protected through this order and receive heritage status (Ali et al., 2016), helping to ensure their benefits continue to be seen for generations. These laws theoretically form a legal safety net which prevents the unnecessary removal of heritage trees (unless one poses a threat to public safety) and further spurs additional policies and management practices that lay the framework for a heritage tree program (Jim, 2017). While some programs will consist of one to all three levels of legal government support, it is important to note that as more agencies become involved with a heritage program, the enforcement and management processes will become more complex and difficult (Jim, 2004a). These complexities have been well documented in Guangzhou, where federal and provincial laws exist but are enforced and managed by each individual municipality (Jim, 2004a). With many levels of government and their laws all interacting with one another, there are often questions of responsibility, especially for those who manage such tree programs and determine their eventual effectiveness (Jim, 2004a). In order to increase the implementation and effectiveness of legal protections, public support must be obtained which can lead to the enactment of laws that result in safeguards for heritage trees.

Assessing the public's knowledge and views of heritage trees is one way to determine how to increase public support for these trees. One study that may be universalized to some extent took place in Guangzhou, China and saw Chen (2015) evaluate the willingness-to-pay of local residents for heritage tree programs. A questionnaire completed by 593 citizens determined

that only 44.4% of those interviewed thought that individual households should provide the government with a one-time payment to support these trees (Chen, 2015). In a second study conducted the same year, Chen and Hua (2015) reported that support for a heritage tree conservation fund had decreased to 23.2%. However, after learning more about these trees a number of respondents stated that they would be willing to support a conservation program for heritage trees (Chen, 2015). This shows that heritage tree values need to be conveyed to the public through educational methods in order to increase support for these trees (Chen, 2015) and potentially spur the creation of legal policies that could complement the criteria used to protect these unique specimens by adding additional safeguards.

1.3 Research Question and Objectives

The intent of this study is to identify if a consensus exists regarding the most important criteria used to determine heritage tree status. Through the implementation of a multi-stage Delphi research design, this study attempts to identify consensus amongst a panel of international experts on the criteria required to assess and define heritage tree status.

Research Question: What core criteria should be considered when designating a heritage tree?

A comprehensive literature review and an examination of 46 heritage tree programs from around the world have identified the criteria currently used and best practices associated with such programs. These data were then synthesized to create 11 categories representing 40 distinct heritage tree criteria, forming the foundation of the survey and highlighting the disparity seen amongst many of these heritage tree programs. After these initial data were

derived, the study's expert panel was chosen based on the four criteria proposed by Adler and Ziglio (1996) and featured members who have extensive experience working with heritage tree programs from different professional backgrounds (NGOs, government agencies and private corporations). This diversity helps to fully represent the views of those involved in the heritage tree process as such programs can be heavily influenced by all three of these sectors. Due to the specific qualifications required and with relatively few experts available for such a topic, a snowball sampling method was used to form the panel based on referrals from those in the heritage tree field. Each expert approached was provided with an overview of the intended research, its purpose and potential benefits and the final result saw the following number of representatives join the study from the United States (3), Australia (3), Asia (2), South America (2), Canada (1), New Zealand (1), South Africa (1), U.K (1) and Europe (1). By assembling this expert panel and providing them with the terminology and criteria currently used, a list of the most important criteria used to determine heritage tree status may be generated to provide a standardized foundation based on expert consensus for current and proposed heritage tree programs. This should reduce the amount of redundant errors seen among these programs and improve their effectiveness which should ultimately result in the increased protection of these trees and the many benefits they provide.

1.4 Methods

With 60 terms used to denote trees of importance (see Jim, 2017, p. 290), identifying a single name to use can be difficult. An analysis of the literature identified 46 heritage tree programs that have adopted terms such as: "heritage trees," "champion trees," "significant trees," "monumental trees," "ancient trees," "memorial trees", "veteran trees", etc. These data were

quantified to produce the most common term used to represent these trees, while also identifying a unique set of 40 criteria and their corresponding definitions which were then placed into one of eleven categories. While there are far more than 46 heritage tree programs in existence, the decision to stop at this quantity was made once information from programs became redundant and no new components were being derived. The result from this research highlighted a clear need to systematically evaluate these components through the use of expert opinion to obtain a list of the core criteria that should be used in a heritage tree program.

1.4.1 The Delphi Method

The Delphi method is a process that relies upon expert opinion to obtain consensus on a given topic through the use of multiple survey iterations. This method was initially created in the 1950s by the RAND Corporation to obtain consensus from a group of experts regarding the number of A-bombs that would be required to impact military locations of interest (Dalkey & Helmer, 1963). This process required a reliable way to obtain consensus from these experts and was accomplished through a "series of intensive questionnaires interspersed with controlled opinion feedback" (Dalkey & Helmer, 1963, p. 458). While the Delphi method was originally designed for military purposes, it has since been adopted by researchers in different fields from around the world (Skulmoski, Hartman & Krahn, 2007), ranging from medical inquires (Keeney, Hasson & McKenna, 2006) to developing vulnerability and adaptation assessment frameworks (McLeod, 2012). As such, this technique has proven to be a useful methodology for many fields when trying to obtain consensus from a panel of experts on a given topic that may have incomplete knowledge (Skulmoski et al., 2007).

Through the feedback process, each subsequent survey iteration is able to evolve and become closer to obtaining consensus from the expert panel as opinions "tend to converge as the experiment continues" (Dalkey & Helmer, 1963, p. 459). When determining consensus, there is no single value attributed to this goal in the literature (Keeney, Hasson & McKenna, 2006). A common value for consensus is seen with a threshold of 51% (Loughlin & Moore, 1976), however, it can be much higher as the determining factor for consensus may depend on the topic being analyzed (Keeney et al., 2006). This is best described by Keeney et al. (2006) when they provide contrasting situations of a life or death decision regarding "when to turn off a respirator for a patient in an intensive care unit", compared to something far less critical as "the selection of a new nurses' uniform" (Keeney, Hasson & McKenna, 2006, p. 210). In these cases, the authors cite that for the respirator scenario, having 100% consensus might be an ideal threshold, while 51% could be sufficient when deciding upon the nursing uniforms. Any criteria that have reached consensus in a given round are removed from future iterations (Stewart, Gibson-Smith, MacLure, Mair, Alonso, Codina, et al., 2017), leaving only those that have failed to reach the determined threshold.

Due to the diversity seen throughout the literature regarding how the Delphi method should be used (i.e. consensus, number of experts, number of survey rounds, etc.), this technique allows researchers to modify it based on their specific needs (Keeney et al., 2006). However, according to Rowe & Wright (1999) there are four items that are essential components to any of these variated methods:

1) Anonymity: Experts are able to convey their opinions in a confidential manner without influence from social pressures through the use of questionnaires;

2) Iteration: Survey iterations provide experts the opportunity to review/change their previous responses in subsequent rounds without fear of what their colleagues would think;

3) Controlled feedback: The expert panel is provided with the responses of their colleagues' in-between rounds. This can be presented as basic statistical information (mean or median) and/or as summaries of stated opinions; and

4) Statistical aggregation of group response: Provides the opportunity for quantitative data to be analyzed.

As a result, while there are variations of the Delphi method, these four attributes should always be used, although, there are numerous ways in which they can be implemented (Rowe & Wright, 1999).

While the lack of specific guidelines for aspects of the Delphi method leaves much of its interpretation up to the researcher, there are a few benefits that compensate for this. According to Okoli and Pawlowski (2014), four benefits of using the Delphi method are: a) "avoiding direct confrontation of the experts" by remaining anonymous through the use of the researcher who acts as a moderator and collects, synthesizes and reports the results from the previous survey; b) experts do not have to physically meet (valuable for international studies); c) provides a flexible design that allows for follow-ups; and d) has low non-response and attrition rates due to "personally obtained assurances of participation" (Okoli & Pawlowski, 2014, p.16, 19, 20). As a result, "the Delphi method is a flexible research technique well suited when there is incomplete knowledge about a phenomena" (Skulmoski et al., 2007, p.12) and

may be able to provide a researcher the ability to obtain data on topics that might otherwise be difficult to study using alternative methods.

1.4.2 The Expert Survey

A Delphi study typically begins one of two ways, either with a qualitative assessment involving the selected expert panel to generate the content that will be used for the survey based on their opinions (Jones, Sanderson & Black, 1992), or through the use of a literature review (Keeney et al., 2006). From this first stage which lays the foundation for each survey iteration, a summary will be produced that will form the first questionnaire (Keeney et al., 2006). Once the first survey has been sent to the expert panel and completed, it is then returned to the researcher to be analyzed (Skulmoski et al., 2007). From these results, the second survey will be created based on the responses from the previous round and this process will continue until the third round is complete (Skulmoski et al., 2007). However, it is important to note that between each round, the panel will have the opportunity to confirm their responses to ensure that their views were interpreted correctly (Skulmoski et al., 2007; McLeod, 2012). According to Skulmoski et al. (2007), this process will continue until "the research question is answered" and can be obtained when "consensus is reached, theoretical saturation is achieved, or when sufficient information has been exchanged". Generally, the duration of a Delphi study is three iterations as seen with Jones et al. (1992), but this process can be completed in as few as one to two rounds (Skulmoski et al., 2007). However, there are no specific guidelines in the literature

and the number of rounds used can depend upon the amount of time a researcher has to spend on the project and the specifics of the initial research question (Keeney et al., 2006).

This study uses a modified version of the Delphi process recommended by Skulmoski et al. (2007) and was created based on the 40 criteria and best practices derived from the literature and associated 46 case studies. The initial pilot survey was tested by six individuals not related to the study to assess for clarity, content, structure and navigation. This produced the first survey iteration that consisted of 40 closed-ended and 40 open-ended questions, the latter of which allows the expert panel to provide feedback related to the closed-ended questions, suggest new content for subsequent survey rounds and explain why certain criteria obtained very low importance values. A high level of consensus was achieved if ≥75% of the expert panel considered a criterion *significantly important* (category 4) or *critically important* (category 5). Consensus was also achieved if <25% of the expert panel considered a criterion significantly or critically important, indicating that a criterion should not be used in a heritage tree program. Criteria in between these two results with values of 25%-50% and 50%-75% had low and medium levels of consensus respectively. With no agreed upon value for consensus throughout the literature (Keeney, Hasson & McKenna, 2006), these values were selected in order to obtain a high degree of certainty that the core criteria produced were of importance to the vast majority of the expert panel.

1.4.3 Selection of Expert Panel

The process of selecting experts for a Delphi study is based on non-probability sampling techniques (Keeney et al., 2006), as this method relies upon the opinion of experts rather than

the general population. Adler and Ziglio (1996) have suggested that the following four criteria must be met in order to qualify as an expert:

1) knowledge and practical engagement with the issues under investigation;
2) capacity and willingness to contribute to the exploration of a particular problem;
3) assurance from experts that sufficient time will be dedicated to the Delphi exercise; and
4) skills in written communication and in expressing priorities through voting procedures.

Once these conditions have occurred, obtaining an adequate sample size for the survey is required. For the Delphi method, there are no “minimum or maximum” values attributed to this (see Evans, 1997, p.124), although 10-15 participants are generally considered to be ideal (Adler & Ziglio, 1996; Skulmoski et al., 2007).

1.5 Organization of Thesis

This thesis is composed of four chapters. The first discusses the current state of heritage trees, research question and objectives and the methodology used for this study. The second chapter focuses on the terminology and criteria found throughout the literature and 46 heritage tree case studies. The third chapter examines the results and findings from this study in a paper format that will be published and the fourth chapter touches upon important aspects of the study, research implications and opportunities for future research that should take place to build upon the foundation laid by this study.

CHAPTER 2

HERITAGE TREE LITERATURE REVIEW

This chapter focuses on the current state of heritage trees from various countries around the world. An analysis of the literature and 46 case studies identifies the need for a standardized set of heritage tree criteria, in addition to providing the terminologies currently used to describe these trees and 40 initial heritage tree criteria used as the foundation for this study.

2.1 Defining Heritage Trees

2.1.1 Terminology

Creating a universally agreed upon definition of a heritage tree may seem like a simple task, but with 60 terms used to denote these important specimens (see Jim, 2017, p. 290*),* this task is surprisingly complex. A global review of 46 heritage tree programs identified terms such as: "heritage trees," "champion trees," "significant trees," "exceptional trees," "monumental trees," "ancient trees," "memorial trees", "veteran trees", etc. (see Table 1). This saw the term heritage tree used 22 times, showing its prominence throughout the literature and in the observed case studies. It is important to note an irregularity seen with champion trees, specifically how they can appear in heritage tree programs as a criterion (Minneapolis Park and Recreation Board, 2018), but are also recognized as standalone components of "Champion Tree" programs in other cases (American Forests, 2018). Scotland is one example of this hybridization between heritage and champion trees that sees all individuals awarded heritage status, with a special designation given to those that are the tallest, largest-girthed (diameter)

and/or oldest of their species (Rodger et al., 2003). This concept of having sub-classifications was also seen in Turkey where their monumental tree program had individual classifications for historical, folkloric, mystical and dimensional trees (Genc & Guner, 2001). By bringing these concepts together the current fragmentation associated with these programs can be reduced and help produce a standardized and consolidated program. In accordance with this, the term heritage tree will be used to describe these specimens throughout this thesis based on its frequency of use in the observed case studies, the ability for this term to encompass the characteristics of trees with other epithets (Rodger et al., 2003) and also having been formally designated as such by experts in the field (Jim, 2017, p.279*)*.

2.1.2 Criteria

There currently exists a plethora of criteria used to award heritage tree status. From the literature reviewed and an examination of 46 heritage tree case studies, 40 criteria were synthesized from these heritage tree components and organized into 11 categories which can be found in Table 2 along with their frequency of use in Figure 1. However, when looking at these criteria it is important to note what they are, how they are used and distinctions within each of the presented categories.

Size

Heritage tree size criteria differ based on four sub-components (*Non-Specific*, *Program-Specific*, *Species-Specific* and *Champion)* that have been identified and labeled as such based on their associated characteristics found throughout the literature. The first three are relatively intuitive in that *Non-Specific* indicates that size was a criterion but no minimum threshold was given

(Dreslerova, 2017), *Program-Specific* refers to a single minimum size threshold set for all heritage trees within a program (Government of South Australia, 2011; Ali et al., 2016) and *Species-Specific* assigns minimum size thresholds for each species (Orlowski & Nowak, 2007). Special attention needs to be given to the *Champion* criterion due to the complexity associated with its use. Champion trees receive this designation based on physical characteristics such as height, diameter/circumference and crown spread. Programs generally award the champion title to either a) the largest specimen per species for a given metric (Johnson, 2011); or, b) the tree with the greatest cumulative score derived from a formula based on height, circumference and crown spread (American Forests, 2018). Both the *Species-Specific* size and *Champion* size criteria require baseline metrics for each species to produce thresholds and award heritage status (Orlowski & Nowak, 2007; American Forests, 2018), whereas *Non-Specific* size and *Program-Specific* size do not (Government of South Australia, 2011; Dreslerova, 2017). Size thresholds for the *Program-Specific* criterion can vary across programs as seen in Perak, Malaysia where a tree must have a circumference of at least five meters, while in the Adelaide region of South Australia this metric is three meters (Government of South Australia, 2011). *Non-Specific* size was the most frequently used size criterion in the heritage tree case studies, occurring in 37% of those examined, highlighting the preference that these programs have when selecting heritage status based on physical aspects. This was followed by *Champion* (28.3%), *Species-Specific* (17.4%) and *Program-Specific* with (15.2%).

Table 1. Heritage Tree Terminology Used in 46 Case Studies

Terminology	Case Study*	Frequency
Heritage Tree	1, 4†, 7, 8, 11, 13, 15, 16, 17, 18, 20, 22, 25, 30, 31, 33b‡, 34, 38, 39, 41, 43, 45d§	22
Champion Tree	2, 3†, 29, 33a‡, 35, 36, 37, 45c§	8
Significant Tree	9, 10, 14, 19, 21, 27, 32	7
Exceptional Tree	12, 42	2
Monumental Tree	46	1
Historical Monument Tree	26a**	1
Folkloric Monument Tree	26b**	1
Mystical Monument Tree	26c**	1
Dimensional Monument Tree	26d**	1
Veteran Tree	45b§	1
Witness Tree	5†	1
Heritage Large Tree	40	1
Old-Valuable Tree	28	1
Moses Cleveland Tree	44	1
Ancient Tree	45a§	1
Remarkable Tree	6	1
Largest Tree	23	1
Memorial Tree	24	1

* Case studies are referenced in Appendix 2

† Each has a unique terminology and criteria but all under Arizona's "Magnificent Tree" program.

‡ Two terms and criteria from the same source: a = Champion Tree and b = Heritage Tree.

§ Four terms used by the same source: a = Ancient Tree, b = Veteran Tree, c = Champion Tree and d = Heritage Tree.

** Four terms are used by the same source: a = Historical Monument Tree, b = Folkloric Monument Tree, c = Mystical Monument Tree and d = Dimensional Monument Tree.

Table 2. Criteria Used in 46 Heritage Tree Case Studies

CRITERIA BY CATEGORY	CASE STUDY*	DEFINITION
AGE		
Age (non-specific)	8†, 9, 10, 12, 14, 15, 16, 17, 21, 24, 32, 34, 37, 38, 39, 42, 46	No specific age threshold is used.
Age (program-specific)	1, 5, 22†, 28†, 44	A single age threshold is assigned to all trees.
Age (oldest specimen of species in region)	13†, 41	The oldest specimen of a species.
Age (species-specific)	6, 20†, 26d†, 45a†	Age thresholds are assigned for each species in the program.
HISTORICAL VALUE		
Historical Value	1, 3, 6, 7, 8†, 9, 10, 11, 13†, 14, 15, 16, 17, 18, 19, 20†, 21, 22†, 24, 25, 26a†, 28†, 30†, 31, 32, 33b†, 34, 37, 38, 39, 41, 42, 43, 45d†, 46	Associated with an important historical place, event or date.
Historic Person/Memorial Planting	3, 6, 9, 10, 11, 12, 14, 15, 18, 19, 20†, 21, 22†, 25‡, 28†, 32, 33b†, 34, 37, 38, 39	Planted for or by a person with historical significance.
Remnant	9, 19, 20†	Represents characteristics of a previously significant era.
Represented in Historical Documents	33b†	Mentioned or visually depicted in historical documents.
CULTURAL VALUE		
Cultural Value	1, 3, 7, 9, 11, 12, 17, 19, 24, 25‡, 28†, 30†, 31, 37, 38, 41, 42, 45d†, 46	Associations with past and current community groups.
Religious/Spiritual Value	6, 9, 12, 32, 46	Associated with religious and spiritual practices.
Legends/Mythical/Folklore Value	6, 24, 26b†, 26c†, 33b†	Associated with legends, mythical stories and/or folklore.
Aboriginal Association	9, 10, 12, 14, 21, 32	Importance or association to aboriginal cultures and events.
Social/Community Value	3, 9, 11, 12, 17, 19, 31, 32, 34	Prominent and provides a connection with the community.
National Interest	38	A vital component of a country's stated cultural/conservation goals.
Local Significance	9	Locally known as a key fixture within the community.
Size		
Size (non-specific)	10, 12, 13†, 14, 15, 16, 17, 21, 22†, 24, 25, 30†, 32, 34, 37, 39, 42	No specified size threshold is used.
Size (program-specific, non-champion)	1, 8†, 20†, 22†, 27, 28†, 31†	A single size threshold is assigned to all trees.
Size (species-specific)	6, 18, 20†, 23, 26d†, 28†, 35‡, 46	Size thresholds are assigned for each species in the program.
Champion Size	2, 3, 9, 13, 29†, 30†, 33a†, 36, 38, 40, 41, 43, 45c†	Represents the largest physical metric(s) for each species.
Aesthetic Value		
Aesthetics	6, 8†, 9, 10, 12, 14, 18, 19, 20†, 21, 25, 29†, 31, 32, 37, 38, 42, 43, 45d	A visually impressive specimen that stands out due to its representation of unusual size, age, captivating flowers, seeds, leaves and/or other aspects.

* Case studies are referenced in Appendix 2
† See Appendix 1 for supplementary information
‡ Primary/mandatory criteria (if secondary criteria are listed for program)

Table 2. (Continued) Criteria Used in 46 Heritage Tree Case Studies

Criteria by Category	Case Study*	Definition
Botanical Value		
Botanical Value	7, 6, 8†, 9, 10, 12, 14, 16, 18, 19, 20†, 21, 25, 31, 32, 38, 45d†, 46	Unique or exceptional botanical, horticultural or biological value.
Endemic	42	Valued in a given geographic area due to its endemic status.
Rarity	1, 9, 10, 12, 14, 17, 19, 21, 25, 28†, 29†, 32, 38, 39, 41, 42, 45d†	A tree that is considered rare due to its endangered status.
Specific Species/Species Significance	1, 15, 16, 34	A specific species of tree that is deemed to be of importance.
Landmark/Location		
Landmark/Location/Landscape	1, 8†, 9, 10, 12, 13†, 14, 15, 17, 19, 20†, 21, 24, 25, 30†, 32, 34, 37, 38, 39, 41, 45d†, 46	A visually dominant component of the landscape.
Edge of Natural Range	9, 10, 12, 14, 19, 21, 32	Represents the edge of a species natural range for a specific area.
Unusual Species for Area/Outside Natural Range	6, 8†, 20†, 28†	An unusual specimen for a specific area.
Collection/Grove/Avenue	39	A grove or avenue of trees grouped together in close proximity.
Form/Structure		
Form/Structure/Morphology	1, 6, 8†‡, 9, 13†, 20†‡, 22†, 25, 28†, 39, 45b†, 46	Displays ideal/ interesting characteristics that set it apart.
Unusual/Curious Growth Form	10, 12, 14, 19, 21, 32, 41	Unique/out of the ordinary physical form for species.
Ability for Maximum Potential Growth	8†‡, 16†, 20†‡	Must have enough space to reach its maximum physical metrics.
Non-Hazard/Obstruction	18	Not a hazard to the public that could warrant its eventual removal.
Outstanding Example of Species	1, 10, 12, 13†, 14, 21, 32, 41	Represents a species optimal form/structure.
Health	1, 8†‡, 9, 12, 16‡, 25, 35, 39‡	Deemed healthy by a certified professional arborist
Accessibility		
Publicly Accessible	1	Publicly accessibility that allows for interaction with the community.
Visible from Publicly Accessible Locations	8†‡, 18, 20†‡,	A tree being considered for heritage status that must be visible to the public.
Benefits		
Economic Benefits	37	Provides economic benefits usually through ecotourism.
Significant Ecological/Environmental Value	9, 12, 19, 21, 28†, 46	Provides ecological/environmental benefits for a specific area.
Outstanding Habitat Value	9, 12, 14, 19, 21, 45b†, 46	Produces micro-habitats for various organisms.

*Case studies are referenced in Appendix 2
† See Appendix 1 for supplementary information
‡ Primary/mandatory criteria (if secondary criteria are listed for program)

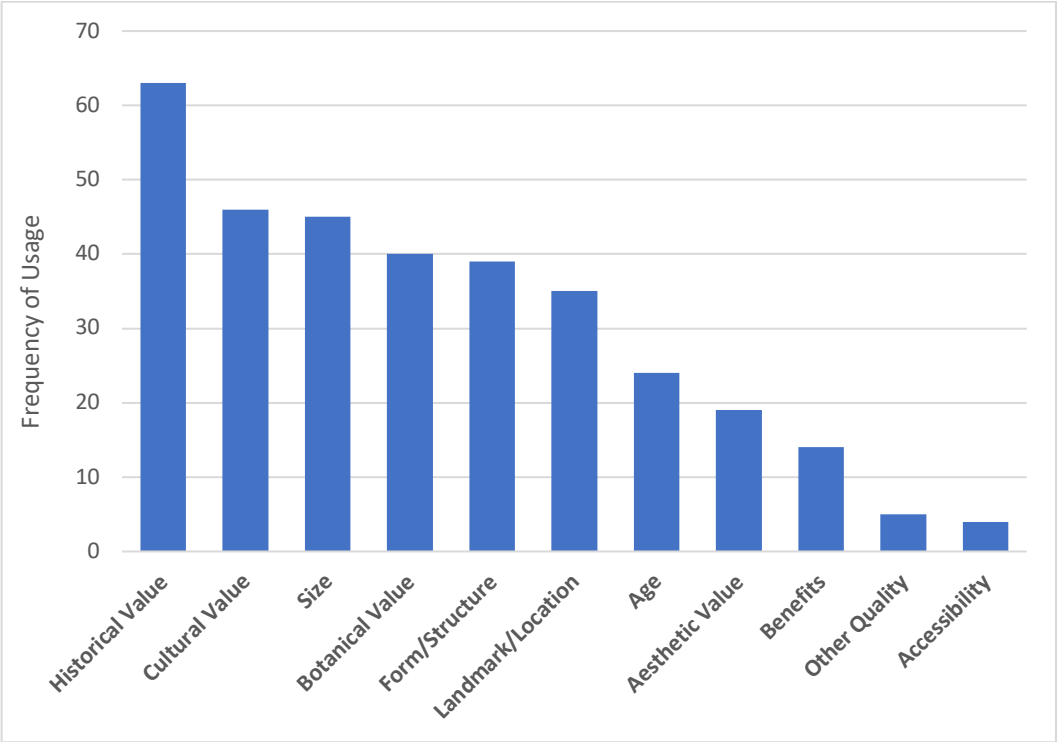

Figure 1. The Frequency of Grouped Criteria Used in 46 Global Heritage Tree Programs

Age

For age there are four sub-criteria that have been identified and labeled as such based on their associated characteristics. *Non-Specific* (Oregon Heritage Tree Program, 2011), *Program-Specific* (Wasman, 2015; County of San Diego Parks and Recreation, 2018), *Species-Specific* (City of West Hollywood, 2018) and *Oldest Specimen of Species in Region* (Trees Winnipeg, 2018). The first three aforementioned criteria are identical in their definitions and use to their size criteria counterparts, while the *Oldest Specimen of Species in Region* is similar to champion size in that the oldest tree for a specific species in a region will receive heritage tree status (Trees Winnipeg, 2018). As with the *Size* category, age thresholds for the *Program-Specific* criterion

can vary among programs with one stating that a tree must be at least 50 years old (County of San Diego Parks and Recreation, 2018), while another only allows trees that pre-date 1796 when the city of Cleveland was founded (Wasman, 2015).

The majority of heritage tree programs examined that use an age criterion do not require a specific threshold to be met (60.7%), although in Asian countries many heritage trees are over a century old (Ali et al., 2016; Jim, 2004a). Guangzhou, China is one example that places a heavy emphasis on age criteria with nearly all of their heritage trees being over 100 years old (Jim, 2004a). While there are a few trees under this centennial benchmark, as of 2004 75% of heritage trees in Guangzhou were between the ages of 100-200, with some individuals as old as 450 years (Jim, 2004a). However, Lindenmayer & Laurance (2017) challenge the use of age as a criterion due to the difficulty sometimes seen when acquiring such a metric. Instead, they propose that a more stringent hybrid evaluation system be used which incorporates both diameter and height to determine "relative size" and award heritage status to trees of each species that are in the top five percentile (Lindenmayer & Laurance, 2017, p. 1437). Non-Specific was the most commonly used age criterion in the case studies (37%), followed by Program-Specific (10.9%), Species-Specific (8.9%) and Oldest Specimen in Region (4.3%).

Historical Value

Historical Value, *Historical Person/Memorial Planting*, *Remnant* and *Represented in Historical Documents* are the four criteria that have been produced related historical value content found in the literature. As the name implies, the *Historical Value* criterion is used for trees that are associated with a historical place (City of Spokane Urban Forestry Department, 2018), event

(Oregon Heritage Tree Program, 2011) and/or date (Minneapolis Park and Recreation Board, 2018) that has a lasting and important contribution to a given geographic area. *Historical Person/Memorial Planting*, allows a tree to receive heritage status if it is associated with a well-known individual (Woodland Trust, 2008) or planted by a historical figure (County of San Diego Parks and Recreation, 2018). *Remnant* refers to a tree that represents a landscape style from a significant era (City of West Hollywood, 2018) or highlights another valued style (City of Hobart, 2018; City of Sydney, n.d.) and finally, *Represented in Historical Documents* shows a current tree that is present in "sketches, journals, photographs or writings related to a historical event" (Nebraska Forest Service, 2018, About Champion and Heritage Trees section, para. 5). *Historical Value* was the most frequently used criterion for this category throughout the case studies with (76.1%) followed by Historic Person/Memorial Planting (45.7%), Remnant (6.5%) and *Represented in Historical Documents* (2.2%). This shows the overwhelming importance that heritage tree programs place on a broad historical component compared to more specific aspects.

Cultural Value

The literature has identified seven cultural value criteria seen through *Cultural Value*, *Religious/Spiritual Value*, *Legends/Mythical/Folklore Value*, *Aboriginal Association*, *Social/Community Value*, *National Interest* and *Local Significance*. *Cultural Value* has been used to describe trees that a community has associations with (City of Hobart, 2018) or are of importance to a cultural group (Republic of South Africa, Department of Water Affairs and Forestry, 2003). These trees are renowned for their cultural heritage (Zapponi, Mazza, Farinam Fedrigoli, Mazzocchi & Roversi, 2017) and have to be protected based on this appreciation

(Dreslerova, 2017). Programs can also assign heritage status to trees that reference religion (Zapponi et al., 2017) or spiritual components (City of Melbourne, 2012), forming the foundation for the *Religious/Spiritual* criterion. Heritage trees have also been identified as such based on their associations to legends (Nebraska Forest Service, 2018) and folklore (Genç & Güner, 2001). An example of the latter has been seen in Golhisar, Turkey through the occurrence of a tradition that sees a newlywed bride visit the "tomb of an auspicious person beneath the tree" before returning home after the marriage ceremony (Genç & Güner, 2001, p. 1). *Aboriginal Association* is prominent in many Australian programs (City of Kingston, 2015; City of Moonee Valley, 2017; City of Yara, 2018) and represents a tree that is "associated with aboriginal activities or culture" (City of Yara, 2018, p. 3) or "valued for continuing and developing cultural conditions" (City of Melbourne, 2012, p.7). While relatively intuitive, *Social/Community Value* has been used to describe a tree that provides a special connection to the community (City of Sydney, n.d.) that can be seen through "positive community engagement focused around engagement with the tree" (City of Melbourne, 2012, p. 7). *National Interest* is a component that has been identified as an important criterion in Scotland (Rodger et al., 2003) to identify trees of importance at a national scale. This stands in contrast to the *Local Significance* criterion that sees values attached to a well-known tree by the local community due to the "sense of place" they provide and are significant enough that their removal could impact the local community (City of Hobart, 2018, p. 3). It is important to note the focus that some heritage tree programs place on these cultural criteria (Forests Ontario, 2017b) compared to the sheer physical metrics used by others (American Forests, 2018) and addresses an important aspect of these programs, one that acknowledges and

celebrates the past through these living monuments that are fixed components in society, even as landscapes change (see Lindenmayer & Laurance, 2017, p. 1442-1443). *Cultural Value* was the most frequently used criterion for this category throughout the case studies with (41.3%) followed by *Social/Community Value* (19.6%), *Aboriginal Association* (10.9%), *Legends/Mythical/Folklore* (10.9%), *National Interest* (2.2%) and *Local Significance* (2.2%).

Botanical/Horticultural/Arboriculture/Biological Value

Botanical criteria are prominent components of heritage tree programs and have been synthesized into the four unique criteria of *Botanical/Horticultural/Arboriculture/Biological Value*, *Endemic*, *Rarity* and *Specific Species/Species Significance* to represent their use. *Botanical/Horticultural/Arboriculture/Biological Value* has been used to highlight trees that display exceptional horticultural value which could make them a valuable source for future propagation efforts based on their genetic components (City of Melbourne, 2012). While the majority of programs use the term horticultural value, botanical, arboriculture and biological value have also been included due to the similar properties they represent and to ensure they are considered when this criterion is being used. While the *Endemic* criterion was only seen in the case study from Hawaii (University of Hawaii, 2018), its use can allow valued endemic tree species to receive heritage status. *Rarity* has been used to designate heritage status to trees that are considered rare or very localized and have the ability to enrich the diversity seen in an urban forest through their presence (City of Melbourne, 2012). While some programs do not define the geographic scale that constitutes rarity (Seattle Department of Transportation, 2018), Italy allows both local and exotic species to be considered rare (Zapponi et al., 2017) while Ontario, Canada has two separate categories to reflect rarity at local and global scales

(Forests Ontario, 2017c). *Specific Species/Species Significance* is used to award heritage status to specific types of trees (City of Portland Parks and Recreation, 2016) that have been deemed significant due to their species type (City of Lake Oswego Department of Planning and Building Services, 2015). Of these four criteria, the broadly defined *Botanical/Horticultural-/Arboriculture/Biological Value* was used the most frequently in the case studies (39.1%), followed closely by *Rarity* (37%), *Specific Species/Species Significance* (8.7%) and *Endemic* (2.2%).

Aesthetics

The aesthetic value humans place on trees has been well documented by Tyrvainen, Pauleit, Seeland and de Vries (2005). From this, it is not surprising to see that *Aesthetic Value* was the fifth most commonly used criterion in the case studies, occurring in 41.3% of those examined. Programs use this criterion to acknowledge the outstanding beauty that certain trees have (City of Melbourne, 2012) or those that have unique aesthetic qualities (City of Spokane Urban Forestry Department, 2018).

Form/Structure/Morphology

Form/Structure/Morphology, *Unusual/Curious Growth Form*, *Outstanding Example of Species*, *Ability for Maximum Potential Growth*, *Non-Hazard/Obstruction* and *Health* are criteria that have been derived from the literature to represent impressive/unusual tree form and initial requirements pertaining to aspects such as structure, health and available room to grow. *Form/Structure/Morphology* is a broad definition that is based on trees that display exceptional form (Seattle Department of Transportation, 2018) and structure compared to other specimens

of the same species in a program's geographic area (City of West Hollywood, 2018). Related to this is the *Unusual/Curious Growth* criterion which allows trees to receive heritage status if they possess uncommon physical features and/or growth forms and can be seen with abnormal growths, fused branches, unusual pruning, etc. (City of Melbourne, 2012). In comparison, *Outstanding Example of Species* focuses on the most ideal specimens from each species (City of Melbourne, 2012) from a local to an international level (City of Yara, 2018). The remaining three components, *Ability for Maximum Potential Growth*, *Non-Hazard/Obstruction* and *Health* are all related in that they act as pre-requisite criteria for certain programs in order for a heritage tree to be designated (Seattle Department of Transportation, 2018; City of Coronado, n.d.). If this requirement is not met, even if a tree possesses one or more of a heritage tree program's stated criteria it cannot receive this classification (Seattle Department of Transportation, 2018). To use each of these three respective criteria a tree must either "have full potential to reach mature size and form, taking into consideration site constraints such as adjacent buildings, parkways, roadways, utilities, etc." (City of Coronado, n.d., p. 1), not be considered a hazard to public safety (City of Spokane Urban Forestry Department, 2018), or must be deemed healthy by an arborist (City of Portland Parks and Recreation, 2016). Of these six criteria, Form/Structure/Morphology was used the most frequently in the case studies (26.1%), followed by Outstanding Example of Species (17.4%), Health (17.4%), Unusual/Curious Growth Form (15.2%), Ability for Maximum Potential Growth (6.5%) and Non-Hazard/Obstruction (2.2%).

Landmark/Location/Landscape

Heritage trees can be denoted as such due to their importance as landmarks and the unique geographic locations where they are found. *Landmark/Location/Landscape*, *Edge of Natural Range*, *Unusual Species for Area/Outside of Natural Range* and *Collection/Grove/Avenue* have been produced from the literature in order to represent these characteristics. *Landmark-/Location/Landscape* has been used by programs in areas such as Scotland (Rodger et al., 2003), Hawaii (University of Hawaii, 2018) and Melbourne (City of Melbourne, 2012), to allow trees to receive heritage status based on providing a significant contribution to the landscape or enhancing the character of an area (City of Melbourne, 2012). These trees often act as landmarks due to their importance in the physical landscape (City of Lake Oswego Department of Planning and Building Services, 2015) and their removal "would fundamentally alter" the character of the landscape (City of Hobart, 2018, p. 3). *Edge of Natural Range* and *Unusual Species for Area/Outside of Natural Range* are two criteria that utilize a particular geographic location to award heritage status. The former has been seen in Hobart, Tasmania and is used to place significance on trees that represent the end of their natural range (City of Hobart, 2018), while the latter focuses on species that are unusual for a given area and has been seen with the city of Coronado's heritage tree program (City of Coronado n.d.). *Collection/Grove/Avenue* as a distinct criterion was only utilized in Seattle and represents "a notable grove, avenue, or other planting" (Seattle Department of Transportation, 2018, Heritage Tree Program, para. 4). However, it is important to note that while many programs do not use this as a standalone criterion, they do allow groves of trees to receive heritage status together (City of Melbourne, 2012; University of Hawaii, 2018). *Landmark/Location/Landscape* was used the most often of

these four criteria in the case studies (50%), followed by *Edge of Natural Range* (15.2%), *Unusual Species for Area/Outside of Natural Range* (8.7%) and *Collection/Grove/Avenue* (2.2%).

Publicly Accessible

Publicly Accessible and *Visible from Publicly Accessible Locations* are two pre-requisite criteria that have been used in a similar fashion to the *Health* criterion in the Form/Structure-/Morphology category. These criteria have been observed in programs along the West Coast of the United States and ensure that candidates are accessible to the public (Ali et al., 2016) or visible from publicly accessible locations (City of Coronado, n.d.) such as along roads or in public spaces (City of Spokane Urban Forestry Department, 2018). *Visible from Publicly Accessible Locations* was the most frequently used criterion from this category in the observed case studies (6.5%), followed by *Publicly Accessible* (2.2%).

Benefits

Economic Benefits, *Significant Ecological/Environmental Value* and *Outstanding Habitat Value* were the three criteria produced for this category. The *Economic Benefits* criterion was exclusively seen in South Africa where trees are able to receive heritage status if they are able to produce economic benefits through eco-tourism (Republic of South Africa, Department of Water Affairs and Forestry, 2003). *Significant Ecological/Environmental Value* is attributed to trees that "make a significant contribution to the integrity of an ecological community" (City of Sydney, n.d.), or facilitates a positive change in the local micro-climate (City of Melbourne, 2012). *Outstanding Habitat Value* recognizes trees that "provide breeding and foraging habitat, roosting sites and refuge" (City of Hobart, 2018, p. 3) and are significantly important for various

types of fauna (City of Moonee Valley, 2017). *Outstanding Habitat Value* was the most common criterion of these throughout the case studies (15.2%), followed by *Significant Ecological-/Environmental Value* (13%) and *Economic Benefits* (2.2%).

Other Unique Qualities

Other Unique Qualities is a criterion that has been enacted by 10.9% of the examined heritage tree programs to account for characteristics that may not be encompassed by the aforementioned criteria. Trees that receive heritage status based on this criterion exemplify a significant aspect that is unique enough to warrant this distinction (City of Hobart, 2018).

2.2 Summary

From this literature review, the terminology and criteria used by heritage tree programs from around the world have been analyzed. The most common term used for such trees has been derived, in addition to the 40 unique criteria used among the 46 examined heritage tree case studies. This information has identified the need for a standardized set of heritage tree criteria and provides the foundation for the remainder of the study that utilizes the Delphi research method in an attempt to obtain expert consensus on the most important criteria that should be used by a heritage tree program.

CHAPTER 3

Establishing Consensus Core Criteria for the Protection of Heritage Trees

This chapter discusses the implementation, analysis and findings of the heritage tree criteria research study. Beginning with a review of the current state of heritage tree literature, this research investigates criteria used to establish heritage tree status through a process of expert consensus, and presents a final set of core criteria that could be implemented by heritage tree programs globally.

3.1 Introduction

The protection of important tree specimens dates back to the middle ages when one of the first known references to tree conservation was seen in Bohemia in the year 1189 (Dreslerova, 2017). Since that time, trees around the world have been valued for a variety of attributes (historical, cultural, environmental) and programs have been established to acknowledge and protect unique specimens. While the goal of all these programs is to conserve important trees, there has been a lack of consensus on the key characteristics or attributes should be used to designate these specimens. In certain cases, the focus has been placed on historical and cultural criteria (Forests Ontario, 2017b), while other programs place a greater emphasis on physical metrics (American Forests, 2018). Adding to this discourse are anthropogenic threats that potentially jeopardize highly valued specimens (Jim, 2004a). Though an analysis of the heritage tree literature, and the examination of 46 case studies from around the world, the most common terms and criteria used to identify heritage trees have been identified. These criteria

were presented to a panel of international experts using the Delphi method (Dalkey & Helmer, 1963) in an attempt to identify consensus core criteria which can be used to protect individual specimens and support the work of existing or proposed heritage tree programs. This will allow heritage tree programs to identify candidates using a set of expert verified criteria, ensuring that only the most important specimens are selected, while also providing the foundation required for these programs to thrive.

3.2 Heritage Tree Literature

Terminology

Creating a universally agreed upon definition of a heritage tree may at first seem like a simple task, but with 60 terms used to denote these important specimens (see Jim, 2017, p. 290), this objective is surprisingly complex. A global review of 46 programs identified terms such as: "heritage trees," "champion trees," "significant trees," "exceptional trees," "monumental trees," "ancient trees," "memorial trees," "veteran trees," etc. (see Table 3). These terms utilize many of the same essential components and values but seem use these different titles based on the region where each respective program occurs. The term significant tree is associated with programs in Australia (City of Moonee Valley, 2017; City of Hobart, 2018; City of Yarra, 2018), monumental tree is commonly used in Europe (Zapponi, Mazza, Farinam Fedrigoli, Mazzocchi & Roversi, 2017), old-valuable tree (Jim & Zhang, 2013) and heritage tree (Jim, 2004a; Thaiutsa, Puangchit, Kjelgren & Arunpraparut, 2008; Chen & Hua, 2015; National Parks Board Singapore, 2017) have occurred in Asia and heritage tree (City of Portland Parks and Recreation, 2016; Forests Ontario, 2017b; Trees Winnipeg, 2018) and champion tree (American Forests, 2018; Nebraska Forest Service, 2018) are the most common terms used in North

America. While it is noted that programs in each region can choose the terminology that is deemed to be the best fit for them, as the term heritage tree occurs most frequently (22 times) in the observed case studies and has also been formally designated as such by others in the field (Jim, 2017, p.279), it will be used to describe these specimens from this point forward.

Criteria

These sources also identified 40 unique criteria which were classified into one of 11 categories to discover the core components used in these programs (Table 4). This plethora of criteria becomes even more convoluted when analyzing sub-criteria components found for size and age. Both of these have four sub-criteria that have been used in at least one heritage tree program and while each are rather intuitive, special attention needs to be given to the champion criterion due to the intricacy of its use.

Champion trees present an interesting conundrum in that they can be a component of heritage tree programs (Minneapolis Park and Recreation Board, 2018), or recognized individually in "Champion Tree" programs (American Forests, 2018). In both programs, these trees are valued for their physical metrics such as height, diameter/circumference and crown spread, from which a champion title is awarded to either: a) the tree with the greatest cumulative score derived from a formula representing all three metrics (American Forests, 2018); or b) the largest specimen per species for a given metric (Johnson, 2011). Age can also be a metric in programs that use the latter method, specifically when identifying the oldest specimens of each species (Rodger et al., 2003). While certain programs choose to focus on aspects such as size criteria (Nebraska Forest Service, 2018), others place the greatest emphasis on historical and

cultural aspects (Forests Ontario, 2017b). The priorities placed on the two aforementioned types of criteria addresses an important component of heritage tree programs that celebrates the past through these living monuments, even as the landscapes around them change (see Lindenmayer & Laurance, 2017, p. 1442-1443). However, these trees are increasingly under threat as the natural environment is altered due to construction (Jim, 2004a, 2004b). Between 1986-1995, mortality rates of 21.5% were seen among the 209 original HTs in Guangzhou, China (Jim, 2004a).

Table 3. Heritage Tree Terminology Used in 46 Case Studies

Terminology	Case Study*	Frequency
Heritage Tree	1, 4†, 7, 8, 11, 13, 15, 16, 17, 18, 20, 22, 25, 30, 31, 33b‡, 34, 38, 39, 41, 43, 45d§	22
Champion Tree	2, 3†, 29, 33a‡, 35, 36, 37, 45c§	8
Significant Tree	9, 10, 14, 19, 21, 27, 32	7
Exceptional Tree	12, 42	2
Monumental Tree	46	1
Historical Monument Tree	26a**	1
Folkloric Monument Tree	26b**	1
Mystical Monument Tree	26c**	1
Dimensional Monument Tree	26d**	1
Veteran Tree	45b§	1
Witness Tree	5†	1
Heritage Large Tree	40	1
Old-Valuable Tree	28	1
Moses Cleveland Tree	44	1
Ancient Tree	45a§	1
Remarkable Tree	6	1
Largest Tree	23	1
Memorial Tree	24	1

* Case studies are referenced in Appendix 2

† Each has a unique terminology and criteria but all under Arizona's "Magnificent Tree" program.

‡ Two terms and criteria from the same source: a = Champion Tree and b = Heritage Tree.

§ Four terms used by the same source: a = Ancient Tree, b = Veteran Tree, c = Champion Tree and d = Heritage Tree.

** Four terms are used by the same source: a = Historical Monument Tree, b = Folkloric Monument Tree, c = Mystical Monument Tree and d = Dimensional Monument Tree.

Table 4. Criteria Used in 46 Heritage Tree Case Studies

CRITERIA BY CATEGORY	CASE STUDY*	DEFINITION
AGE		
Age (non-specific)	8†, 9, 10, 12, 14, 15, 16, 17, 21, 24, 32, 34, 37, 38, 39, 42, 46	No specific age threshold is used.
Age (program-specific)	1, 5, 22†, 28†, 44	A single age threshold is assigned to all trees.
Age (oldest specimen of species in region)	13†, 41	The oldest specimen of a species.
Age (species-specific)	6, 20†, 26d†, 45a†	Age thresholds are assigned for each species in the program.
HISTORICAL VALUE		
Historical Value	1, 3, 6, 7, 8†, 9, 10, 11, 13†, 14, 15, 16, 17, 18, 19, 20†, 21, 22†, 24, 25, 26a†, 28†, 30†, 31, 32, 33b†, 34, 37, 38, 39, 41, 42, 43, 45d†, 46	Associated with an important historical place, event or date.
Historic Person/Memorial Planting	3, 6, 9, 10, 11, 12, 14, 15, 18, 19, 20†, 21, 22†, 25‡, 28†, 32, 33b†, 34, 37, 38, 39	Planted for or by a person with historical significance.
Remnant	9, 19, 20†	Represents characteristics of a previously significant era.
Represented in Historical Documents	33b†	Mentioned or visually depicted in historical documents.
CULTURAL VALUE		
Cultural Value	1, 3, 7, 9, 11, 12, 17, 19, 24, 25‡, 28†, 30†, 31, 37, 38, 41, 42, 45d†, 46	Associations with past and current community groups.
Religious/Spiritual Value	6, 9, 12, 32, 46	Associated with religious and spiritual practices.
Legends/Mythical/Folklore Value	6, 24, 26b†, 26c†, 33b†	Associated with legends, mythical stories and/or folklore.
Aboriginal Association	9, 10, 12, 14, 21, 32	Importance or association to aboriginal cultures and events.
Social/Community Value	3, 9, 11, 12, 17, 19, 31, 32, 34	Prominent and provides a connection with the community.
National Interest	38	A vital component of a country's stated cultural/conservation goals.
Local Significance	9	Locally known as a key fixture within the community.
Size		
Size (non-specific)	10, 12, 13†, 14, 15, 16, 17, 21, 22†, 24, 25, 30†, 32, 34, 37, 39, 42	No specified size threshold is used.
Size (program-specific, non-champion)	1, 8†, 20†, 22†, 27, 28†, 31†	A single size threshold is assigned to all trees.
Size (species-specific)	6, 18, 20†, 23, 26d†, 28†, 35‡, 46	Size thresholds are assigned for each species in the program.
Champion Size	2, 3, 9, 13, 29†, 30†, 33a†, 36, 38, 40, 41, 43, 45c†	Represents the largest physical metric(s) for each species.
Aesthetic Value		
Aesthetics	6, 8†, 9, 10, 12, 14, 18, 19, 20†, 21, 25, 29†, 31, 32, 37, 38, 42, 43, 45d	A visually impressive specimen that stands out due to its representation of unusual size, age, captivating flowers, seeds, leaves and/or other aspects.

*Case studies are referenced in Appendix 2
† See Appendix 1 for supplementary information
‡ Primary/mandatory criteria (if secondary criteria are listed for program)

Table 4. (Continued) Criteria Used in 46 Heritage Tree Case Studies

Criteria by Category	Case Study*	Definition
Botanical Value		
Botanical Value	7, 6, 8†, 9, 10, 12, 14, 16, 18, 19, 20†, 21, 25, 31, 32, 38, 45d†, 46	Unique or exceptional botanical, horticultural or biological value.
Endemic	42	Valued in a given geographic area due to its endemic status.
Rarity	1, 9, 10, 12, 14, 17, 19, 21, 25, 28†, 29†, 32, 38, 39, 41, 42, 45d†	A tree that is considered rare due to its endangered status.
Specific Species/Species Significance	1, 15, 16, 34	A specific species of tree that is deemed to be of importance.
Landmark/Location		
Landmark/Location/Landscape	1, 8†, 9, 10, 12, 13†, 14, 15, 17, 19, 20†, 21, 24, 25, 30†, 32, 34, 37, 38, 39, 41, 45d†, 46	A visually dominant component of the landscape.
Edge of Natural Range	9, 10, 12, 14, 19, 21, 32	Represents the edge of a species natural range for a specific area.
Unusual Species for Area/Outside Natural Range	6, 8†, 20†, 28†	An unusual specimen for a specific area.
Collection/Grove/Avenue	39	A grove or avenue of trees grouped together in close proximity.
Form/Structure		
Form/Structure/Morphology	1, 6, 8†‡, 9, 13†, 20†‡, 22†, 25, 28†, 39, 45b†, 46	Displays ideal/ interesting characteristics that set it apart.
Unusual/Curious Growth Form	10, 12, 14, 19, 21, 32, 41	Unique/out of the ordinary physical form for species.
Ability for Maximum Potential Growth	8†‡, 16†, 20†‡	Must have enough space to reach its maximum physical metrics.
Non-Hazard/Obstruction	18	Not a hazard to the public that could warrant its eventual removal.
Outstanding Example of Species	1, 10, 12, 13†, 14, 21, 32, 41	Represents a species optimal form/structure.
Health	1, 8†‡, 9, 12, 16‡, 25, 35, 39‡	Deemed healthy by a certified professional arborist
Accessibility		
Publicly Accessible	1	Publicly accessibility that allows for interaction with the community.
Visible from Publicly Accessible Locations	8†‡, 18, 20†‡,	A tree being considered for heritage status that must be visible to the public.
Benefits		
Economic Benefits	37	Provides economic benefits usually through ecotourism.
Significant Ecological/Environmental Value	9, 12, 19, 21, 28†, 46	Provides ecological/environmental benefits for a specific area.
Outstanding Habitat Value	9, 12, 14, 19, 21, 45b†, 46	Produces micro-habitats for various organisms.

*Case studies are referenced in Appendix 2
† See Appendix 1 for supplementary information
‡ Primary/mandatory criteria (if secondary criteria are listed for program)

These rates increased to 29% when looking at the same program over a longer period of time (1985-2007) (Chen, 2015) and was also seen in Hong Kong between 1993-2005 when 14% of their heritage trees were lost (Jim, 2004b), showing the impact that human activity can have on these trees.

Legal protections are one method that can be used to help alleviate the mortality trend seen with heritage trees. Guangzhou, China has eleven laws across all three levels of government (five federal, one provincial and five municipal) (Jim, 2004a), Hawaii, USA has a statewide law (University of Hawaii, 2018) and Perak, Malaysia enacts a Tree Preservation Order to "protect trees in the interest of public amenity." While these laws can provide a theoretical safety net, as more agencies become involved, enforcement and management practices can become increasingly difficult as different levels of government and their laws interact (Jim, 2004a). Adding to this complexity is a lack of support on behalf of the public as Chen (2015) saw in 2013 when only 44.4% of residents in Guangzhou, China supported a one-time payment to assist the government with heritage tree programs. This value decreased to 23.2% during a subsequent study the same year by Chen and Hua (2015), resulting from a distrust of the government and an inadequate amount of available information on heritage trees (Chen & Hua, 2015). Public awareness of heritage tree values through educational methods needs to occur in order to increase support for these trees (Chen, 2015), including associating heritage trees with social values (Blicharska & Mikusinski, 2014). Books (Rodger et al., 2003; Johnson, 2011), websites and maps are mediums that have be used to educate the public about the values of heritage trees (Forests Ontario, 2017b; The Outdoor Circle, 2017). By expanding these resources to

further disseminate knowledge of heritage trees, public awareness should increase and could lead to increased support for heritage tree programs.

The diversity seen among heritage tree programs suggests a need to identify shared values and produce a set of consensus core criteria that represent a foundation for current and proposed heritage tree programs. This would assist these programs in identifying ideal heritage tree candidates, facilitate the sharing of knowledge pertaining to best practices and result in increased protections for these trees.

3.3 Research Design

The Delphi method is a process that involves controlled feedback to help a group of experts reach consensus on a given topic (Dalkey & Helmer, 1963). Typically, three iterations are seen when conducting a study using Delphi (Jones et al., 1992), although according to Skulmoski et al. 2007, this process can be completed in as few as one or two rounds. While there are no "minimum or maximum" values regarding the number of experts that should participate in a Delphi study (see Evans, 1997, p.124), 10-15 are generally considered to be ideal (Adler & Ziglio, 1996; Skulmoski et al., 2007). Non-probability sampling techniques should be used to form the panel (Keeney et al., 2006) as expert opinion is being sought rather than that of the general population.

A three iteration Delphi survey modified from the recommendation of Skulmoski et al. (2007) was used for this research (see Figure 2). 40 heritage tree criteria from the 46 examined case studies provided the framework for the initial survey that consisted of 40 closed-ended and 40 open-ended questions. Closed-ended questions used to evaluate the presented criteria were

based on a 5-point Likert Scale. Open-ended questions presented at the end of each section and conclusion of the survey provided experts with the opportunity to convey additional comments related to the closed-ended questions, suggest new content, modify existing questions and justify criteria that received very low percentage of importance values. This process also provided a more comprehensive reasoning as to why certain criteria were selected or omitted from the presented framework (McLeod, 2012). Any criteria that reached consensus were omitted from future survey iterations (Stewart, Gibson-Smith, MacLure, Mair, Alonso, Codina, et al., 2017), leaving only those that failed to reach the consensus threshold. The pilot survey was tested by six individuals not related to the project to assess the content, structure and navigation of the survey.

A high level of consensus on important criteria was achieved if ≥75% of the expert panel considered a criterion *significantly important* (category 4) or *critically important* (category 5). Consensus was also achieved when <25% of the expert panel considered a criterion significantly or critically important. Criteria in between these two results with values of 25%-50% and 50%-75% had low and medium levels of consensus respectively. With no set value for consensus in the literature (Keeney, Hasson & McKenna, 2006), these values were chosen in order to obtain a high degree of certainty that the selected criteria were of importance to the vast majority of the expert panel.

The first iteration of the survey was sent to the panel of 15 heritage tree experts through the survey software Qualtrics. A summary of the results detailing the percentage of importance values for each of the criteria along with expert feedback was then provided to the panel. A

"Criteria Consensus" document was also emailed to the panel between each survey listing the criteria that had reached consensus and were scheduled to be removed from the survey as a result. This process was used to confirm the results from the first two rounds and allowed the panel to agree or disagree with the findings. If one or more members of the panel disagreed with the decision to remove any of the criteria, these would be re-incorporated into the subsequent round of the survey for further discussion.

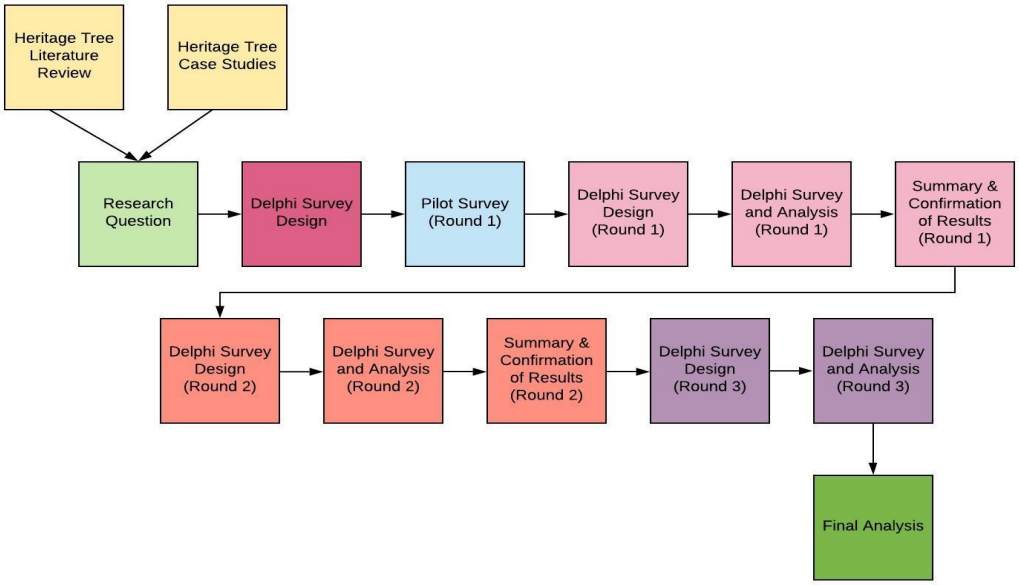

Figure 2. Research Design (adapted from Skulmoski et al., 2007)

The second round of the survey was created from these results and featured all of the criteria that had not achieved consensus in the first round, in addition to new content that had been suggested by the panel. The process from the first round was repeated to analyze the data produced from the second iteration of the survey. However, as the third round of the survey was the final iteration, any criteria that had values <70% were removed prior to its onset based on a lack of any significant changes towards reaching high consensus after the first two rounds.

3.4 Results

The first round of the survey saw a response rate of 100% with an average submission time of 13.7 days. The 40 criteria presented in this round resulted in 9 high, 16 medium, 13 low and 2 very low consensus values. Eleven criteria reached the consensus threshold, albeit nine were due to high consensus (*Historical Value, Cultural Value, Aboriginal Association, Social/Community Value, National Interest, Local Significance, Landmark/Location/Landscape, Botanical/Horticulture/Arboriculture/Biological Value* and *Rarity)*, while the remaining two resulted from very low consensus values (*Program-Specific Age* and *Program-Specific/Non-Champion Size*). It should be noted that 10 rather than all 11 criteria were removed after the first round due to the *Rarity* criterion. Expert recommendation suggested that this criterion be divided into two distinct criteria (*Rarity* and *Endangered*), even though it had reached consensus in the first round. This saw these two criteria introduced in the second survey to be re-evaluated based on this change. The outcome of the analysis was eight consensus core criteria, which suggests that these criteria should always be considered in heritage tree programs.

The second round of the survey saw a response rate of 100% with an average submission time of 12.4 days. The 38 criteria presented in this round resulted in 4 high, 14 medium, 17 low and 3 very low consensus values. There were seven criteria that reached consensus in the second round, albeit four were due to high consensus (*Rarity, Represented in Historical Documents, Endangered* and *Historic Person/Memorial Planting)*, while three received very low consensus values (*Other Unique Qualities, Publicly Visible Locations* and *Health)*, prompting the removal of these seven criteria from further discussion in the third round. Furthermore, 26 criteria that

had importance values <70% for categories 4 and 5 were presented to the panel for confirmation of removal from the study due to a lack of any significant change towards reaching consensus after the first two rounds. The panel disagreed with the removal of five of these (*Aesthetics, Ecological/Habitat Value, Species-Specific Age, Legends/Mythical/Folklore Value* and *Oldest Specimen of Species in Region)* which saw them included in the third round.

The third round of the survey obtained a 93% response rate with an average submission time of 9.5 days. The 12 criteria presented in this round resulted in 4 high, 7 medium, 1 low and 0 very low consensus values. The four high consensus criteria were represented by *Remnant, Outstanding Example of Species, Species Specific Size* and *Historical Witness*.

The 50 criteria examined in the study saw 21 reach consensus based on the expert panel's recommendations (see Table 5). 16 of these had high consensus and should be used in a heritage tree program, while the remaining five had very low consensus values and should not. The remaining 29 situational criteria were divided into medium and low consensus with 11 and 18 criteria representing each respectively. Heritage tree programs can use these criteria, although they often only apply in select geographic locations, which is why their importance value did not reach the ≥75% required to be considered important for all heritage tree programs. It is important to note that while criteria with high consensus values should be used in a heritage tree program, ultimately the decision to include all or some of these, in addition to criteria with medium and low consensus values, is up to each respective heritage tree committee.

3.5 Analysis

This study was able to identify consensus on 16 core criteria for heritage tree programs. Through an examination of the responses from the expert panel the reasoning for their selection can be derived. Key findings from the study are found below that highlight the most important aspects from each of the categories the criteria were divided into.

Age

No age criteria were able to achieved consensus due to a lack of agreement by the panel on specific values that should be used. The experts indicated the importance of using age criteria but were unable assign values based on two concerns. First, it is difficult to obtain accurate age values for a tree as this process requires ample time and resources to complete. The limited resources that many heritage tree programs have often prevents this type of information from being obtained. Second, a heritage tree program's geographic location influences what values/thresholds are used to indicate age. For example, an Oak tree in Europe may be qualify for age if it has existed for several centuries, while in another location the same species of Oak might qualify for the same status if it is only one hundred years old. The general opinion from the expert panel is that *Age* should be used in a heritage tree program, although the specifics of its use should be determined on a case-by-case basis to accurately reflect the values and conditions of the geographic region. Some programs with access to age data may wish to assign specific thresholds for each species, while others lacking evidence of age might examine a tree and award heritage status if it is "significantly mature and therefore worth preserving."

Historical Value

Five criteria from the *Historical Value* category reached high consensus and demonstrated the importance that is placed on historical content during the heritage tree selection process. Determining what qualifies as historical was a concept brought up throughout the study with some experts stating that minimum age thresholds should be used, while others felt that each heritage tree nominee should be viewed on a case-by-case basis. This was expressed by one expert who felt a greater emphasis should be placed on trees associated with older historical events compared to younger ones, although there was no agreement on this at the conclusion of the study. The final verdict was that specific metrics used to define what constitutes as historical should be left up to each respective heritage tree program. Attaining accurate historical records that could be used to connect a tree to a specific historical event was another aspect raised during the study. This problem appears to be more prevalent in smaller programs or those with limited resources that are unable to devote time and finances to searching for such documents. One expert suggested a reasonable amount of historical evidence would be one method to overcome this through the logic of “guilty by association,” allowing trees to receive heritage status with minimal verified data.

Table 5. Summary of Heritage Tree Criteria Assessment Through Three Survey Iterations*

Criterion	R1 % of Importance	R2 % of Importance	R3 % of Importance	Final % of Importance
Historical Value	100.0	N/A	N/A	**100.0**
National Interest	93.3	N/A	N/A	**93.3**
Landmark/Location/Landscape	93.3	N/A	N/A	**93.3**
Botanical/Horticulture/Arboriculture/Biological Value	93.3	N/A	N/A	**93.3**
Local Significance	93.3	N/A	N/A	**93.3**
Remnant	73.3	73.3	92.9	**92.9**
Rarity	93.3	86.7	N/A	**86.7**
Represented in Historical Documents	73.3	86.7	N/A	**86.7**
Endangered	Introduced R2	86.7	N/A	**86.7**
Cultural Value	80.0	N/A	N/A	**80.0**
Aboriginal Association	80.0	N/A	N/A	**80.0**
Social/Community Value	80.0	N/A	N/A	**80.0**
Historic Person/Memorial Planting	66.7	80.0	N/A	**80.0**
Species Specific Size	66.7	73.3	78.6	**78.6**
Outstanding Example of Species	66.7	73.3	78.6	**78.6**
Historical Witness	Introduced R3	Introduced R3	78.6	**78.6**
Aesthetics	73.3	53.3	71.4	**71.4**
Champion Size - Category	60.0	73.3	71.4	**71.4**
Relic Specimen	Introduced R3	Introduced R3	71.4	**71.4**
Religious/Spiritual Value	53.3	66.7	N/A	**66.7**
Champion Size - Cumulative Points	Introduced R2	73.3	64.3	**64.3**
Collection/Grove/Avenue	73.3	60.0	N/A	**60.0**
Biological Heritage	Introduced R2	60.0	N/A	**60.0**
Oldest Specimen of Species in Region	60.0	60.0	57.2	**57.2**
Legends/Mythical/Folklore Value	60.0	60.0	57.1	**57.1**
Economic Benefits	40.0	53.3	N/A	**53.3**
Species-Specific Age	53.3	60.0	50.0	**50.0**
Edge of Natural Range/Localized Distribution	46.7	46.7	N/A	**46.7**
Significant Environmental Value	46.7	46.7	N/A	**46.7**
Unusual Species for Area/Outside Natural Range	40.0	46.7	N/A	**46.7**
Productive Trees	Introduced R2	46.7	N/A	**46.7**
Non-Hazard/Obstruction	53.3	46.7	N/A	**46.7**
Unique Location/Context	Introduced R2	46.7	N/A	**46.7**
Seed Source/Propagation Stock	Introduced R2	46.7	N/A	**46.7**
Resistant to Disease	Introduced R2	46.7	N/A	**46.7**
Ecological/Habitat Value	40.0	53.3	42.9	**42.9**
Specific Species/Species Significance	66.7	40.0	N/A	**40.0**
Ability for Maximum Potential Growth	53.3	40.0	N/A	**40.0**
Non-specific Size	46.7	40.0	N/A	**40.0**
Endemic	46.7	40.0	N/A	**40.0**
Form/Structure/Morphology	46.7	40.0	N/A	**40.0**
Growth Conditions	Introduced R2	33.3	N/A	**33.3**
Publicly Accessible	33.3	26.7	N/A	**26.7**
Non-Specific Age	33.3	26.7	N/A	**26.7**
Unusual/Curious Growth Form	33.3	26.7	N/A	**26.7**
Other Unique Qualities	33.3	20.0	N/A	**20.0**
Publicly Visible Locations	40.0	13.3	N/A	**13.3**
Program Specific/Non-Champion Size	13.3	N/A	N/A	**13.3**
Health	53.3	13.3	N/A	**13.3**
Program-Specific Age	13.3	N/A	N/A	**13.3**

* R1-R3 identify the survey round being examined

Cultural Value

Five criteria obtained high consensus for the *Cultural Value* category producing the same amount of recommended heritage tree criteria as the *Historical Value* category. This shows the importance the expert panel placed on these cultural criteria when selecting a heritage tree. Two aspects associated with this category were raised that saw a nearly equal divide amongst the panel regarding how the selected criteria should be used. First, while the *Local Significance* and *National Interest* criteria achieved high consensus values in the first round, as the study progressed there were some experts who felt that these two criteria should become supplementary information, rather than standalone heritage tree criteria. Portions of the second and third rounds of the study were spent trying to identify if these two criteria should be removed from the recommended heritage tree criteria list, or if they should remain as indicated after the first round. The result from these open-ended questions showed a nearly equally divide amongst the panel on this topic. Some felt that these two criteria were unique and contributed important aspects to a heritage tree program. Others argued that the geographic scale (local, state/provincial, regional, national or international) at which a heritage tree criterion is selected should be used to complement the other 14 criteria that reached high consensus. For example, if a tree received heritage tree status based on the *Historical Value* criterion, the level at which it is valued would also be stated (e.g. *Historical Value* - National or, *Species Specific Size* - Local). At the conclusion of the study there lacked any concrete agreement as to how this should be treated. The result saw these two components remain as recommended heritage tree criteria for the purposes of this research, but the decision of which option to use will be up to each respective heritage tree committee.

Second, there was some discussion amongst the expert panel regarding the title and definition used to represent the *Aboriginal Association* criterion which obtained high consensus in the first round. The majority of the panel felt that a more accurate term would be *Indigenous Cultural Association* and is identified as such for the final definition used in this paper. It is important to note that some experts strongly recommended that each heritage tree program that uses this criterion corresponds with local indigenous groups to receive their feedback on what term they prefer as this can vary depending on geographic location.

Size

One criteria attained high consensus for the *Size* category. The specifics of using a size criterion for a heritage tree program generated a great deal of discussion among the expert panel throughout the survey leading to a general lack of agreement as to how such criteria should be used. This was evident as only one *Size* criterion reached consensus with a percentage of high importance at the survey's conclusion. Some experts felt that trees representing a *Size* criterion could have the potential to overshadow all other heritage tree criteria as these are usually the most recognizable to the general public. However, is important to note that all 16 of the consensus core criteria are equally important and conveying this to the public in an effective way will be an essential task for agencies and organization that manage heritage tree programs.

Specific thresholds and calculations that should be used for *Size* criteria were also focal points that the panel had difficulties agreeing on. Throughout the survey experts raised concerns about the difficulty a heritage tree program could have when trying to determine a specific size threshold for each species. This issue primarily extends to small and/or underfunded programs

that may desire to include a *Size* criterion but do not have the resources to do so, similar to the presented *Age* criteria. Through increased communication and the sharing of data between heritage tree programs, this issue could be alleviated and should be considered.

Botanical/Horticultural/Arboriculture/Biological Value

Three criteria obtained high consensus from the *Botanical/Horticultural/Arboriculture-/Biological Value* category. The key aspect from this category was the distinction established between the concepts of rarity and endangered after the first round of the study. Initially these two components were one single heritage tree criterion called *Rarity* that reached a high consensus value during the first survey. After this round, some experts stated that these two components were unique enough to be classified as separate criteria and were introduced into the second round as such. This iteration saw both criteria reach consensus although there was a divide on what geographic scale each would be set at. Some experts felt that a tree should be deemed rare and/or endangered at a regional scale, while others felt a global perspective was more accurate. At the conclusion of the study there was no definitive agreement by the panel, which suggests that each heritage tree committee should decide on the term that is most applicable for their program.

Aesthetics

The *Aesthetics* criterion did not reach consensus during this study although its position at the medium/high consensus threshold indicates that many on the panel realized its potential value. Some experts stated that this criterion could provide the opportunity for “intangible” features of a tree to be incorporated into a heritage tree program, while others felt that this criterion

was too subjective and could lead to its misuse by an individual on a heritage tree committee in order to pursue a personal agenda. Furthermore, experts on the panel felt that the alternative 49 criteria presented in the study adequately covered all aspects required to determine heritage tree status.

Form/Structure/Morphology

Four criteria reached consensus from the *Form/Structure/Morphology* category, albeit one had high consensus while the remaining three had very low consensus values. Specific attention should be given to these three components (*Non-Hazard/Obstruction*, *Ability for Maximum Potential Growth* and *Health*) as they provide important insight into the heritage tree nomination process. The survey data indicated that these should be used on a case-by-case basis as supplementary information to exclude trees that would otherwise receive heritage tree status rather than as criteria. Threats posed by trees to public safety and infrastructure, especially in urban areas, can be problematic. By using these three evaluation components when assessing a tree for heritage status the likelihood of such issues can be reduced. Every mitigation effort should take place to reduce/remove these aforementioned risks and only in cases where this cannot be accomplished should a tree be excluded from a heritage tree program even if it meets one or more of the 16 recommended criteria.

Landmark/Location/Landscape

Only one criterion obtained a high consensus for the *Landmark/Location/Landscape* category. Two concerns related to how climate change could impact trees selected based on this category and what should be used as supplementary information were the reasons for this outcome.

Experts on the panel raised the issue of how a changing climate could lead to future impacts on the health and survival of these trees, especially those which are considered old. This concern was specifically attributed to the *Relic Specimen* criterion with the recommendation from the panel that all trees should qualify for heritage status unless there is a threat to public safety that cannot be mitigated. These changing environmental conditions could also allow useful scientific information to be derived by examining how trees survive outside of their natural range and adapt to new environmental conditions. This knowledge can then be used to prepare urban forest practitioners for a range of climate scenarios, potentially leading to increased care for heritage tree species. The Collection/Grove/Avenue and *Unusual Species for Area/Outside of Natural Range* criteria did not obtain high consensus but were identified by members of the panel as useful components of a heritage tree program when used in conjunction with consensus core criteria to create a more robust and informative program.

Publicly Accessible

The expert panel identified two important concepts from the *Publicly Accessible* category even though none of its criteria reached high consensus. The first pertains to the increase in public support that access to heritage trees can provide, as more exposure and interactions between the public and these trees can translate into a greater appreciation of them. However, it should be noted these interactions can threaten heritage trees through an increase in anthropogenic traffic (walking, vehicles, construction equipment, etc.). This could be prevented through the implementation of Soil Protection Zones (SPZ) around each heritage tree so that soil compaction does not occur. Second, it is imperative that any documents showing the location

of these trees clearly distinguish trees on public and private land to respect private property rights.

Benefits

No criteria from the *Benefits* category were able to obtain attain high consensus in this study. All trees provide benefits and while heritage trees may be able to produce these in greater quantities, the panel stated that this can be difficult to quantify and the difference may not be large enough to justify the designation of heritage status. However, conveying the benefits of heritage trees can be valuable when trying to gain public support and should be used as supplementary information within a program.

Other Unique Qualities

No criteria reached high consensus from the *Other Unique Qualities* category. The subjectivity associated with this criterion and adequate representation of potential heritage characteristics by other criteria were the reasons for this outcome.

3.6 Findings

The intent of this research was to identify the consensus core criteria that are shared among heritage tree programs around the world to form a standardized foundation that can be used by current and proposed programs. Many of these initiatives have to develop a set criteria on their own with little guidance often resulting in the recurrence of common mistakes. This research presents a solution to this through a set of 16 expert verified criteria developed from an initial set of 40 criteria from the literature and 10 others produced from expert feedback

throughout the study (See Table 6). However, there are five requirements associated with these criteria that must be obtained in order for them to be used.

The first involves the need to define thresholds for the *Historical Value*, *Historic Person/Memorial Planting*, *Historical Witness*, *Represented in Historical Documents*, *Remnant*, *Rarity* and *Endangered* criteria as the expert panel was unable to agree upon specific values by the end of the study. For criteria that focus on historical components, it is important for a heritage tree program to define what constitutes as historic so that subjectivity can be reduced during the nomination process. This also applies to the *Rarity* and *Endangered* criteria when setting the geographic scale at which these trees will be evaluated. Second, there needs to be access to documents that can verify a tree's relationship with a given criteria. This is especially important for historical criteria that rely predominately on such documents to award heritage status. Third, expert consultation can be used in cases where documents are limited or cannot be obtained. This can also be the primary method used to award heritage status for a criterion such as *Outstanding Example of Species* where expert opinion is necessary to compare the characteristics of one tree to another. Fourth, public consultation is required for many of the criteria that are associated with cultural values. As many of these rely upon the importance an individual, community and/or group places on a given tree, it is necessary to gather information from these sources to determine heritage status. Finally, baseline metrics for height, diameter/circumference and crown spread need to be produced to use the *Species-Specific Size* criterion. Without assigned thresholds for each species in a program, it will be difficult to evaluate a tree using this criterion. While creating size thresholds can be problematic for programs with limited resources, this can potentially be overcome by obtaining information

from similar heritage tree programs that have produced these data for the same species. By using the aforementioned requirements, a heritage tree program will be able to reduce the subjectivity seen during the nomination process and ensure that only the most qualified candidates are awarded heritage status.

This was the first known instance of using the Delphi method to obtain consensus core criteria for heritage trees and the findings revealed three aspects that were unanticipated at the beginning of this project. The first relates to the unusually large number of criteria that reached high consensus. Of the 46 heritage tree case studies examined, none contained more than 13 criteria, with many having 8-10. The occurrence of 16 recommended core criteria could be the result of the consensus threshold being set at ≥75%, although even if this was raised to ≥80%, there still would have been 13 criteria that reached consensus with high values. This seems to indicate that common values exist amongst heritage tree programs, regardless of geographic location or scale and that a standardized heritage tree program is plausible. Second, the lack of any *Age* criteria reaching high consensus seems peculiar as older trees tend to be valued throughout society (Blicharska & Mikusinski, 2014). However, in the examined case studies *Age* criteria only occurred 60.8% of the time which is similar to what this research showed with the highest *Age* criterion (*Oldest Specimen of Species in Region*) receiving a 57.3% value from the expert panel. It is interesting to note that of the 28 case studies that used an *Age* criterion, 17 of these (60.7%) used a non-specific threshold metric.

Table 6. Consensus Heritage Tree Core Criteria

CRITERIA	DEFINITION	REQUIREMENTS
Historical Value	A tree that is both associated with a historical place, event or date and makes a lasting and important contribution to a given area.	1) Access to historical documents or confirmation by an expert in this field. 2) A metric to identify what constitutes as historic.
National Interest	A tree with a characteristic(s) so important that it is considered a vital component of a country's stated cultural/conservation goals. These trees can also be recognized and included in heritage tree programs at lower geographic scales such as states/provinces, counties and municipalities.	1) Reference to documents stating a nation's desired cultural and/or conservation goals.
Landmark/Location/ Landscape	A tree that is visually dominant in the landscape and often contributes aesthetically to the local area. This type of tree can also be associated with various historical events that it continues to represent. The removal of such a tree would drastically alter the local area in a negative way.	1) Public consultation or nominations that identify a connection with the local community.
Botanical Value	A tree that has unique or exceptional botanical, horticultural, arboricultural or biological value. These trees are often a valuable source for future propagation efforts based on their genetic components.	1) Access to botanical/biological documents or confirmation by an expert in this field.
Local Significance	A tree that is locally known as a key fixture within the community. The removal of such a tree can negatively impact the community through a change in aesthetics and/or loss of an iconic natural structure.	1) Public consultation or nominations that identify a connection with the local community.
Rarity	A tree that is rare due to its infrequent occurrence.	1) Access to botanical/biological documents or confirmation by an expert in this field. 2) Geographic scale that will be used to define rarity.
Represented in Historical Documents	A tree that is mentioned or visually depicted in historical documents.	1) Access to historical sketches, journals, photos or other relevant documents. 2) A metric to identify what constitutes as historic.
Endangered	A tree that is valued based on its endangered status.	1) Access to conservation documents or reference guides such as the IUCN's Red List of Threatened Species. 2) Geographic scale that will be used to define endangered.
Indigenous Cultural Associations	A tree of importance to indigenous cultures and/or associated with various indigenous events.	1) Consultation with local indigenous groups to obtain information and consent.
Cultural Value	A tree that represents a wide range of cultural aspects and values which benefit a community or specific culture. This can include an association with past and current groups. E.g. a plant that was and remains a part of a specific group's culture. This tree can provide a sense of place for those in the local community, act as a fundamental component of a community's identity, etc.	1) Consultation with the public/community groups or nominations that identify a connection with the local community.

Table 6. (Continued) Consensus Heritage Tree Core Criteria

CRITERIA	DEFINITION	REQUIREMENTS
Social/Community Value	A well-known tree that is prominent in the community and provides a connection for those who interact with it.	1) Public consultation or nominations that identify a connection with the local community.
Historic Person/Memorial Planting	A tree that was planted for, by or in association with a historically significant person. A tree can also receive this distinction if it was planted to commemorate an event, group or institution of importance.	1) Access to historical/cultural documents or confirmation by an expert in this field. 2) A metric to identify what constitutes as historic.
Remnant	A tree that represents the characteristics of a previously significant era (e.g. one that predates colonization), the work of a master artist and/or possesses high artistic values. This includes, but is not limited to, tree lined avenues and areas where historically unique landscaping designs/styles are still visible.	1) Access to documents that show the landscape characteristics of a previous era, verification of a master artist's association or evaluation confirming the presence of artistic values.
Species-Specific Size	Size is used to compare physical metrics (height, diameter and crown spread) only amongst trees of the same species to determine what is large. This helps to contrast the different physical metrics that various species can exhibit to more accurately show what is considered to be large.	1) Baseline size metrics (height, diameter/circumference and crown spread) for each species associated with the program.
Outstanding Example of Species	An exemplary tree that represents a species optimal form/structure.	1) Expert consultation to verify exemplary status. This can be conducted by experts in the fields of: Arboriculture, Horticulture, Silviculture or something similar.
Historical Witness	A tree that has "witnessed" an important historical and/or cultural event. This can occur if a tree is located at the site of a notable event and/or was somehow a part of the acts that transpired.	1) Access to historical documents or confirmation by an expert in this field. 2) A metric to identify what constitutes as historic.

This value conflicts with the findings seen as the *Age (non-specific)* criterion received just 26.7%. This seems to indicate that while the majority of programs currently using *Age* criteria prefer to include age without specific thresholds, the expert panel felt that alternative options such as the *Oldest Specimen of Species in Region* or *Species-Specific Age* criteria could be a better fit, although on a case-by-case basis. The qualitative data shows that age is an important component for a heritage tree program but the inability of the panel to agree upon a single *Age* criterion signifies the difficulty seen when trying to reach consensus on such a metric.

Finally, the inability of the *Aesthetics* criterion to reach consensus was surprising as one of the most common traits associated with trees is their intangible visual appeal (Tyrvainen, Pauleit, Seeland, de Vries, 2005). A lack of a specific agreed upon definition and characteristics being covered by other criteria in the study were the main reasons for this omission. Nevertheless, it is interesting to note that the *Aesthetics* criterion obtained a value of 71.4% in this study while only 41.3% of the examined case studies use this criterion. This seems to infer that this component may be more valued than in the past and could be considered for heritage tree programs on a case-by-case basis if an agreed upon definition is produced.

3.7 Conclusion

Prior to this study there lacked an expert verified, systematic set of criteria that identified heritage tree candidates. Through the use of the Delphi method 16 consensus core criteria were produced that serve as an initial template for current and proposed heritage tree programs. The criteria and best practices produced from this study have the ability to change how heritage tree programs operate which could lead to more successful outcomes. These data

can be used by heritage tree experts from government agencies, nonprofits and private companies to improve or begin a program based on these standardized fundamental components. The dissemination of ideas and information by programs that use this systematically verified set of criteria is now possible which can address common issues and reduce the expenditure of limited resources. This also provides the opportunity for a network of heritage tree programs to form that facilitate the spread of information related to heritage tree best practices and should lead to the increased protection of these valuable specimens.

Three methods should be used to further verify these data going forward. First, this study should be replicated to increase the number of experts surveyed. This would allow additional experts to provide further insight into the criteria derived from this study and potentially identify new components that may not have appeared or been addressed during this research. Second, the 29 situational criteria that had medium and low levels of consensus in this study should be examined for their importance from national to local scales in different geographic regions. This would complement the 16 consensus core criteria that have been identified and allow a unique palette of heritage tree criteria to be produced for locations that have these programs or wish to begin one. Finally, case studies should occur at various geographic scales in several countries to test the application of these data in real life scenarios. In doing so, the validity of the results should increase while also discovering additional areas of improvement that were beyond the scope of this initial study. Through these three research opportunities a more robust and comprehensive framework will be attained that should lead to the increased protection of these highly valued tree specimens.

CHAPTER 4

CONCLUSION

4.1 Summary

This survey was able to utilize the opinions of 15 heritage tree experts through the use of the Delphi method to identify a set of 16 consensus core criteria that should be used in a heritage tree program. These criteria were produced through an analysis of 50 heritage tree criteria derived from the literature, 46 case studies and feedback from the panel throughout the three iteration Delphi study. A comparison of the 16 most frequently used criteria in the examined case studies (Figure 3) and the 16 consensus core criteria from this research show that 9 of these overlap, with the remaining 7 consensus core criteria having been derived from two that were occasionally used in the case studies, three that were only seen in one case study each and two that were introduced during this study (see Table 7). This shows that the expert panel did agree with the importance of some of the criteria currently used by heritage tree programs, but also identified new components that should be used based on shared values at a global scale. Several best practices found in the literature were also supported by the panel, suggesting that these should be used in combination with the aforementioned criteria to improve current and proposed heritage tree programs and allow them the greatest opportunity to protect these valued specimens.

The 16 consensus core criteria derived from this study were more than initially anticipated as the case studies observed had a maximum of 13 criteria with the majority ranging from 8-10.

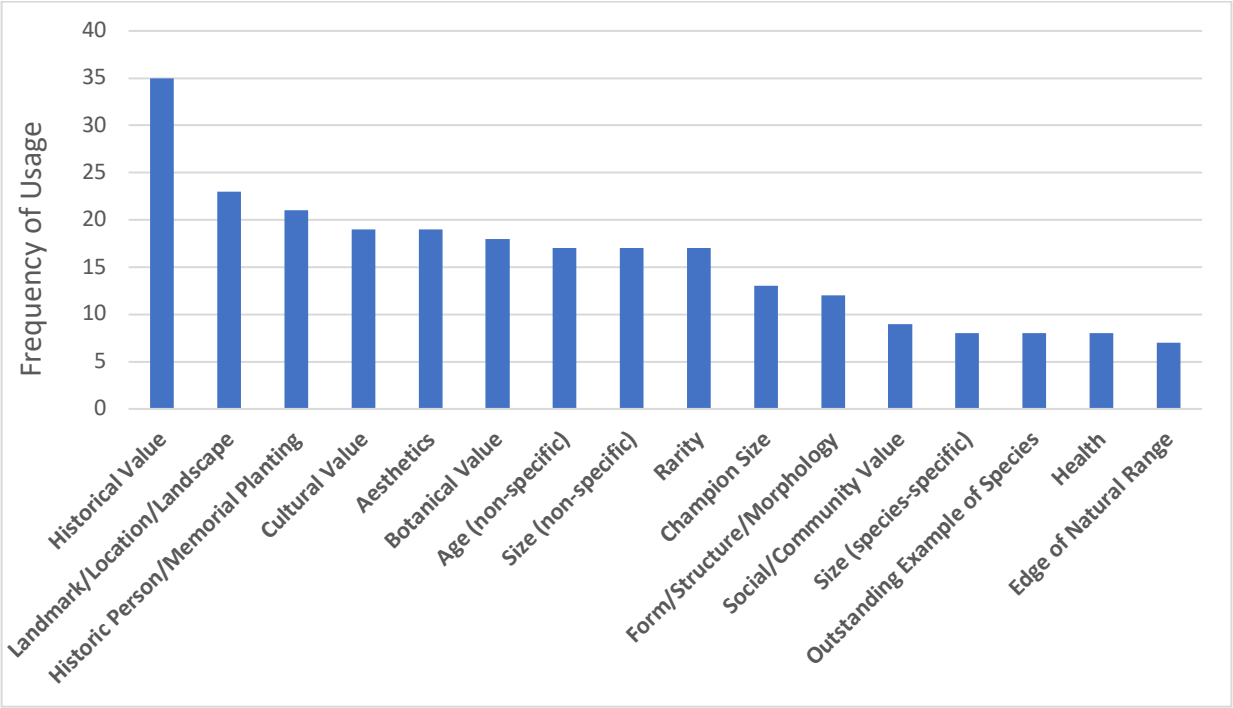

Figure 3. 16 Most Frequently Used Criteria in 46 Heritage Tree Case Studies

Table 7. Comparison of Consensus Core Criteria Percentages of Importance and Frequency of Use in Case Studies

Criterion	% of Importance in Study	% Found in Case Studies
Historical Value*	100	76.1
National Interest	93.34	2.2
Landmark/Location/Landscape*	93.34	50
Botanical Value*	93.34	39.1
Local Significance	93.33	2.2
Remnant	92.86	6.5
Rarity*	86.67	37
Represented in Historical Documents	86.67	2.2
Endangered	86.67	N/A (Introduced in Study)
Cultural Value*	80	41.3
Aboriginal Association	80	10.9
Social/Community Value*	80	19.6
Historic Person/Memorial Planting*	80	45.7
Species Specific Size*	78.57	17.4
Outstanding Example of Species*	78.57	17.4
Historical Witness	78.57	N/A (Introduced in Study)

* Consensus core criteria that were also among the 16 most frequently used criteria in the examined case studies

This value may have been attributed to the consensus threshold being established at ≥75% although if this was raised to ≥80%, there would have still been 13 criteria that reached consensus with a percentage of high importance. This seems to indicate that at the root of heritage tree programs lies a foundation supported by many of the same values and essential characteristics. However, the inability of criteria from the *Age* and *Aesthetics* categories to reach consensus proved to be an interesting discovery as they are aspects commonly associated with trees.

The *Age* and *Aesthetics* categories were expected to produce criteria that reached high consensus prior to the onset of the study. This assumption was based upon the value society seems to place on trees that are old (*Blicharska & Mikusinski, 2014*) and exhibit impressive visual traits (*Tyrvainen et al., 2005*). This was not the case for *Age* criteria based on the data produced from this study which mimics what was seen in the case studies. The *Oldest Specimen of Species in Region* criterion received the highest percentage of importance value for *Age* criteria throughout this study with 57.2%, which is similar to the 60.8% value associated with *Age* criteria in the examined case studies. It is interesting to note that of the 28 case studies that use age as a criterion, 17 of these (60.7%) used a non-specific metric. This contradicts the findings from this study for the *Non-Specific Age* criterion which received a percentage of importance value of 26.7%. The expert panel indicated that specific age metrics such as *Oldest Specimen of Species in Region* or *Species-Specific Age* could be a better fit for heritage tree programs, albeit on a case-by-case basis. Qualitative data from this study indicated that age is an important component of a heritage tree program but an inability to agree upon a single metric can often hinder its use. This shortcoming experienced by the panel, in addition to a

potential lack of accurate age data, may help explain why so many heritage tree programs include age as a criterion without specific thresholds and shows why Lindenmayer & Laurance (2017) challenged the use of age as a criterion due to the issues that arise when trying to acquire such data. *Aesthetics* failed to reach consensus based on the lack of a specific agreed upon definition, in addition to having all potential heritage tree characteristics represented by other criteria in the study. However, the results from the study indicate that many on the panel saw value in this criterion based on the 71.4% importance value attributed to it. This is far higher than the 41.3% seen throughout the case studies and could indicate that support may be increasing for this criterion and the intangible benefits it represents. While *Age* and *Aesthetics* were identified throughout the study as important aspects of a heritage tree program, an inability to adequately define and indicate specific thresholds for these categories and their associated criteria ultimately led to their exclusion from the final list of 16 recommended heritage tree criteria.

The selection of the *Species-Specific Size* criterion as one of the consensus core criteria displayed an example where the panel was able to agree upon a specific threshold to be used in a heritage tree program. This result contradicts what was seen in the case studies where *Non-Specific Size* was the most prominently used (37%) compared to *Species-Specific Size* (17.4%). This could be explained by the baseline data that is required when using the latter criterion. This assumption was supported by some of the experts who stated that the need to develop baseline metrics for each species could prevent certain heritage tree programs from being able to use the *Species-Specific Size* criterion as a result of limited or lacking resources to derive the required data.

These results seem to indicate a preference by the expert panel towards having well defined metrics and definitions that would help reduce the subjectivity currently seen with their use in several heritage tree programs (Figure 4) and allow for greater standardization to be seen. However, as the panel was only able to agree upon a threshold for the Species-Specific Size criterion, programs that choose to use the situational *Aesthetics* and *Age* criteria should ensure that standardized thresholds are set by their heritage tree committee.

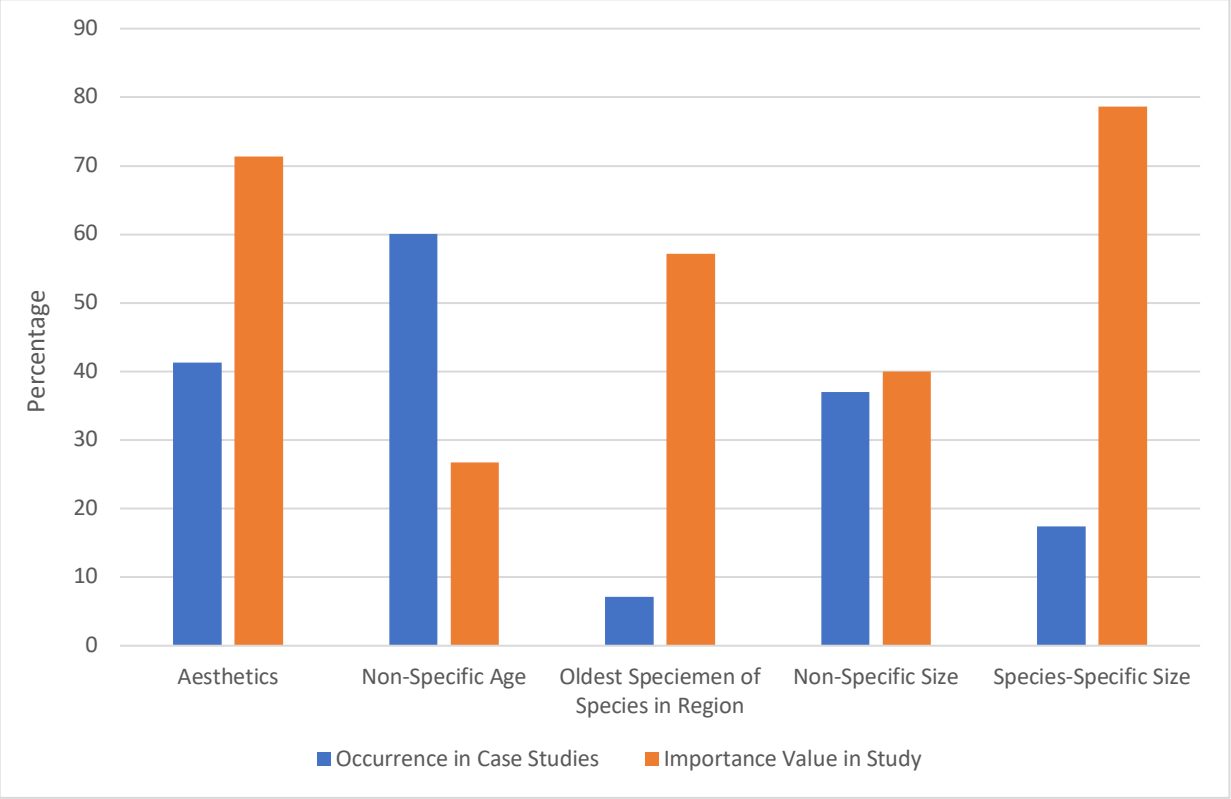

Figure 4. Comparison of Criteria Occurrence in 46 Case Studies and Importance Value in Study

Even though the study produced 16 consensus core criteria that should be used as the foundation for a heritage tree program, it is important to note that the remaining 29 situational criteria that received medium or low consensus can be utilized by a heritage tree program if the selection committee deems that one or more of these provide important context in a program's

specific geographic region. This seemed to be the case with many of these 29 criteria as they appear to only be valued and applied by certain programs.

4.2 Research Implications

The intent of this research was to identify the consensus core criteria that are shared among heritage tree programs around the world to form a standardized foundation that can be used to more accurately identify trees of importance. This was the first known instance that used the Delphi method to obtain the consensus core criteria for heritage trees and showed its ability to successfully attain the goals of this study through the use of multiple iterations and expert feedback. This process led to increased consensus as the survey progressed and saw criteria removed that were not valued or only important to specific programs, leaving only the most important components of a heritage tree program. However, the significant amount of time required to use this method was one aspect that was problematic. While it was known prior to the onset of the study that the Delphi method can be a lengthy process that is often underestimated by a researcher (Keeney et al., 2006), this was still experienced during the study as the duration of the three surveys alone amounted to 236 days. Two reasons for this were due to some experts taking upwards of six weeks to submit their responses, in addition to the *"Criteria Consensus"* documents that were used to verify the results from the first and second rounds. While the latter of these was an essential component of the research to ensure the data were interpreted correctly, it increased the duration of the study equivalent to nearly two additional survey rounds which expanded the total time the survey took to complete.

Nevertheless, the findings from this research now provide a systematic framework for current and proposed heritage tree programs that would like to use this set of 16 expert verified consensus core criteria to improve their programs at a time when these are rapidly being created to protect the world's most important tree specimens. The expert panel was also able to confirm the findings from the literature showing the importance of legal protections and public support, while also identifying funding opportunities that can allow these heritage tree programs the greatest chance to succeed. There has been stated interest from members of the panel and heritage tree program managers who are planning on implementing these findings in their own initiatives to see if the overall effectiveness of their programs will increase. This shows that this research can have immediate benefits that could lead to the beginning of a global network of heritage tree programs that would allow these initiatives to assist one another. Through continued interactions with these experts this could become a reality and help them attain their goals of protecting trees of importance.

4.3 Management Implementation

A heritage tree program must meet five requirements to successfully implement the derived consensus core criteria. The first involves the need to define thresholds for criteria that were unable to establish these throughout the research study. This primarily applies to criteria in the *Historical Value* category along with the *Rarity* and *Endangered* criteria in order to define what constitutes as historical and the geographic scale at which rarity and endangered will be evaluated. The 46 case studies also lacked a definitive threshold for historical criteria which is in agreeance with the response from the expert panel that a threshold for this category should be decided upon by each respective heritage tree program. *Rarity* and *Endangered* were used

three different ways throughout these same case studies as seen by: a) including local and global species under the same category (Zapponi et al., 2017); b) providing two separate distinctions for local and global scales (Forests Ontario, 2017c); or c) a lack of a specified geographic scale (Seattle Department of Transportation, 2018), indicating that a heritage tree program should choose the option that is most applicable to them. Second, there needs to be access to documents that can verify a tree's relationship with a given criteria. This is especially important for historical criteria that rely predominately on such documents to award heritage status. Third, expert consultation can be used when documents are unavailable, as supplementary information or if expert opinion is required as is the case with the *Outstanding Example of Species* criterion. Fourth, public consultation is required for many of the criteria from the *Cultural Value* category. These criteria rely upon the importance an individual, community and/or group places on a given tree so there is a necessity to gather information from these sources to determine heritage status. Finally, baseline metrics for height, diameter-/circumference and crown spread need to be gathered to use the *Species-Specific Size* criterion. An inability to produce species-specific thresholds for these three metrics will make it difficult to evaluate a tree using this criterion. While the expert panel did acknowledge that creating size thresholds can be problematic for programs with limited resources, this can potentially be overcome by obtaining information from similar heritage tree programs that have produced these data for the same species. Through the use of the aforementioned requirements, a heritage tree program will be able to reduce the subjectivity seen during the nomination process and ensure that only the most qualified candidates are awarded heritage status.

The need for pre-requisite criteria when designating heritage status was another common relationship seen between the literature and expert responses. *Health*, *Non-Hazard/Obstruction* and *Ability for Maximum Potential Growth* were all recommended by the panel as aspects that should be used to exclude trees that do not meet these requirements. However, they act as supplementary information that should be used on a case-by-case basis rather than as standalone criteria as is seen with *Health*, *Non-Hazard/Obstruction* and *Ability for Maximum Potential Growth* in Portland, Oregon (City of Portland Parks and Recreation, 2016), Spokane, Washington (City of Spokane Urban Forestry Department, 2018) and Coronado, California (City of Coronado, n.d.) respectively.

The study also identified best practices associated with legal protections, public support and funding that should be used to increase the effectiveness of a heritage tree program. The unanimous response from the expert panel indicated that legal protections for heritage trees should be included as a fundamental component of heritage tree programs. These legal policies would help facilitate better management and protection measures for heritage trees, while also helping to ensure that increasing pressure from development (especially in urban areas) will not lead to the removal of these trees due to the safety nets these policies can provide (Jim, 2017). While it was noted that the creation of legal protections can often be difficult, one way to help with this process could be to model after locations with legal protections already in place and use these as templates based on the precedence they have set. Examples have been found in Europe (Dreslerova, 2017; Zapponi et al., 2017), Australia (Melbourne, 2012), North America (Forests Ontario, 2017a; University of Hawaii, 2018) and Asia (Jim 2004a) and should be used to assist heritage tree programs that desire to implement this essential component.

Public education is a key aspect of a heritage tree program that has the ability to place these trees in the public eye and lead to an upturn in support which could ultimately facilitate increased legal protections, funding etc. Through the use of technology as a means to convey information to the public in an easily accessible and understandable way, outreach can take place to let the public know why these trees are important and how their respective programs function. Interactive maps, websites and social media are different mediums that can be used to accomplish this, although this information must be presented in a clear and concise manner as an abundance of criteria can create confusion and potentially lose support as a result. Furthermore, it is important that transparency occurs when presenting aspects of a heritage tree program to the public. What criteria determines heritage tree status, how these trees are selected for this designation, why they are important and what the qualifications of the heritage tree committee are, act as essential facets that should be used to gain public support.

Funding has been identified as a limitation for many heritage tree programs that can hinder the effectiveness of these programs due to a lack of allocated resources. Heritage trees can often be viewed as problematic when inadequate resources are provided to support their maintenance and can lead to their neglect and eventual removal. Through increased public support a greater amount of funds can be appropriated to offset the costs of maintaining these trees, while also having the potential to place a greater emphasis on the benefits that heritage trees provide. There are three potential funding sources for heritage tree programs that should be explored as suggested by the expert panel. The first is from the government (local, state and/or federal) that should incorporate funding for heritage trees in their annual budgets as many of these trees are on public land. Environmental and/or tourism taxes could generate

funds through this mechanism that can then be used support the maintenance of these trees and the programs that manage them. The private sector can be a second source of funds that would be supplementary to the aforementioned government support, specifically those in the tree industry (i.e. landscaping, nurseries, etc.). Additional financial support could also be generated from companies not associated with the tree industry, although this would most likely occur through a partnership where these benefactors receive public recognition for their support (i.e. a "sponsor a tree program"). Third, nonprofit organizations have the capability to play two important roles, first as a generator of funds through grants and second, as the managers of heritage tree programs. This unique position to be able to generate funds and implement heritage tree programs themselves allows nonprofits to bring government agencies and private corporations to the discussion table which could lead to the formation of a rigorous heritage tree program that is properly managed.

4.4 Opportunities for Future Research

This research study has identified several opportunities for future research on heritage trees. Establishing thresholds for the consensus core criteria that were unable to be agreed upon by the panel should be one facet that is focused on to reduce the subjectivity that can arise when using these criteria. While this may not be possible for all of the criteria, the examined case studies have shown that multiple options exist for some of these (i.e. Rarity and Endangered) and a threshold to determine what constitutes as historical would be extremely helpful to further standardize the heritage tree nomination process. Additional research should also examine which of the 29

situational criteria that had medium and low consensus are valued by heritage tree programs at smaller geographic scales. This could build off of the global values produced from this study and begin at a national level that works towards a local scale. This would allow an additional set of criteria to be recommended for each of these programs based on the stated values and goals for their geographic area. Using a Delphi method similar to the one in this study would be one way to accomplish this. Future surveys should also assess the number of heritage tree programs that would utilize the 16 consensus core criteria from this study. This would ideally incorporate a large number of programs from around the world at all geographic scales. This would help to further verify if the criteria derived from this study are applicable to a majority of these programs, in addition to the identification of new components that may have overlooked.

The best practices identified in the literature and this study should be further refined to be able to complement the aforementioned 16 consensus core criteria. By analyzing how to best initiate and utilize legal protections, public support, funding and criteria pre-requisites such as health and non-hazard status, this can act as supplementary information to help produce a more comprehensive framework for a heritage tree program. Next, this study should be replicated several times to accumulate more insight from additional heritage tree experts on the criteria and best practices presented in this study. This would allow for increased validity in the presented results, while also allowing additional content to be produced that could further enhance heritage tree

programs. Finally, the findings from this study should be used in established and/or proposed heritage tree programs to assess their practicality and effectiveness in various case studies around the world. If successful, this would justify the creation of an international heritage tree program that would act as a resource to aid programs that have adopted the recommendations from this study and lead to the creation of a network of standardized heritage tree programs that many experts in this field have desired.

4.5 Conclusion

This study was able to derive the 16 core heritage tree criteria that should be used when implementing a program of this nature. These results are significant as they not only provide an initial framework for a heritage tree program, but also seem to indicate that these programs value many of the same characteristics to identify trees of significance. This is the first known instance that has utilized the Delphi method to determine the fundamental criteria for a heritage tree program through the use of expert opinion. These findings should have immediate benefits as heritage tree program managers begin to enhance current and proposed programs based on the recommendations produced by the expert panel. Going forward these initial findings should be expanded upon through additional research to create a more comprehensive framework for heritage tree programs. This could be achieved through an analysis of the 29 situational criteria identified in this study from a national to local scale to produce a set of region-specific heritage tree criteria. The implementation of the derived consensus core criteria and associated best practices in case studies around the world should

also occur to identify strengths and weaknesses associated these components, in addition to their practical application. The consensus core criteria produced from this research can now serve as an important catalyst to assist heritage tree programs and ensure that only the most important tree specimens receive heritage status. Through this standardized evaluation system, the current patchwork of heritage tree programs now has the potential to become a unified network as experts disseminate these findings among their initiatives, which should lead to the increased awareness and protection of these trees and the many benefits that they provide.

APPENDICES

Appendix 1: Heritage Tree Criteria Supplementary Information*

Case Study	Supplementary Information
8 & 20	Different minimum thresholds exist for specific species. Non-native trees = 24-inch DBH Southern California native trees = 8-inch DBH
13	Criteria exist for the largest individual of a species as well as non-specific size
22	Two size criteria are mentioned. A minimum DBH (must be at least 8-inches) as well as the ability for a tree to be "unique or special in size"
26	There are four separate terms used, each with their own criteria, albeit from the same source. They will be identified as the following: - 26a = Historical Monument Tree - 26b = Folkloric Monument Tree - 26c = Mystical Monument Tree - 26d = Dimensional Monument Tree
28	Size criteria features both program specific minimums (DBH = ≥ 1m, height = ≥ 25m and crown spread = ≥ 25m), in addition to species-specific components
29	Each criterion is awarded per species (e.g. you can have up to six trees per species listed as a Champion Tree) (tallest, oldest, most spreading, heaviest, most beautiful, rarest)
30	Program incorporates two types of size criteria. "Champion" size (largest of species) and significant size (very large but not the largest of the species)
33	There are two separate terms used, each with their own criteria, albeit from the same source. They will be identified as the following: - 33a = Champion Tree - 33b = Heritage Tree
45	There are four separate terms used, each with their own criteria, albeit from the same source. They will be identified as the following: o 45a = Ancient Tree o 45b = Veteran Tree o 45c = Champion Tree o 45d = Heritage Tree

* Only the primary criteria for each program were included. However, if a secondary criteria was seen in one program that matched the primary criteria for another [i.e. Historic Person/Memorial Planting as was seen in Nebraska (primary) and Hong Kong (secondary)] then it was included as criteria for both programs.

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