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Research Article

Establishing consensus criteria for determining heritage tree status

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ABSTRACT

Heritage trees are identified and valued based on important historical, cultural and physical criteria that these specimens possess. This research attempts to support heritage tree programmes by identifying a standardised set of expert-verified criteria that can be applied 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 programme. A three iteration Delphi method was used to evaluate the criteria and allowed additional content to be generated by the panel. The result saw 50 criteria analysed to produce a set of 16 consensus core criteria and an additional 29 situational criteria that can apply on a case-by-case basis. This study identified the existence of 16 common values shared among these tree programmes and serves as an initial template for use by current and proposed heritage tree programmes to select ideal candidates. Through this standardised evaluation system, the current patchwork of heritage tree programmes now has the potential to become a unified network leading to the increased awareness and protection of these trees.

KEYWORDS

Heritage trees; significant trees; exceptional trees; monumental trees; tree conservation; Delphi research method

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 1189 (Dreslerova, 2017). Since that time, trees around the world have been valued for a variety of attributes (e.g. historical, cultural, environmental) and programmes have been established to acknowledge and protect unique examples. While the goal of all these programmes is to conserve important trees, there has been a lack of consensus on the key characteristics or attributes that should be used to designate these specimens. Standardised evaluation methods have been proposed in the past (see Flook, 1996; Barrell Tree Consultancy, 2013) but this research is distinct in that it represents the first global, systematic, peer-reviewed investigation of heritage tree selection criteria to guide existing or proposed conservation programmes.

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

Heritage tree literature

Creating a universally agreed 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 objective is surprisingly complex. A global review of 46 programmes identified terms such as: "heritage trees," "champion trees," "significant trees," "exceptional trees," "monumental trees," "ancient trees," "memorial trees" and "veteran trees" (Ritchie, 2019, p. 17). These terms utilise many of the same essential components and values, but apply the terminology based on practices in the region where these programmes are situated. While individual programmes in each region choose terminology that is deemed best for their purposes, the term "heritage tree" occurs most frequently (22 times) in observed case studies (Ritchie, 2019) and has been formally defined by experts in the field (Jim, 2017, p. 279). "Heritage tree" will, therefore, be used exclusively to describe these specimens from this point forward.

Criteria

Ritchie (2019) also identified 40 unique criteria which were classified into 11 categories that represent core components of these programmes (Table 1). This plethora of criteria becomes even more convoluted when analysing size and age sub-criteria. Both size and age have four sub-criteria that have been used in at least one heritage tree programme, and while each case is 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 as this category can be a component of an individual heritage tree programme (Minneapolis Park and Recreation Board, 2018), or an individually recognised specimen in champion tree programmes (American Forests, 2018). In both cases, these trees are valued for physical metrics such as height, diameter/circumference or crown spread. A "Champion" title is awarded to: 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 used in programmes that apply the latter method, specifically when identifying the oldest specimens of each species (Rodger, Stokes, & Ogilvie, 2003).

While certain programmes choose to focus on aspects such as size (Nebraska Forest Service, 2018), others place the greatest emphasis on historical and cultural aspects (Forests Ontario, 2017). The priorities placed on the two aforementioned criteria address an important aspect of heritage tree programmes that celebrates the past through these living monuments, even as the surrounding landscapes change (see Lindenmayer & Laurance, 2017, p. 1442–1443). However, many of these trees are under increasing threat as the natural environment is altered due to construction (Jim, 2004a, 2004b). Between 1986 and 1995, mortality rates among the 209 original heritage trees in Guangzhou, China were 21.5% (Jim, 2004a). These rates increased to 29% over the period 1985 to 2007 (Chen, 2015). This phenomenon was also seen in Hong Kong between 1993 and 2005 when 14% of their heritage trees were lost (Jim, 2004b).

The development of individual frameworks by heritage tree programmes to address the loss of valued tree specimens has resulted in the diverse set of criteria used to identify these trees around the world (Ritchie, 2019). However, evaluation methods exist

Table 1. Criteria Used in 46 Heritage Tree Case Studies

CRITERIA BY CATEGORY	CASE STUDY*	DEFINITION
AGE		
Non-Specific Age	8, 9, 10, 12, 14, 15, 16, 17, 21, 24, 32, 34, 37, 38, 39, 42, 46	No specific age threshold is used.
Programme-Specific Age	1, 5, 22, 28, 44	A single age threshold is assigned to all trees.
Oldest Specimen of Species in Region	13, 41	The oldest specimen of a species.
Species-Specific Age	6, 20, 26d†, 45a†	Age thresholds are assigned for each species in the programme.
HISTORICAL VALUE		
Historical Value	1, 4, 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, 4, 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		
Non-Specific Size	10, 12, 13, 14, 15, 16, 17, 21, 22, 24, 25, 30, 32, 34, 37, 39, 42	No specified size threshold is used.
Programme-Specific, Non-Champion Size	1, 8, 20, 22, 27, 28, 31	A single size threshold is assigned to all trees.
Species-Specific Size	6, 18, 20, 23, 26d†, 28, 35‡, 46	Size thresholds are assigned for each species in the programme.
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.
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.

(*Continued*)

Table 1. (Continued).

CRITERIA BY CATEGORY	CASE STUDY*	DEFINITION
LANDMARK/LOCATION/LANDSCAPE		
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/Localized Distribution	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/MORPHOLOGY		
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 accessible that allows for interaction with the community.
Publicly Visible 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.
OTHER QUALITY		
Other Unique Quality	1, 6, 9, 25, 43	Unique qualities or traits not recognized by the aforementioned criteria.

Notes

*Case studies are referenced in Appendix 1

†Separate terms used within the same program, each with their own criteria

‡Primary/mandatory criteria (if secondary criteria are listed for programme)

that aspire to provide a standardised format at national and international scales. *The Standard Tree Evaluation Method* (STEM) produced by Flook (1996) is a comprehensive framework that has been utilised extensively in New Zealand, having been adopted by over 40 Councils to classify their heritage and "notable trees" (New Zealand Notable Trees Trust, n.d.). *TreeAH* is an example of a heritage tree evaluation methodology that was initially produced for use in the U.K. but has expanded to examine trees internationally due to the lack of any formalised heritage tree framework, especially at the local level (Barrell Tree Consultancy, 2013). However, while both of these evaluation methods were produced through consultations with experts, there lacks a systematic, peer-reviewed assessment to determine what heritage tree selection criteria should be used to guide current and proposed programmes regardless of geographic location.

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

Materials and methods

The most common terms and criteria used to classify heritage trees have been identified through an analysis of heritage tree literature and the examination of 46 case studies from around the world (Ritchie, 2019, p. 17). These criteria were presented to a panel of international experts using the Delphi method (Dalkey & Helmer, 1963) in an attempt to empirically identify consensus core criteria which can be used to protect individual specimens and support the work of existing or proposed heritage tree programmes. This will allow heritage tree programmes 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 heritage tree programmes to thrive.

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). Three iterations are used in most Delphi studies (Jones, Sanderson, & Black, 1992), although the process can be completed in as few as one or two rounds (Skulmoski, Hartman, & Krahn, 2007). While there are no "minimum or maximum" 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 are generally used to form the panel (Keeney, Hasson, & McKenna, 2006) as expert opinion is being sought rather than any survey of the general population.

A three iteration Delphi survey modified from the recommendation of Skulmoski et al. (2007) was used in this study (Figure 1). Forty heritage tree criteria from the 46 examined case studies by Ritchie (2019) provided a framework for the initial survey that consisted of 40 closed-ended and 40 open-ended questions. Closed-ended questions were used to evaluate the presented criteria using a 5-point Likert scale. Open-ended questions presented at the end of each section and at the conclusion of the survey also provided experts with the opportunity to convey additional comments, suggest new content, modify existing questions, and justify retaining criteria that scored very low in terms of importance. This input also allowed individuals to provide more detailed reasoning to

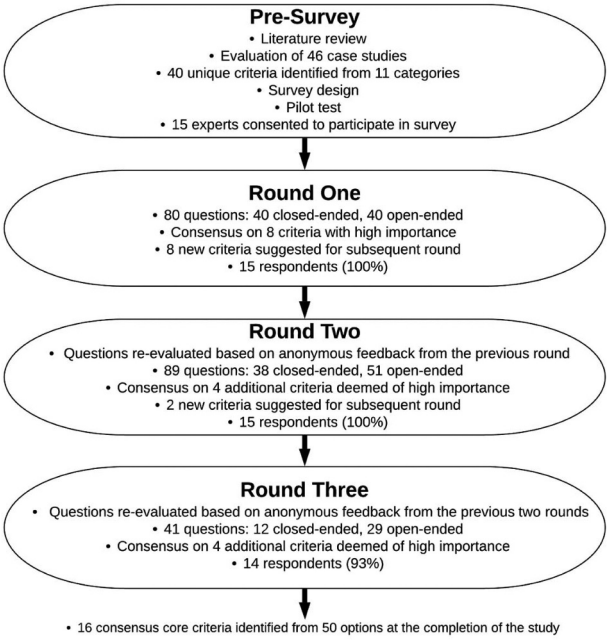

Figure 1. Research design (adapted from Birko, Dove, & Ozdemir, 2015).

the full panel to explain why certain criteria should be selected or omitted (McLeod, 2012). Any criteria that reached consensus were omitted from future survey iterations (Stewart et al., 2017) leaving only the criteria that failed to reach the consensus threshold. The pilot survey was tested by six individuals not related to the project to assess survey content, structure and navigation.

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 when <25% of the expert panel considered a criterion significantly or critically important. Criteria in between these two results with values of 25% to 50% and 50% to 75% had low and medium levels of consensus respectively. With no set value for consensus in the literature (Keeney et al., 2006) these values were chosen to obtain a high degree of certainty that the selected criteria were of importance to the substantial majority of the panel.

The first iteration of the survey was sent to the panel using the survey software Qualtrics. After receiving input from all experts, a summary of results along with feedback was subsequently provided to the panel. A criteria consensus document was also emailed to the panel between survey iterations listing criteria that reached consensus and were scheduled to be removed. 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, it was re-introduced to the subsequent round for further discussion. The second round was created from these results and featured all criteria that had not achieved consensus, in addition to new content suggested by the panel. The process outlined for round one was repeated to analyse the data produced in the second iteration of the survey. In the third and final

survey iteration, any criterion with <70% consensus that showed no movement towards reaching a higher level of agreement in previous rounds was removed.

Results

The first round of the survey saw a response rate of 100% with an average submission time of approximately 14 days. This round resulted in 9 high, 16 medium, 13 low and 2 very low consensus values for the criteria assessed (Table 2). Eleven criteria reached the consensus thresholds, nine with high consensus values, and two with very low consensus values. It should be noted that only 10 criteria were removed after the first round. Expert recommendation suggested that *Rarity* be divided into two distinct criteria (*Rarity* and *Endangered*) even though it had reached consensus in the first round. The result saw the reintroduction of the *Rarity* criterion with a new definition and the introduction of the *Endangered* criterion in the second round for evaluation based on this change.

The second round also had a response rate of 100% with an average submission time of 12 days. The 38 criteria presented in this round resulted in 4 high, 14 medium, 17 low and 3 very low consensus values. Seven additional criteria reached consensus in the second round, with four achieving high consensus values and three receiving very low consensus values. 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 criteria (*Aesthetics, Ecological/Habitat Value, Species-Specific Age, Legends/Mythical/Folklore Value* and *Oldest Specimen of Species in Region)* which were retained in the third round. The third round of the survey obtained a 93% response rate with an average submission time of 10 days. The 12 criteria presented in this round resulted in 4 high, 7 medium, 1 low and 0 very low consensus values.

The expert panel created for this study reached consensus on 21 criteria for heritage tree programmes. Sixteen achieved high consensus and should be considered by all heritage tree programmes, while the remaining five had very low consensus values which implies limited utility. The remaining criteria were divided into 11 medium consensus and 18 low consensus values which may be useful in specific circumstances or individual geographic locations. While we emphasise that the 16 criteria achieving high consensus values with respect to importance should be considered by all heritage tree programmes, the final mix of criteria selected (including those with medium and low values) is ultimately up to individual heritage tree committees. The key findings of the study are provided below and are divided into their core components, including comments provided by the expert panel that highlights their reasoning for these decisions. Additional results for all 11 categories in the study can be found elsewhere (see Ritchie, 2019, p. 42–50).

Age

The expert panel recognised the importance of the age criteria but was unable to assign values based on two concerns. First, it is difficult to obtain accurate age values for a tree as this requires time and resources to complete. Heritage tree programmes often possess limited resources and this may prevent this type of information being obtained. Second, the geographic location of a heritage tree programme influences the values/

Table 2. Summary of heritage tree criteria assessment through three survey iterations*.

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

(*Continued*)

Table 2. (Continued).

Category	Criterion	R1% of Importance	R2% of Importance	R3% of Importance	Final % of Importance
Form/Structure/Morphology	Ability for Maximum Potential Growth	53.3	40.0	N/A	**40.0**
Size	Non-specific Size	46.7	40.0	N/A	**40.0**
Botanical Value	Endemic	46.7	40.0	N/A	**40.0**
Form/Structure/Morphology	Form/Structure/Morphology	46.7	40.0	N/A	**40.0**
Size	Growth Conditions	Introduced R2	33.3	N/A	**33.3**
Accessibility	Publicly Accessible	33.3	26.7	N/A	**26.7**
Age	Non-Specific Age	33.3	26.7	N/A	**26.7**
Form/Structure/Morphology	Unusual/Curious Growth Form	33.3	26.7	N/A	**26.7**
Other Unique Qualities	Other Unique Qualities	33.3	20.0	N/A	**20.0**
Accessibility	Publicly Visible Locations	40.0	13.3	N/A	**13.3**
Size	Programme Specific/Non-Champion Size	13.3	N/A	N/A	**13.3**
Form/Structure/Morphology	Health	53.3	13.3	N/A	**13.3**
Age	Programme-Specific Age	13.3	N/A	N/A	**13.3**

*R1-R3 identify the survey round being examined

† High importance in round one but reintroduced for re-evaluation in round two based on modifications from expert panel

‡ New criterion produced by subdividing/reorganising an original criterion from Table 1

thresholds used to indicate age. The general opinion of the expert panel is that *Age* should be used by heritage tree programmes, but the specific parameters of its use should be determined on a case-by-case basis to accurately reflect the values and conditions of the geographic region. Programmes with access to age data may wish to assign specific thresholds for each species, while those lacking age data could potentially award heritage status if the specimen is significantly mature and worth preserving.

Historical value

Concerns over the definition of "historical" were raised throughout the study. Some experts suggested that minimum age thresholds be used, while others felt that each heritage tree nominee should be considered on a case-by-case basis. The latter position was expressed by an expert who felt more emphasis should be placed on trees associated with older historical events, although there was no agreement on this issue at the conclusion of the study. Again, the panel decided that specific metrics used to define "historical" should be left up to individual heritage tree programmes. Obtaining accurate historical records that connect a tree to a specific historical event was another issue raised during the study. This problem appears to be more prevalent in smaller programmes, or those with limited resources that are unable to devote time and resources towards researching documents. One expert suggested that this could be overcome if a reasonable amount of historical evidence was provided allowing trees to receive heritage status with minimal verified data.

Cultural value

Two issues associated with cultural value were raised that divided the panel. First, while *Local Significance* and *National Interest* criteria achieved high consensus values in the first round, a number of experts felt that these two criteria represent supplementary information, rather than stand-alone heritage tree criteria. Discussions during the second and third rounds of the study focused on trying to determine if these two criteria should remain in the core consensus category as decided in round one or be removed. Analysis of the open-ended questions showed a near equal divide amongst the panel on this topic. Half of the experts felt that these two criteria were unique and contributed important information to a heritage tree programme, while the other half argued that it was more appropriate for geographic scale (local, state/provincial, regional, national, international) 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 should also be stated (e.g. *Historical Value – National*). No consensus emerged on this issue at the conclusion of the study, and these two components remained as core heritage tree criteria for the purposes of this research. The expert panel once again recommended that individual heritage tree committees consider which approach to adopt for the *Local Significance* and *National Interest* criteria.

Second, the expert panel discussed the title and definition of the *Aboriginal Association* criterion which obtained a high level of consensus in the first round. A majority of the panel felt that a more accurate term would be *Indigenous Cultural*

Association and this terminology was incorporated into the final list of core criteria. It is important to note that some experts also strongly recommended that heritage tree programmes that use this criterion communicate with local indigenous groups to receive their feedback on terminology which can vary depending on geographic location.

Size

The *Size* criterion generated a great deal of discussion among the expert panel throughout the survey, but no general agreement was reached regarding how this metric should be applied. Accordingly, only one *Size* criterion reached high consensus at the conclusion of the survey. Some experts felt that *Size* could potentially overshadow all other criteria since this is typically the most recognisable characteristic of heritage trees for the general public. It is important to note, however, that all 16 of the consensus core criteria are equally important and conveying this to the public in an effective manner is an essential task for agencies and organisations that manage heritage tree programmes. Specific thresholds and calculations used for *Size* criterion were issues that the panel also had difficulty agreeing upon. The experts regularly raised concerns about the difficulties heritage tree programmes face in determining a specific size threshold for each species. This issue primarily extends to small and/or underfunded programmes that wish to include a *Size* criterion and is similar to the issues discussed above in the *Age* criteria section. This issue could be alleviated by increased communication and information sharing between heritage tree programmes.

Aesthetics

The *Aesthetics* criterion did not reach consensus during this study, although its position in the medium/high consensus category suggests that a number of experts support its potential value. Many experts stated that this criterion could provide an opportunity for intangible features to be incorporated into a heritage tree programme, while others felt that this criterion was too subjective and could potentially be misused by heritage tree committees. Furthermore, experts on the panel felt that the alternative 49 criteria presented in the study adequately covered all aspects of aesthetics that may arise while determining heritage tree status.

Form/structure/morphology

While *Non-Hazard/Obstruction, Ability for Maximum Potential Growth* and *Health* did not reach high consensus, these criteria do provide important insights into the heritage tree nomination process. Survey comments suggested that these criteria should be used on a case-by-case basis as supplementary information to exclude trees that may otherwise receive heritage tree status. Threats posed by trees to public safety and infrastructure can be problematic, and by using these evaluation criteria, the likelihood of difficulties associated with these issues can be reduced. Every mitigation effort should be adopted to reduce or eliminate these risks, and trees should only be excluded from a heritage

tree programme in cases where mitigation is not possible (even if it meets one or more of the 16 recommended criteria).

Discussion

The intent of this research was to identify consensus core criteria for heritage tree designation. These criteria represent a standardised foundation that can be used by heritage tree programmes around the world. Many programmes are forced to develop criteria on their own with little or no guidance which often results in sub-optimal practice or the repetition of common mistakes. This research presents a set of 16 expert verified criteria (Table 3) developed from an initial set of 40 criteria derived from a global literature review (Ritchie, 2019), and 10 additional criteria produced from expert discussions that took place throughout the study (Table 4). There are, however, five requirements associated with this framework that must be in place for the criteria to be used successfully.

The first involves the need to define case-specific thresholds for the *Historical Value, Historic Person/Memorial Planting, Historical Witness, Represented in Historical Documents, Remnant, Rarity* and *Endangered* criteria since the expert panel was unable to agree upon global values by the end of the study. For criteria that focus on historical components, it is important for a heritage tree programme 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 predominantly 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. It is difficult to evaluate a tree using this criterion without assigned thresholds for each species in a programme. While creating size thresholds can be problematic for programmes with limited resources, this can potentially be overcome by obtaining information from similar heritage tree programmes that have produced these data for the same species. Fulfiling these requirements will allow heritage tree programmes to reduce subjectivity in the nomination process and ensure that only the most qualified candidates receive heritage status.

This was the first known application of the Delphi method to obtain consensus core criteria for heritage trees, and the findings revealed three aspects that were unanticipated at the beginning of the research. The first relates to the 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 only eight to ten (Ritchie, 2019). Agreement on 16 core criteria could be the result of the consensus threshold being set at ≥75%, although 13 criteria would have reached consensus even if the threshold had been raised to ≥80%. This finding seems

Table 3. 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 recognised and included in heritage tree programmes 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, arboriculture 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.

(*Continued*)

Table 3. (Continued).

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 colonisation), 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 programme.
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.

*Originally titled *Aboriginal Association*. Modified to reflect expert consensus at the conclusion of the study.

Table 4. Ten heritage tree criteria produced throughout the study.

CRITERIA	DEFINITION
Endangered	A tree that is valued based on its endangered status.
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.
Relic Specimen	A tree that is a relic of a former ecosystem. For example, a species of tree that may have once been common in an area but now only a few individuals remain.
Champion Size-Cumulative Points	A tree that has the greatest point total for its species in a programme's geographic region based on girth (diameter/circumference), height and crown spread.
Biological Heritage	A tree that is the progeny of a known heritage tree or other tree of value. An example of this can be seen with the descendents of the "Lone Pine" in Australia.
Productive Trees	A tree that was planted and/or preserved due to its use as a culturally important resource (food source, medicinal purposes, useful materials, etc.)
Unique Location/Context	A tree found at an unusual location. An example of this would be a tree that is growing on a grave site.
Seed Source/Propagation Stock	A tree that is an important source of seed or propagation stock.
Resistant to Disease	A tree that is valued due to its ability to resist disease and/or exposure to climatic conditions over time.
Growth Conditions	A tree that has achieved sizeable growth for its species in poor conditions. These conditions could be the result of climate or soil factors

to indicate that common values exist amongst heritage tree programmes, regardless of geographic location or scale, and that a standardised heritage tree assessment framework 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). The *Age* criterion was, however, applied in only 60.8% of the examined case studies (Ritchie, 2019), which is similar to the 57.3% consensus value achieved by the *Oldest Specimen of Species in Region* criterion in this research. It is also interesting to note that 17 of the 28 case studies (60.7%) used a non-specific threshold metric for the *Age* criterion (Ritchie, 2019). This contradicts the findings of this research where the *Age (non-specific)* criterion received just 26.7%. This suggests that a majority of programmes currently using an *Age* criterion prefer non-specific thresholds, but 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 depending on site specific circumstances. Age is an important component for a heritage tree programme, but the inability of the panel to agree upon a single *Age* criterion highlights the difficulty of trying to reach consensus on this 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). The lack of a specific agreed upon definition, and the overlap between aesthetics and other criteria included in the study were the main reasons why this criterion was not included in the final core criteria list. 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 applied this criterion (Ritchie, 2019). This may suggest that this component may be more valued now than in the past and could be considered for inclusion into heritage tree programmes on a case-by-case basis assuming that a definition can be agreed upon.

Conclusions

This research represents the first global, systematic, peer-reviewed investigation of heritage tree selection criteria to guide existing or proposed conservation programmes. Using the Delphi method, 16 core criteria were identified. These metrics can serve as an initial template for current and proposed heritage tree programmes. The criteria produced from this study have the ability to improve the performance of heritage tree programmes which could lead to more successful outcomes. These data can also be used by heritage tree experts from government agencies, non-profit organisations and private companies to improve or establish programmes based on these standardised core components. The dissemination of ideas and information by programmes that apply these criteria can address common issues and reduce the expenditure of limited resources. Communication on shared standards also provides an opportunity to develop a network of heritage tree programmes that facilitate the spread of information related to heritage tree best practices and lead to the increased protection of these valuable specimens.

Three issues need to be addressed going forward. First, this study should be replicated to increase the number of experts surveyed and to provide further insight into the criteria derived from this study. Replication of the study may also identify new components that may not have been identified or addressed in this research. Second, the 29 situational criteria that possessed medium and low levels of consensus in this study should be examined for their importance in various geographic regions and at different scales (e.g. national to local scales). 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 new and existing programmes. Finally, case studies should occur at various geographic scales in different countries to test the application of these data. This would address the validity of the core criteria identified in this study and could provide opportunities for improvement that were beyond the scope of this initial study. Ongoing research such as this would provide for a more robust and comprehensive framework and lead to the increased protection of highly valued tree specimens.

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Geolocation information

This research examines the criteria that should be used to identify trees of importance (Heritage, Significant, Exceptional, Monumental, Champion, etc., trees) at any geographic scale. Therefore, the geolocation for this article is a global perspective.

Disclosure statement

No potential conflict of interest to report by the authors.

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Appendix 1. References for Table 1

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