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Facultad de Ciencias Forestales

Magíster en Áreas Silvestres y Conservación de la Naturaleza

CHARACTERIZATION OF PATRIMONIAL *NOTHOFAGUS OBLIQUA* TREES IN THE CITY OF TEMUCO

Proyecto de grado presentado como parte de los requisitos para optar al grado de Magíster en Áreas Silvestres y Conservación de la Naturaleza.

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Proyecto de grado presentado como parte de los requisitos para optar al grado de Magíster en Áreas Silvestres y Conservación de la Naturaleza

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ABSTRACT

Existing tree conservation strategies in Chile are sometimes not enough to protect trees considered special. To counter this problem, the city of Temuco recently passed an ordinance that will protect certain individual trees by declaring them patrimonial, which includes extra protections like fines for their damage. Proposals are sought. *Nothofagus obliqua* (roble) trees are considered one of the most abundant and valuable species in Temuco for being instrumental in the development of the city, and for the spiritual value that they hold for the indigenous Mapuche people, amongst other reasons. This study explored the characteristics (diameter at breast height (DBH), age, height, crown area, visibility, aesthetics of the area, perception of social value, comparison to robles in reference ecosystem) of the thirty largest robles (by DBH) in Temuco.

The results of this study show that many trees in Temuco and its reference ecosystem, Parque Rucamanque, possess traits that make them worthy of special protections. Though trees in the reference ecosystem were on average larger by DBH and height, some robles in Temuco were relatively large for their species. As well, crown area was on average larger in the city than the park. Given the minimum age of 132 years found through the core samples, it is likely that some robles are older than the city itself (140 years), meaning that the trees are inheritances from ancestors such as the Mapuche people.

The results also provide insights into which specific trees may be best for patrimonial protections. In Temuco, four of the five highest ranking trees were in Plaza Dreves, which had a myriad of biocultural values. The fifth, located at the Teatro Municipal, was particularly large for the city, and known to have recreational value. In Parque Rucamanque, the five highest ranking trees were found to be valuable for their size and accessibility, located on the Union, Pu Aliwen, and Triwe trails. It is recommended that these ten trees be included in a patrimonial tree route.

Key words

Temuco, Patrimonial trees, urban conservation, tree tour, *Nothofagus obliqua* (roble)

RESUMEN

Las estrategias de conservación de árboles existentes en Chile a veces no son suficientes para proteger los árboles considerados especiales. Para contrarrestar este problema, la ciudad de Temuco aprobó recientemente una ordenanza que protegerá ciertos árboles individuales declarándolos patrimoniales, lo que incluye protecciones adicionales como multas por daños. Se buscan propuestas.

Los árboles de *Nothofagus obliqua* (roble) son considerados una de las especies más abundantes y valiosas de Temuco por ser fundamentales en el desarrollo de la ciudad y por el valor espiritual que tienen para el pueblo indígena mapuche, entre otras razones. Este estudio exploró las características (diámetro a la altura del pecho (DAP), edad, altura, área de copa, visibilidad, estética del área, percepción de valor social, comparación con los robles en el ecosistema de referencia) de los treinta robles más grandes (por DAP) en Temuco.

Los resultados de este estudio muestran que muchos árboles de Temuco y su ecosistema de referencia, el Parque Rucamanque, poseen características que los hacen merecedores de protección especial. Aunque los árboles en el ecosistema de referencia eran en promedio más grandes por DAP y altura, algunos robles en Temuco eran relativamente grandes para su especie. Además, el área de la copa era en promedio más grande en la ciudad que en el parque. Dada la edad mínima de 132 años encontrada a través de los tarugos, es probable que algunos robles sean más antiguos que la ciudad misma (140 años), lo que significa que los árboles son herencias de ancestros como el pueblo mapuche.

Los resultados también brindan información sobre qué árboles específicos pueden ser mejores para las protecciones patrimoniales. En Temuco, cuatro de los cinco árboles de mayor rango estaban en Plaza Dreves, que tenía una miríada de valores bioculturales. El quinto, ubicado en el Teatro Municipal, era particularmente grande para la ciudad y conocido por tener valor recreativo. En el Parque Rucamanque, se encontró que los cinco árboles de mayor rango eran valiosos por su tamaño y accesibilidad, ubicados en los senderos Union, Pu Aliwen y Triwe. Se recomienda que estos diez árboles sean incluidos en una ruta de árboles patrimoniales.

Key words

Temuco, Árboles patrimoniales, conservación urbana, tour de árboles, *Nothofagus obliqua* (roble)

1. INTRODUCTION

The proportion of the human population that lives in urban spaces is increasing, and is expected to rise 70% by 2050 (Wyse *et al.,* 2015). Greater urban development can result in many economic and social benefits, but also carries with it many negative risks. Urbanization is often linked to ecological degradation and disturbance such as habitat fragmentation and urban heat sinks (Seto *et al.*, 2012). These in turn threaten biodiversity and contribute to global climate change (McKinney, 2002).

One of the most important things that can be done to counter the ill effects of urban growth is to protect urban trees. While replanting efforts are beneficial, it is also important to protect existing trees. While it is not feasible or necessary to protect all trees, efforts should be made to protect individual trees that are of particular importance, known as ´patrimonial trees´ (Romero, 2020; Benedetti *et al*., 2023). The concept of patrimonial trees is used throughout the world, though it may take on different names or structures. Similar to the idea of protecting the family´s jewels, patrimonial protection means stewarding certain trees considered special to the community, so that they may be enjoyed by future generations. Just as certain inheritances may be more valuable depending on the community´s preferences, the values of the community also determine which trees are considered ´treasures.´

Urban patrimonial trees may hold special historic value to the population; therefore, protecting them in turn protects a part of the community's identity. They may also be protected because they offer a number of vital biological services: they support wildlife like birds and insects (Rasey, 2004; Larrieu and Cabanettes, 2012; Speight, 1989), as well as saproxylic organisms such as epiphytes (Read, 2000; Butler *et al.,* 2002; Ranius *et al.,* 2008) and fungi (Cooke, 1984; Boddy, 2001). They may also regulate the temperature (Bowler *et al.,* 2010), and reduce air contamination (Nowak *et al.,* 2006), including carbon (Polo *et al.* 2017). Such services are increasingly important in Temuco, a city in south-central Chile that is growing in population and size (Macrotrends, 2022).

Temuco, originally the epicenter of Chile's largest indigenous culture, the Mapuche, is now one of the largest cities in the country and faces problems stemming from urban growth (Gutiérrez *et al.,* 2020). It needs protections for its urban trees that offer particular biocultural values (Municipalidad de Temuco 2021). Temuco´s population of 221.375 residents is increasing at a rate of about 1% each year and is predicted to follow this trend for the foreseeable future (Macrotrends, 2022). It is also one of the country's most polluted cities in terms of air quality (Lombrana *et al.,* 2020). Due to high poverty rates and its location in the

central valley of the Araucania region, air pollution threatens residents´ health (Lombrana *et al.,* 2020; Díaz-Robles *et. al* 2014). Trees are known to decrease levels of particulate matter, ozone, nitrogen dioxide, sulfur dioxide, and carbon monoxide (Nowak *et al.,* 2006). However, urban growth is threatening Temuco´s most valuable trees; if the trees stand in the way of development, they can be cut down, rather than adapting the city around what is already there naturally (Schlegel *et al.,* 2020).

Temuco recently passed legislation to better protect its trees. One of the new categories of protection introduced was for patrimonial trees. In Temuco, they are seen as individual trees that are outstanding in terms of their species, size, aesthetic, age, biological, spiritual and/or historic value (Municipalidad de Temuco, 2021). There have yet to be studies analyzing the characteristics of individual trees in Temuco and which deserve patrimonial protection.

Nothofagus obliqua (roble) is listed by the municipality as being one of the highest value species in the city (Municipalidad de Temuco, 2021). Among the plethora of positive traits they possess, roble (*Nothofagus obliqua*) are part of the city´s patrimony; they hold spiritual value to the indigenous Mapuche people, and can be important to Temuco residents,´ if not Chileans,´ sense of identity (Schlegel *et al.,* 2020). Additionally, they provide shade, helping to cool urban heat sinks, without contributing to allergens in the air (Hoyle, 2020).

This study assessed the different values of roble trees in order to help the city of Temuco consider which are most valuable and could be designated patrimonial by the city. Determining which trees are valuable and protecting these as patrimonial trees could help protect residents´ sense of community and identity, be profitable for the city by making it more attractive to tourists, and even decrease the number of traffic accidents (Castillo Ibáñez, 2022). It could also contribute positively to Temuco´s long term plans, such as reducing air contamination, and providing environmental education (MMA, 2022).

2. STUDY OBJECTIVE

2.1 General objective

Characterize the patrimonial trees of *Nothofagus obliqua* in the city of Temuco.

2.1.1 Specific objectives

1. Identify patrimonial trees of *Nothofagus obliqua* in a reference ecosystem, Parque Rucamanque.
2. Identify patrimonial *Nothofagus obliqua* individuals in public spaces in Temuco.
3. Develop a catalog for the patrimonial trees chosen to contribute to the creation of a patrimonial tree route.

2.2 Study question:

What are the characteristics (DAP, age, height, crown area, visibility, aesthetics of the area, perception of social value, comparison to robles in reference ecosystem) of robles in Temuco that are recommended for patrimonial status and to be part of tree tours?

3. BIBLIOGRAPHIC REVIEW

3.1 Importance of urban tree conservation

Conservation of urban trees is important for a number of reasons. The trees may have religious significance for indigenous groups (Castillo Ibáñez, 2022). From both an academic and touristic perspective, urban trees can offer a tangible idea of a species´ characteristics so that one can learn to recognize it before going into a forest. Also, portions of the urban population will always find it difficult to access the forest, another reason why it is vital to conserve the trees that are accessible within the city limits (CONAF, date unknown). Finally, urban trees can support economic development by making an area more attractive for investment and tourism (Nesbitt *et al.*, 2017).

Urban trees are also important for safety and wellbeing. In addition to directly cleaning the air, trees can also reduce the number of cars on the road, as they can make a place more pleasant for walking or biking, especially in the summertime, by offering shade (Bowler *et al.,* 2010). Also, urban trees have been linked to decreased antidepressant prescriptions (Taylor *et al.*, April 2015). The effects of seeing a beautiful tree in the city can be quite profound. Some urban trees can inspire a sense of awe upon seeing or learning about them. Keltner (2023) says awe has been shown to calm down one´s nervous system and trigger the release of oxytocin, a hormone that promotes trust and bonding. As well, this sensation of seeing a large or beautiful tree can slow down your heart rate, deepen breathing, and even aid in digestion (Reese, 2023). As a result, urban trees can reduce stress and calm traffic, helping to prevent accidents (Van Treese II *et. al.*, 2017).

Ancient and/or large trees in urban areas in particular are valuable. These trees are particularly awe-inspiring, as their vastness often transcends our understanding of the world (Reese, 2023; Polo *et al.,* 2017). They can be important sources of genes that are resistant to pathogens or tolerant to stress (Lonsdale, 2013), serve as religious symbols (Polo *et al.*, 2017) and create sources of shade (Polo *et al.,* 2017). The root systems are often intertwined with those of the trees around them, providing stability (Popkin, 2022). According to popular theory, they help other trees, using a system of mycorrhizae on their roots to transfer nutrients to trees that are young and/or affected by disease, and to communicate when there is a drought (Popkin, 2022). Finally, large old trees can lead to new insights into long-term environmental changes and historical disturbances (Phillips *et al.,* 2008).

3.2 Threats to trees

Today a great percentage of large and/or ancient trees in urban and rural spaces are exposed to cutting, disease, and other threats (Bütler *et al.,* 2021; Phillips *et al.,* 2008; Schlegel *et al.,* 2020; Lonsdale, 2013). Urban trees in general experience threats from human development, such as disease resulting from loss of soil, improper care, cutting, and loss of habitat (Romero and Hauenstein, 2014). Urban trees also face threats from climate change. A study conducted in the Valdivian ecoregion, about 170 km to the south of Temuco, found that *Nothofagus obliqua* there will suffer from future drought worsened by climate change (Aguilera-Betti *et al.*, 2015).

Their loss would not only be detrimental to the human community but could also destabilize the ecosystem and/or human community surrounding them (Popkin, 2022). Furthermore, the loss of even just one large and/or old tree can release relatively large stores of carbon into the atmosphere, exacerbating climate change (Ayres and Lombardero, 2000). Finally, losing these trees can cause a loss to a community or individual´s identity (Polo *et al.,* 2017).

3.3 Forms of urban tree conservation

Many conservation measures aimed at protecting urban trees are often not enough to protect them from threats like climate change, pathogens, diseases, changes in soil use, urbanization, and market volatility (Henríquez, 2013; Escalona, 2020; Phillips *et al.,* 2008; Schlegel *et al.,* 2020; Lonsdale, 2013). However, there are certain measures that are more successful than others. For example, there is precedent creating local identity for trees, which has served to protect them. In Athens, Georgia, USA, a property owner decided upon dying, to give the white oak tree on his property that he had grown up with and learned to love ownership of itself and all land within 2,5 m of its trunk (Taylor 2016). Although plants cannot legally own property, the claim has never been challenged in courts (Taylor 2016). The tree became well known by the community, which has come together to protect the tree--when it fell, they planted one of its seeds in its place and local lore holds that every tree in that spot thereafter will own itself (Taylor, 2016). Furthermore, the idea has added to community identity and contributed to tourism (Taylor, 2016).

Like this white oak, there have been other success stories from designating individual trees as patrimonial and implementing environmental education about them (Wyse *et al.,* 2015). Tree tours, whether guided or self-guided, digital or in person, have also been shown to effectively conscientize the public about the characteristics and value of individual trees, and inspire their protection (Ruchter *et al*., 2010).

3.4 Patrimonial Trees around the world

In many countries patrimonial trees are protected using community initiatives and legal means (Huang *et al*., 2020; Polo *et al.,* 2017; García, 2020; Lonsale, 2013; República de Perú 2020). Italy adopted the first law in the world protecting patrimonial trees in 1939 (Cannizzaro and Corinto, 2014). In Mexico, Colombia, and Ecuador, there are registers, books, and patrimonial tree routes for both the city and rural areas (Romero, 2020).

The number of studies on patrimonial trees is growing. In Bahía Blanca, Argentina, they used methods to select patrimonial trees derived from those used by Ecuador, Perú, and Colombia, where patrimonial tree conservation projects appear to be thriving (Benedetti *et al*., 2023).

One of the definitions of patrimonial trees most like that which will be used in this study is the one used in Perú:

> ¨Patrimonial trees are the legacy of a remote past, considered vestiges of the ecosystems that existed long ago, in non-intervened zones as well as urbanized zones, that are notable in general for being long living, tall, or that have a great cultural and historic importance in the location where they are located.¨
>
> (República de Perú, 2020).

Perú´s Forest Service rates size based on a comparison to other trees of the same species (Servicio Forestal y de Fauna Silvestre de Perú, 2020). They consider height, diameter at breast height (DBH), and crown area under the category size (Servicio Forestal y de Fauna Silvestre de Perú, 2020).

The laws that protect patrimonial trees generally prohibit their cut, or any damage to the individual, unless it is posing an imminent threat to people or properties (Polo *et al.,* 2017). Other forms of protection include fences and surgeries. In Colombia, surgery was performed on a 200-year old nogal, the oldest tree in Bogotá, to remove dead parts and enable it to live longer (Observatorio Ambiental de Bogotá, 2017).

Though not considered patrimonial trees, there are also examples of other tree protection that could be incorporated into patrimonial protection. One of the highest forms of tree protection in the world is that given to Hyperion, the tallest tree in the world (115.8 meters). A new law by the U.S. National Park Service (NPS, 2022) prohibits visiting Hyperion at its location in Redwood National Park, with a penalty of up to approximately $4.005.000 CLP

($5,000 USD), or six months in jail for those found near the tree (Enking, 2022). The strict protection comes as a response to damage that has increased since the trees´ discovery in 2006, including people climbing the tree, trampling large amounts of vegetation to get to and from the trees´ off-trail location, failing to properly dispose of human waste, and littering (Enking, 2022). Other patrimonial tree protections generally include fines on a smaller scale, to discourage the same types of behavior.

Though patrimonial trees are a relatively new concept in Chile, native Chilean trees are protected in other parts of the world. This includes trees in locations as far away as Singapore, where a Chilean palm is protected in the largest glass greenhouse in the world (Carbó, 2018). In England´s ´Garden of Eden,´ one of the largest and most novel sustainability projects in the world, there is a space called ´Wild Chile,´ where a variety of native species are included, such as species of Nothofagus, Podocarpus, and Fitzroya (Carbó, 2018). *Nothofagus obliqua* are included in the garden, which receives around a million visitors each year (Carbó, 2018). Furthermore, some Chileans abroad have recognized a eucalyptus and commented “Oh, a Chilean eucalyptus,” pointing to a need for better knowledge of native Chilean trees (Carbó, 2018). While it is positive that native Chilean species are valued and will be protected in other parts of the globe even if they go extinct in their native ecosystems, it seems imperative from an ecological, cultural, and ethical standpoint to protect them in their native land, through legal protections and education (Polo *et al.* 2017; Romero, 2020).

3.5 Patrimonial Trees in Chile

In Chile, the concept of patrimonial trees is relatively new. It is intended to make up for gaps in other conservation laws and programs which do not cover some individual trees that present a high level of natural and cultural value (Yáñez, 2017). Chile´s national park system conserves entire ecosystems, however at times its parks are not enough to protect valuable trees. It was discovered that the oldest tree in the world, the Gran Abuelo, an alerce tree with monumental status (discussed later) and located in the Alerce Costero National Park in Chile, is dying, and much of its death can be attributed to human causes (Ríos, 2022). Visitors to the park walk on its roots and compact the soil around them (Pappas, 2023). Also, the viewing platform is dehydrating the tree, by blocking about 50% of precipitation from reaching its roots (Pappas, 2023). Additionally, national parks do not directly protect urban trees, which can also be of high ecological and cultural value. Protections for such trees are often not enough: while one property owner or groundskeeper may give extra care to a tree, the next may not. A plaza protects trees on some level, but may not protect it from

over-trimming or offer a strong enough fine to deter damage like graffiti (Municipalidad de Temuco, 2021).

Declaring a tree a´monumental´ is another protection that is being considered for certain trees in Chile, which is similar to patrimonial protection. In Chile, monumental protections have historically been awarded to entire tree species. For example, declaring alerce (*Fitzroya cupressoides* (Molina) I.M. Johnst.) a monumental tree species has increased the power of the Corporación Nacional Forestal (CONAF) to regulate its cut, as well as the production and sale of its lumber (Ministerio de Agricultura, 1976). Other species declared monumental include Araucaria (*Araucaria araucana* (Molina) K. Koch, Ministerio de Agricultura, 1987), ruíl (*Nothofagus alessandrii*) and others (Ministerio de Agricultura, 1995). However, it can be difficult to achieve monumental status, as trees have to be of a certain size, and the process can be quite lengthy (Ministerio de Agricultura, 1995). Furthermore, it may be unneccesary to protect the entire species. For example, *Nothofagus obliqua* are only listed as Vulnerable and therefore the entire species may not require such protections. However, there are certain individual trees that are quite valuable and also threatened. These trees can be protected under patrimonial status, on a national or local level, a process which could prove simpler.

Protections for patrimonial trees do exist in Chile and can complement existing protections to cover individual trees that are considered of exceptional value. The most recent book of Patrimonial Trees of Chile focused on trees with cultural value. It was published in January 2022 (Castillo Ibáñez, 2022) and included both native and exotic trees, and considered age, height, DBH, crown spread, health, and biocultural value. However, it did not focus on large or ecologically important trees, but rather selected trees with the highest anthropological value (Castillo Ibáñez, 2022). A patrimonial tree is defined in the book as:

> ¨…a legacy, necessary to protect and preserve, in order to value and treasure it, due to its natural and/or cultural importance, and that must be distinguished for the knowledge of current and future generations. This book is oriented to the approach from its cultural importance.¨
>
> (Castillo Ibáñez, 2022)

For example, the tree´Queñoa en el recinto del Municipio de Putre´ is only 40 years old, 0,3 m DBH, and 10 m high, but was included because it is endemic to the area, and has high social value (Castillo Ibáñez, 2022).

The national registry included a few robles, indicating the high value of this species on a national scale. Robles in other municipalities listed as patrimonial included three individuals: one in Valdivia, noted as being the oldest urban tree known in Chile, 350 years old; a roble in Toltén at the site where the community met to sign the the Foundation of the New Toltén Act after the 1960 earthquake and floods; and a third roble in Quitratué, for which a poem was written by a historic figure (Castillo Ibáñez, 2022).

Various localities in Chile are compiling their own patrimonial tree lists to make up for gaps in the national register, and to be able to manage their own system. For example, Valdivia and Temuco are in the process of designating patrimonial trees (Díaz, 2020). However while Temuco has a legal structure in place, Valdivia has yet to establish legal protections for their trees. Valdivia had conducted a survey of its patrimonial trees as of 2022, but no scientific articles have been found for the study, only news articles (Facforen, 2022). In this survey, they only selected trees that were at least 100 cm DBH and 100 years old, but they included both exotic and native trees of a variety of species. They found around 700 trees (Facforen, 2022).

Valdivia, in fact, is striving to be known as Chile's Ciudad de Árboles Patrimoniales, which would not only be a point of pride, but also could make them more attractive for tourism, university students, and prospective homebuyers (Castillo Ibáñez, 2022). Temuco´s designation could have an equally profitable outcome. If Valdivia does become the official city of Chile´s patrimonial trees, Temuco may also want to follow their lead. Inter-municipal or regional collaboration in the future could be very beneficial.

3.6 Patrimonial Trees in Temuco

The city of Temuco recently passed its own laws pertaining to patrimonial designations as part of the city's first ordinance relating to trees and urban green spaces (Municipalidad de Temuco, November 2021). Patrimonial designation under Temuco´s law is broader, and encompasses trees that are valuable both for their cultural and ecological traits.

Protections for trees are sometimes listed specifically, such as not being allowed to carve into the tree or apply paint or graffiti. Others are more broad, such as the prohibition of anything that might affect the foliage of the tree or its ¨capacity to absorb water.¨ (Chapter II, Article 6).

Under the new law, trees have varying levels of protection, depending on their estimated cultural and biological value. Native, older, healthier, and/or more visible trees have the greatest value.

Values are multiplied by each other to calculate the overall value of the tree:

$$Vt = Vb * fd * fu * fs$$

Vt= Total value of the tree
Vb= Base value of the tree, based on its species
fd= Sanitary factor
fu= Location factor
fs = Singularity factor

Calculation of each tree´s value, Ordenanza Four, Section on Patrimonial Trees, City of Temuco, November 16, 2021.

1. Base value (species and age)
2. Health
3. Location (visibility)
4. Singularity/uniqueness

Patrimonial trees are also considered five times more valuable than other trees (Capítulo IV, Artículo N° 9 and Capítulo XIII Artículo N° 32). Fines for damaging trees protected by the law are given in Unidades Tributarias Mensuales (U.T.M., or monthly tax unit), and range from 1 U.T.M. ($58.772 or $64 USD) to 5 U.T.M. ($293.860 or $321 USD) (Prensa Digital, 2022). With the minimum wage in Chile at 400.000 CLP, this fine is the equivalent of about 15%-73% of a monthly salary (Prensa Digital, 2022).

Trees are also divided into groups based on the determined value of their species. *Nothofagus obliqua* is in Group 3, the group of trees with the highest level of protection. The fines for damaging trees in this group are three times the fine of a tree in Group 1 and range from 3,0 U.T.M ($176.316 or $192 USD) for 1-4 year old trees, to 24,3 U.T.M. ($1.428.160 or $1.558 USD) for trees 96-100 years old.

For example, a 140 year old tree might have medium damage, be located in a park, and be classified as patrimonial:

$$Vt = 24.3 * 0.5 * 2 * 5 = 122.5.$$

This means the individual/group that caused the damage would pay 122.5 U.T.M.

All proposals are to be submitted in October of each year to the Dirección de Medio Ambiente, Aseo, y Ornato (DMAO) (Capítulo IV Artículo 9).

3.7 Education through tree tours

Successful conservation requires an educational component according to Rodrigo Gutiérrez, the city engineer in charge of Temuco´s Urban Parks Department, la Unidad de Parques Urbanos del Municipio de Temuco. Ordenanza N.4 also requires the city to promote educational campaigns with the goal of ¨installing habits and conduct oriented towards the valorization, diffusion, and care of the tree and green areas both for the interior of the municipal administration and for the neighborhood's habitants.¨ (Capítulo III Artículo 8).

Using digital media may increase educational outcomes in tours. Ruchter *et al.* (2010) found that when adults and children were given computers as mobile devices for nature tours, they learned just as much, if not more, than from traditional environmental education (brochures, human guides). In the case of children, when given computers, they were more motivated to engage than those without them. Digital tours can also be preferable during times of pandemic, natural disasters, or other events that make it unsafe to go outdoors (Ayebi-Arthur, 2017; Dhawan, 2020). Finally, digital tours make nature accessible to people with disabilities and allow everyone to access areas that are difficult to access, such as the depths of the sea or the top of a mountain (Ruchter *et al*., 2010).

A group at the Universidad de la Frontera, plans to create a digital tree route as part of the project “Transferencias de conocimientos y puesta en valor del Patrimonio de La Araucanía a través de la virtualización.¨ The study will identify and characterize the largest and/or oldest individuals of each of *Nothofagus obliqua*, *Persea lingue, Laurelia sempervirens,* and *Aextoxican punctatum* located in the city limits, as well as in Parque Rucamanque, a reference ecosystem. Then, it will include the top five most valuable individuals of each species to include in the tour. This way, there are not too many trees on the tour to be overwhelming, it is possible for visitors to visit all the patrimonial trees in a day, and yet there are enough of each species to be interesting. The present study proposes a route and educational waysides, or interpretive signs, for a guided digital tree tour, to increase the connection that citizens have with their natural patrimony and inspire conservation.

4. MATERIALS AND METHODS

4.1 Selection of study Area

4.1.1 Temuco

Temuco was selected as the city for this study principally because people have indicated that there are still large and/or bioculturally valuable roble trees within the city limits that don't yet have sufficient protections, and because the city recently created a law establishing a framework for patrimonial tree protection and is looking for proposals. Temuco was also selected because it is the zone where *Nothofagus obliqua* (roble), the study species, is found in greatest abundance (Riedemann and Aldunate, 2011), and because there is some urgency to implementing protections for these trees due to growing environmental problems.

Temuco is the capital of both the Province of Cautín and the Region of la Araucanía (Unidad de Medio Ambiente y SECPLA, 2019). The city was founded in 1881 as a military base in the middle of indigenous Mapuche territory and roble-laurel-lingue and roble-raulí-coigue forest (Díaz, 2020). Over time, urban development destroyed the native forest in and around the city. The city was more formally established in 1887 and quickly turned into an agricultural and forestry town, for which the products were exported using the railroad system (Díaz, 2020). Robles were the main species used in the construction of Temuco (Romero and Hauenstein, 2014).

Today, the city is again growing rapidly. The population has doubled in the last 35 years (Maturana *et al.,* 2021). Between 2004-2019, it grew 15%, an increase of 37.068 people. As of the 2017 census, the population now stands at about 320,000 people (Maturana *et al.,* 2021). With this population increase, the number of vehicles has nearly doubled in less than twenty years, contributing to air pollution (Maturana *et al.,* 2021). Today, the city has an urban plan called the Plan Regulador Comunal (PRCT), established in 2010, designed to manage urban growth (Rojo-Mendoza and Hernández Aracena, 2019). Yet, the city has been unsuccessful at updating this plan and today the city grows with few checks, causing urban sprawl (Maturana *et al.,* 2021). According to a predicted model of growth, Temuco is expected to develop in an amoeba shape rather than a compact form. In this sense, it goes against all sustainability aspects of the National Urban Development Policy published in 2014 (Maturana *et al.,* 2021).

Climate change is already affecting the city in the form of increased precipitation and flooding in the winter months registered as early as 2017, droughts beginning in 2010, and extreme temperatures, both high and low (Unidad de Medio Ambiente y SECPLA, 2019). One of the objectives of its climate change plan published in 2019 is the conservation of

natural resources in the neighborhoods, and environmental education is one of the methods listed to accomplish this objective (Unidad de Medio Ambiente y SECPLA, 2019), both relating to this study. .

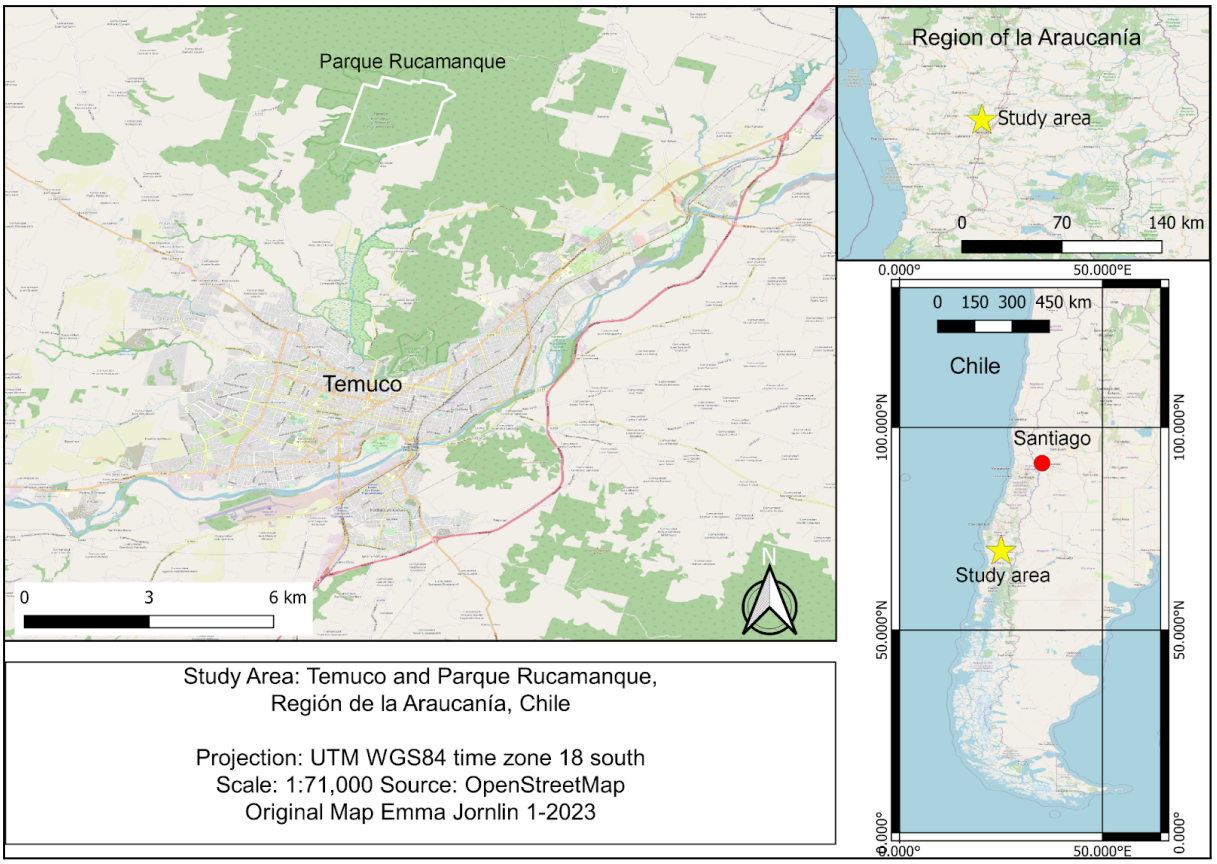
There is some urgency for Temuco to increase its environmental protections. Temuco is one of Chile's most polluted cities, in part because it is located in a valley and also due to rapid population growth and high poverty rates (World Population Review, 2021; Lombrana *et al.,* 2020). Residents burn cheap--often wet--firewood to stay warm and to cook, causing air pollution to rise to internationally high levels during winter and threatening residents´ health (Lombrana *et al.,* 2020). In the winter of 2020, Temuco had the worst air pollution in the world for at least five days in an eight week span before the month of July had even ended (Lombrana *et al.,* 2020). In summer months, wildfires are also a source of air pollution (Lombrana *et al.,* 2020). As well, there is one park in the city, Cierro Ñielol, that is forested and protected by the national parks department, CONAF, however, municipally-run parks feature few trees, compared to the dense vegetation that existed before (Castillo Ibáñez, 2022).

Despite the destruction of the original forest for urban development, rapid population growth, and poverty, there are still native trees that probably are remnants of the original forest of the central valley and the south-central zone of Chile (González and Godoy, 2020). This is likely due to Temuco´s unique history as the epicenter of the indigenous Mapuche peoples´ community; Mapuche people practiced forest conservation in the region now called the Araucanía since approximately 1800 and succeeded in resisting colonization by the Incas, Spanish, and Chilean state until 140 years ago (1881), when the valley of Temuco was one of the last to be colonized by the Chilean state (González and Godoy, 2020; Rojo-Mendoz and Hernández Aracena, 2019; Mieres and Barra, 2014). Today, Temuco has the second highest population of indigenous Mapuche people after Santiago, the nation's capital (Maturana *et al.,* 2021). There are many demands from the Mapuche, including the desire to recover lands stolen from them during colonization, recognition as a nation, and other historical property claims (Maturana *et al.,* 2021). Much of the land surrounding urban Temuco is indigenous owned land, granted to the Mapuche when they were driven out of what is now the city center (Gutiérrez *et al.* 2020). But using legal loopholes, the State allows urban expansion into these peri urban ecosystems, contributing to habitat destruction and social conflicts (Rojo-Mendoza and Hernández Aracena, 2019; Maturana *et al.,* 2021). Protecting trees considered of ecological and/or social value could be a way to resolve some of Temuco´s pollution problems, as well as honor the heritage of the Mapuche people and

others who have conserved the environment of the area for generations, perhaps resolving some of its social strife.

Temuco recently passed an Ordenanza N4 establishing laws to designate and protect patrimonial trees (Municipalidad de Temuco, 2021). This study aims to provide well-informed suggestions as to which should be declared patrimonial.

Figure 1. Map of location of study: Temuco and Parque Rucamanque. Both are located in Región de la Araucanía (the Araucanía region, their location is shown by a yellow star), in south-central Chile.



4.1.2 Reference Ecosystem

First the standard for what constitutes a patrimonial roble tree must be established using a reference ecosystem nearby, in order to understand *Nothofagus obliqua* in a relatively pristine environment (McDonald *et al.,* 2016). There are only two areas of adult native forest remaining in the Central Valley of the region of Araucanía: Parque Ecológico y Cultural Rucamanque, and Cerro Ñielol, both just on the outskirts of the city and connected to each other by the Huimpil-Ñielol mountain ridge (Salas, 2002). Parque Rucamanque has greater

area (408 ha) and has been less impacted, partly as a result of being located further from the city (12 Km vs. 1 Km for Cerro Ñielol), making it the preferred reference ecosystem for Temuco (Salas, 2002).

Parque Ecológico y Cultural Rucamanque, known from here on as Parque Rucamanque, is located to the northeast of Temuco and ranges in altitud from 300-550 meters above sea level (Nuñez *et. al.,* 2015). The property currently belongs to Bienes Nacionales, a national entity, and is currently administered through a free concession by the Universidad de La Frontera (2016-2041) (Díaz, 2020). Although its purpose is to provide opportunities for eco-tourism and recreation, along with scientific research, the park hardly receives any visitors, according to informal conversations with staff.

The park qualifies as a reference ecosystem for Temuco because of its history and health. It is theorized that the area that is now the city once belonged to the same roble-laurel-lingue forests (González and Godoy, 2020; Mieres and Barra, 2014). It has been relatively protected from destructive anthropocentric activities: it was historically used as a source of potable water for the city, but when Temuco grew too large, it began to get its water from a different source (Ñunez *et al.*, 2015; Díaz, 2020). In 1985, the Ministerio de Bienes Nacionales planned to publicly sell Parque Rucamanque to private companies to harvest the trees for lumber (Díaz, 2020). But community organizations lobbied for its protection, and succeeded in having it passed into the hands of the Universidad de La Frontera in 1987, which used it for formative activities and research (Díaz, 2020). These community organizations (Comité Regional de Ecología, Sociedad de Vida Silvestre, Amigos del Árbol, among others) continue to support the conservation of the forest and that of urban trees (Díaz, 2020). The university received a second contract from Bienes Nacionales for a free concession for the area for 2016-2041 to develop the project of Parque Ecológico y Cultural Rucamanque. The park was named a Priority Conservation Site by CONAMA in 2002 (Díaz, 2020). The high level of cyanolichens present show that it is a very stable forest, as these elements are very sensitive to ecological changes like poor forestry practices (Gatica *et al.*, 2011).

4.2 Studied species

Nothofagus obliqua (roble in Spanish, and Patagonian oak or roble beech in English) was selected as the study´s species of interest because it is considered one of the most valuable tree species by the City of Temuco (Municipalidad de Temuco, November 2021), it is one of the four tree species being studied for a patrimonial tree route by the Universidad de la Frontera group, it is the native tree with greatest dimensions in the study area (reaching 53

m height, 2 m DBH) (Gutiérrez, 2016), and it is apparently found in great abundance in Temuco (Riedemann and Aldunate, 2011).

Roble is one of only six tree species in Chile that can grow to over 50 m height (Gutiérrez, 2016). As a pioneer species, it achieves its height by finding open space with lots of light to grow. It has great longevity; in Parque Rucamanque, an individual of almost 500 years has been recorded (Marinao, 2005). It is possible that it is the longest living tree species in Temuco, as well, perhaps even with individuals older than the city itself (Díaz, 2020).

Roble trees offer various ecosystem services. They support epiphytes, bryophytes, and lichen species. Robles support 11 different cortical lichens, more than *Nothofagus dombeyi* (5), *Persea lingue* (5), or *Aextoxicum punctatum*. The larger the roble (by DBH), the greater epiphyte richness (Mansilla, 2003). Taller robles are more valuable for lichen; the greatest lichen diversity is located in the dosel of trees standing at least 50 m tall (Villagra *et al.,* 2021), which is why in this study, height was a variable considered in a tree´s patrimonial ranking. Age was also considered, as older robles are most suited to host vascular epiphytes, in addition to bryophytes and lichens, as they have more microclimates in their branches (Zotz and Vollrath, 2003).

Robles also support at least fifteen species of fungi (Salazar and Palfner, 2013). These include the two most popular edible plants in the region, *Cyttaria espinosae* (commonly known as digüeñe, dihueñe, pronounced ´Dee-when-yehs´), an edible mushroom that grows on roble branches, and *Ramaria flava,* or changle, a ground mushroom often used in empanadas (Salazar and Palfner, 2013; Barreau, 2016). Digüeñe is endemic to central-southern and southern Chile and Argentina, and is dependent on *Nothofagus* trees, usually *Nothofagus obliqua*. It forms cancerous growths on the tree branches, and produces an edible mushroom, which people can harvest between spring and summer (Barreau, 2016). Wild Chilean mushrooms strongly contributing to the national economy (Barreau, 2016). Nicknamed ´white gold,´ digüeñes are sold for up to 20,000 clp/kilo (Barreau, 2016). They are a part of culinary traditions; the city of Cunco even has a culinary week-long festival dedicated to the digüeñe (Barreau, 2016).

Culturally, robles are very integrated into Chilean ways of life, including the language. Young robles are referred to as ¨*roble hualle*,¨ or simply hualle (´why-yay´) while older robles are roble pellín, or simply pellín (´peh-yin´). These are words used throughout the country by all kinds of social groups, not just the indigenous Mapuche (Romero and Hauenstein, 2014). Poetry has been written about these trees, and they are a part of Chilean literature (Castillo Ibáñez, 2022). As robles only exist in a contained region in Chile and Argentina (Romero

and Hauenstein, 2014), having robles in a plaza or street can be a source of identity and pride, more so than with exotics (North Carolina Native Plant Society, date unknown).

Roble has spiritual value. The Mapuche think that it accompanies the individual on Earth and facilitates the transition to the transcendent. They put their dead in hollowed roble trunks to send them into the afterlife (Romero and Hauenstein, 2014; Skewes and Guerra, 2015; Skewes and Guerra, 2016). The Mapuches believe that the act of hugging a roble can help a sick person, and talking to a roble can result in greater wisdom (Skewes and Guerra, 2016).

Additionally, robles offer shade, without contributing to allergens in the air (Hoyle, 2020). They filter the air, offer aesthetic value, and are historically significant (Romeo and Hauenstein, 2014). Roble trees in Temuco are a reminder of the roble-laurel-lingue forest (Nothofago-Perseetum linguae) that grew abundantly from Victoria to Puerto Varas (Romero and Hauenstein, 2014) which was cut down for human development. The species was fundamental in the construction of the railroad and houses at the end of the 19th century that allowed thousands of immigrants to settle in the region (Romero and Hauenstein, 2014). Finally, robles are significant in society today because the wood has high market value for construction due to its durability, though its conservation value may be higher (Romero and Hauenstein, 2014).

While exotic species like pine and eucalyptus may grow to large sizes and have a lot of biocultural value as well, these species can have a detrimental impact on ecosystems: both species consume great amounts of water, more than native *Nothofagu*s species (White *et al*., 2020). Eucalyptus dominates over other species by shading and allopathic effects, producing a chemical that prevents others from growing around it (Joshi and Palanisami, 2011) while *Nothofagus obliqua* is sensitive to light availability, meaning other plants can compete with it (Romero and Hauenstein, 2014). *Pinus radiata* can cause ground acidification (Rouget *et al.,* 2004) and increase harmful fungus levels (Ross *et al.,* 2006), while *Nothofagus obliqua* supports soil communities (De Deyn *et al.,* 2008; Berrios, 2002). Roble also has an interdependent relationship with bees (Montenegro, 2000).

Although these trees have survived changes over time, their natural resilience alone does not protect them from human development. If they are deemed a threat to human safety, or if another use of the space is preferred, they can be cut down (Marinao, 2005). Also, roble requires a good soil and space, often lacking in any city (Romero and Hauenstein, 2014; Ferreira *et al*., 2018).

4.3 Study definition of patrimonial trees

In this study ´patrimonial tree´ will be based on the definitions from legislation in Perú, the national definition in Chile, and the local definition from Temuco. Like the patrimonial trees definition used on a national scale in Perú and Chile, this definition will consider age, height, DBH, crown area, and biocultural value (República de Perú, 2020; Castillo Ibáñez, 2022). Unlike the Chilean definition, it will not consider exotic trees or the health of the tree, and will give all characteristics equal weight, rather than focusing on social value.

The City of Temuco recently established protections for patrimonial trees, declaring that patrimonial trees were now be considered five times more valuable than other trees (Capítulo IV, Artículo N° 9 and Capítulo XIII Artículo N° 32). A definition of a patrimonial tree is not provided, however the ordinance establishes a system to determine the values of city trees, giving greater value to native trees, older trees, healthy trees, and more visible trees (Muncipalidad de Temuco, 2021).

In 2021, 83 citizens of Temuco responded to a survey conducted by an undergraduate student at the Universidad de la Frontera via Instagram, stating that the aspects they consider most important in determining if a tree is patrimonial are: it being a native species, its cultural and historic importance, and finally, its size and longevity (Diaz, 2020).

This study incorporates the values of the municipal government of Temuco and the citizens surveyed by a Universidad de la Frontera student in 2021, as well as tree ranking systems used in other parts of the world. It considered DBH, height, crown area, visibility, minimum age, aesthetics of the area, and biocultural value.

4.4 Selection of individual robles

4.4.1 Tree selection in Parque Rucamanque

First, all the trails and official routes in the park were traversed, identifying the largest and seemingly oldest trees growing on or near to them. Then, trees off-path were visited. The area of Parque Rucamanque (408ha) has been divided into a grid, with 200m-by-200m quadrants. There is inventory data about the diameters and heights of some trees georeferenced in plots within these quadrants (Marinao, 2005; Salas, 2002). The decision about which areas to visit were based on where the trees with greatest DBH and the greatest abundance of those trees have been registered (Marinao, 2005; Salas, 2002). As well, based on the inventory data, a minimum diameter of 130 cm was defined to look for

within each quadrant, with a range of 20 cm tolerance in case it is impossible to find individuals with this diameter (Marinao, 2005).

To determine in which sectors to focus the search for patrimonial trees, the forest structure of the park was used, given the theory that trees generally require a level site to grow to old age (Salas, 2001; Marinao, 2005; Salas and García, 2006; Jones, 1997). Sectors with very steep terrain are considered impossible to traverse and were excluded. A second idea that was employed to determine where to focus the search is the idea that the larger and older trees are usually found close to one another, as they all need the same conditions to grow to old age (Jones, 1997). The search was focused on sectors in which the robles with the largest diameters in Rucamanque were found in previous studies (Marinao, 2005; Salas, 2002). In each quadrant, the entire surface was covered with at least three people walking in the form of a rake.

4.4.2 Tree selection in Temuco

All the public spaces of Temuco were visited in a systematic manner by driving all public roads, using a map of Unidades Vecinales, which correspond to delimitations defined by the municipality. The driver and passenger were scanning the area, looking for large individuals of *Nothofagus obliqua*. Only robles that were clearly large enough for the study by DBH were selected. To determine if they were large enough, the researchers eyed the trees from the car, occasionally wrapped their arms around the tree to judge whether they were at minimum a certain size, and sometimes got out to measure the trees, using a measuring tape, to confirm they were large enough. The DBH of forty trees was measured. From this group, the thirty largest were selected to have all their dimensions measured, as the goal was to get enough data to be able to make statistical comparisons. Thirty is generally the accepted minimum sample size required to realize a statistical analysis based on the average (Peck *et al.,* 2008).

4.5 Measurement of dimensions

For each of the thirty largest trees selected, the location was marked in a GPS. Its diameter at breast height (DBH, measured at 1.3m) was measured. From this list of measurements, the trees with the Crown Area and total height were also measured (García, 2020). The data was documented in a preestablished table and cartography was generated ad-hoc.

4.6 Minimum age

Core samples were taken from trees in Temuco and Parque Rucamanque. However, due to the difficulty of counting rings, minimum age was only estimated for trees in the city.

To estimate the age, two core samples per tree were obtained, noting the height in which the core samples are extracted. The extraction was realized above the slope and from the healthiest-looking part of the tree. The increment sampling was an attempt to reach the pith (Sillett *et al.,* 2019).

No core sample were be extracted but the other characteristics were measured and noted for those individuals for which:

1. The sanitary condition/health does not permit the extraction
2. It has too many deformations (i.e. contrafuertes) that can interfere in the estimation of the age

In the laboratory, the core samples were mounted and processed with a sander to make the tree rings visible (Blanco, 1992). Then, the rings of each core sample were counted using a magnifying glass and the software CooRecorder 7.0 (Blanco, 1992).

Age was also estimated using the following equations for age based on diameter (DBH) for *Nothofagus obliqua:*

$Age = 1024,862824 * exp(-112,0580369/DBH)$ (Marinao, 2005, 37)

$Age = 1/(0.00984776 + 0.240063/DBH)$ (CONAF, 2013, 20).

4.7 Biocultural value

As a social component, the significance of the patrimonial trees to the history of the avenue, neighborhood, or corner were determined by a brief literature review of historical documents (i.e. Navarrete and Chávez, 2020, and the few others that exist) and a review of literature about other patrimonial tree routes that exist in the rest of the world.

As well, a survey (Anex 1) was sent to eight key stakeholders. The idea was to start with eight stakeholders, with two from each branch of the groups working with urban trees: two

from the municipality, two from universities, and two from community organizations. Then, the plan was to use a snowball effect to get referrals from these survey subjects about other potential people to contact for a survey (Abubakar *et al.,* 2015). Unfortunately, only one stakeholder gave a response, and no one provided additional contacts.

Of the eight subjects contacted, two were from the Universidad de la Frontera, recommended by the study´s profesor guía. The remaining subjects were found online by researching the branches of the municipality and community organizations directly working with urban trees in Temuco. For example, contacts were chosen from the participants in the presentation of the book Árboles de Temuco in 2015, those who influenced the Catastro del Arbolado Urbano to Implement Reforestry and Species Change Programs, and from university contacts from professor guides. Two subjects were from the municipality, one from Universidad Santo Tomás, one from the Cámara de Comercio y Turismo, the secretary of the Sociedad Amigos del Árbol, and the president of the Colegio de Ingenieros Forestales Sede Araucanía. As well, the engineer in charge of the Urban Municipal Tree department (Árbol Urbano del Municipio) of the city was surveyed. The survey was sent digitally to contacts´ emails, and was followed up with a text message, for those whose phone numbers were provided.

When only one person responded to the formal survey, informal surveys were also conducted with groundsmen working at Parque German Becker and a security guard at Teatro Municipal. Surveys took place on employees´ breaks during the day at their place of work, near to the trees themselves.

Finally, other contacts (friends, colleagues, Airbnb hosts, hostal guests) were asked offhandedly what they knew about robles in Temuco, such as their biocultural value, and what they knew about the locations of the study.

4.8 Comparison of Temuco with Reference Ecosystem

To determine how the urban trees compare with those of the healthy, reference forest ecosystem, the characteristics of the *Nothofagus obliqua* found in public spaces in Temuco were compared with the patrimonial trees in the reference ecosystem, Parque Rucamanque. A comparison of the medians of the structural variables (DAP, age, height) of the patrimonial trees in the two environments was conducted.

A non-parametric U of Mann-Whitney test was applied using SPSS Statistics. U of Mann-Whitney is used when there is not a normal distribution (Winters, 2010) and where the

null hypothesis is that there is no significant difference between the medians and the distribution is the same for the two samples (Moral, 2012; Laake *et al.,* 2015). In this test, the rank sum of each group is compared. If the p value is greater than alpha, the null hypothesis is accepted, the values for Parque Rucamanque and Temuco are not significantly different. In this study, the alpha value was 0.05 and confidence level was 95%.

Another measure of statistical significance is comparing U values. If the critical U value is greater than the U value, the null hypothesis is accepted. If the critical U value is less than the U value, the null hypothesis is rejected (Moral, 2012; Laake *et al.,* 2015). In this case, the null hypothesis was that there is a significant difference between the values in Parque Rucamanque and Temuco.

The same process was repeated with the heights and ages.

4.9 Creation of a patrimonial tree catalog

Point values for each tree were based on the ranking system created for patrimonial trees by the city of Temuco, and on other well-known systems, such as the Champion Trees ranking used in the United States (Van Pelt, 2003).

This study followed the municipality´s ranking system by considering age and visibility. However, the health of the tree and singularity were not measured due to constraints. Instead, variables from other patrimonial tree studies were used: DBH, height, crown area, area aesthetics, and biocultural value (Polo *et al*., 2017; República del Perú, 2020).

4.9.1 Ranking System for Parque Rucamanque

The ranking system for Parque Rucamanque included DBH, height, and crown area, each of which received the same weight (2-6 pts (Table 1)). It did not include minimum age or biocultural values, as these values are unknown. Visibility/accessibility was given double the weight (4-12 pts), as the goal is for trees on the patrimonial route to be accessible, and trees off trail are very difficult to access, due to dense vegetation and uneven terrain.

Table 1. Ranking System for Parque Rucamanque: DBH, Height, Crown Area, Visibility

DBH	Height	Crown Area	Visibility
2 pt for 96-107 cm	2 pt 36-40 m	2 pt for 0-70 m²	On a trail, close to parking 12
3 pt for 108-119 cm	3 pt 41-45 m	3 pt for 71-140 m²	High--within a minute from trail 10
4 pt for 120-131 cm	4 pt 46-50 m	4 pt for 141-210 m²	Medium--close to trail 2
5 pt for 132-143 cm	5pt 51-55 m	5 pt for 211-280 m²	Low--far off trail 1
6 pt for 144-155 cm	6 pt 56-60 m	6 pt for 281-350 m²	

For example, if a tree had the following characteristics, it would receive the following ranking:

DBH: 109 cm Points: 3

Height: 42 m Points: 3

Crown Area: 83 m² Points: 2

Visibility: On a trail Points: 12

Total points: 20

Ranking: A score of 20 points gave this tree a ranking of 5th place in Parque Rucamanque.

4.9.2 Ranking System for Temuco

In this study, trees were given more points for age, in 20 year increments. Age could also not be given as much weight in this study, as only 60% (18/30) of the trees´ minimum ages were able to be calculated. As a result, as a contrast to Temuco´s system, minimum age was given the same weight as other variables in the study.

Visibility ranking was similar to that of the municipality, with the highest ranking for trees located in plazas, parks, and green spaces. Remaining trees were given, high, medium, or low visibility rankings (Table 2). However, unlike Temuco´s system which values visibility over other variables like size, in this study all variables received the same weight (2-6 points). This was done to include an equal balance of influence from the municipality´s system, as well as other international patrimonial tree ranking systems.

Area aesthetics were also included as a category in Temuco. This was based on how much noise and traffic was noted in the area where the tree was located, and how easy it was to walk around. Trees located in areas with less noise, less traffic, and greater walkability were given higher ranking (Table 2).

Table 2. Ranking System Temuco: Age, Visibility, Area Aesthetics

Category	Age (years)	Visibility	Area aesthetics
Ranking system	2pts for 33-53 3 pts for 54-74 4pts for 75-95 5pts for 96-116 6pts for 117-137	Very high: plaza, parks, green spaces 6 High 5 Medium 4 Low 3 Very low 2	**6 pts** Quiet area, less traffic, easy to get to and to walk around there **5 pts** Easy to get to and walk around **4 pts** Some traffic, somewhat easy to get to and walk around at **3 pts** Somewhat easy to get to and walk around at **2 pts** High traffic area makes it noisy, or area that is difficult to get to and/or walk around at

Ranking for this study was also based on size (DBH, height, crown area) (Van Pelt, 2003; Polo *et al*., 2017; República del Perú, 2020). Larger traits were given more points (Table 3).

Biocultural values were also included, relating to the Chilean patrimonial designation´s focus on the social value of the trees. Only 6, 2 or 0 values were reported for each tree. Therefore, points were simply assigned by the number of values reported (Table 3).

Table 3. Ranking System Temuco: DBH, Biocultural Value, Height, crown area

DBH	Biocultural value	Height	Crown
6 pts 144-164 cm 5 pts 123-143 cm 4 pts 102-122 cm 3 pts 81-101 cm 2 pts 60-80 cm	1 pt for each value listed	6 pts 36-40 m 5 pts 31-35 m 4 pts 28-32 m 3 pts 23-27 m 2 pts 18-22 m	6 pts 261-324 m² 5 pts 197-260 m² 4 pts 133-196 m² 3 pts 69-132 m² 2 pts 5-68 m²

For each tree, the final ranking was created by summing the point values assigned to it for each category:

Final ranking = DBH + Height + Crown Area + Biocultural values + Minimum Age + Visibility + Aesthetics

For example, if a tree had the following characteristics, it would receive the following ranking:

DBH: 127 cm	Points: 5
Height: 28 m	Points: 4
Crown Area: 270 m²	Points: 6
Biocultural values: 6	Points: 6
Minimum Age: 99 years	Points: 5
Visibility: In a plaza	Points: 6
Aesthetics: Some traffic, somewhat easy to get to and walk around at	Points: 4
	Total points: 36

This roble has a total score of 36, which was the highest score, making it the top ranked roble for patrimonial status in Temuco.

4.10 Creation of educational materials

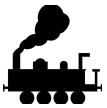
While all patrimonial trees were included in the survey, maps, and statistics, signs were only created for the five highest valued trees in Temuco and Parque Rucamanque, to create an example of what a guide for patrimonial trees could look like. The number five was used because the group at the Universidad de la Frontera will use five individual trees of four native species in their project for a total of 20 in their digital patrimonial tree tour.

Maps were generated to give a visual of the location of the trees and their relation to other areas. Maps were created using both Google Satellite, to show vegetation and other variables, and Google Street Map, to make the idea more relevant to people and show street names.

For the top five ranked trees in Temuco and Parque Rucamanque, a digital wayside-style sign with a small description was included (See Figure 12). This is intended to mirror the books *Árboles Patrimoniales de Chile: una primera aproximación* and *Champion Trees of Washington State* (Castillo Ibañez, 2022; Van Pelt, 2003). It also takes elements from other digital tree tours in other cities.

Biocultural values were given a symbol, to reduce text on educational signs (Table 4).

Table 4. Symbols for biocultural values. Number of trees indicates how many of the 30 trees measured in Temuco were cited as having this biocultural value.

Value	**Number of trees**	**Symbol**	**Value**	**Number of trees**	**Symbol**
Beauty/appearance	8		Contribution to health/wellbeing	9	
Shade/temperature regulation	15		Erosion control	8	
Habitat it creates	14		Historical relic of boundaries, avenues, ancient cemeteries	0	
Reduces contamination	8		Support for economic development	0	
Other	0		Spiritual-religious value	0	

4.10.1 Equivalents for circumference and height

On the signs for each tree, equivalents were also given to help people comprehend the numbers. Circumference was given in the number of people that can wrap their arms around the tree, hands clasped in each others,´ as this is commonly used in U.S. national parks like Sequoia National Park, and perhaps in other parts of the world. Number of people needed to envelop the tree in a hug was estimated using height, as wingspan is generally equal to height. The average person measured in Chile has a height of 166 cm. This was calculated by adding the average height of men in Chile (172.88 cm) and the average height of women in Chile (159.42 cm) (World Population Review, 2023), then dividing by two and rounding to the nearest centimeter. Then, circumferences were divided by average wingspan, 166 cm, and rounded up or down to a whole number to give the number of people required to wrap their arms around the entire tree. For example, if a tree´s circumference was 367 cm, 367/166= 2.2, meaning it would require two people to wrap their arms around the tree.

Height was given in Caupolicán Towers, the highest building in Temuco, which stands at 74 meters (Carmine, 2005). Each height was divided by 74 meters to give the number of towers.

5. RESULTS

5.1 Location of trees measured

The diameters, canopies, and heights of over thirty robles in Parque Rucamanque and Temuco were measured. All trees in Parque Rucamanque were located in adult forest. Most were located in the Western side and around two trails, Triwe and Pu Aliwen. A couple robles were located on the road, Cruce Norte. Most robles off trail were difficult to access, mostly due to thick kila kila vegetation.

Of the robles studied in Temuco, 30 were selected. The trees were concentrated in the central and western part of the city limits. The top 30 largest robles were located in the following locations, in order of quantity of trees: a site near Pumahue (10), Parque Estadio Germán Becker (6), Plaza Dreves (6), Venus and Neptuno streets (2), near Portal de la Frontera (1), Recreo street (1), Hochstetter street (1), Holandesa street (1), Martin Lutero and Los Tepúes streets (1).

5.2 Comparison of dimensions in Temuco and Rucamanque

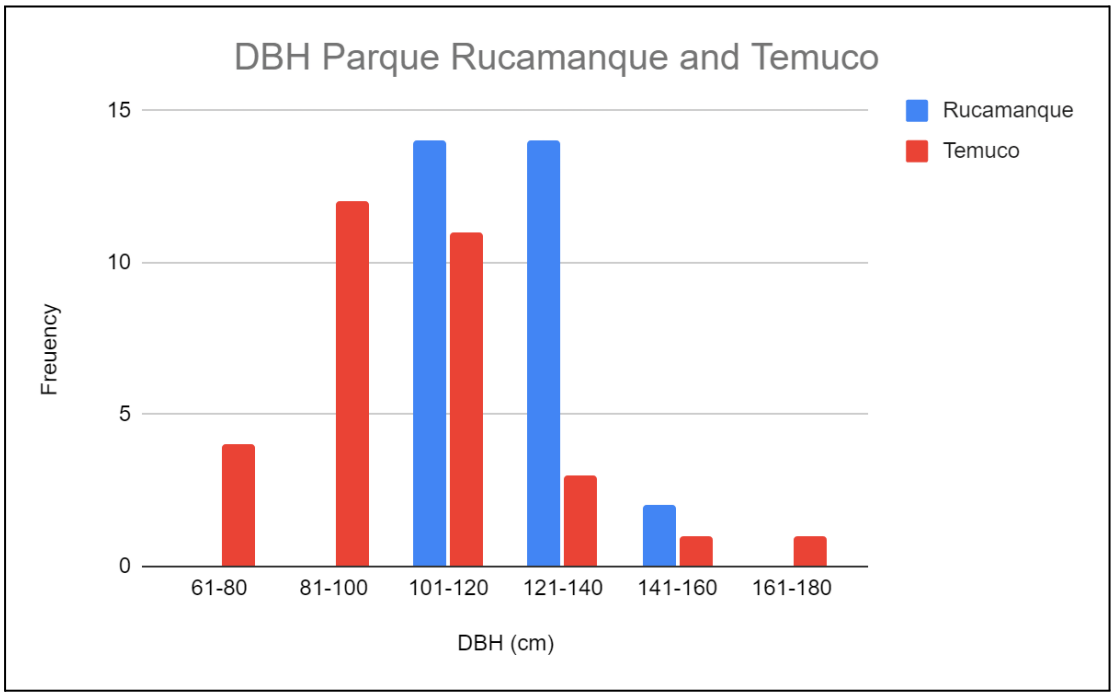
Most physical characteristics were on average greater for robles in the reference ecosystem than for those in the city of Temuco. This included DBH (Table 5, Figure 2) and height (Table 5). Trees in Temuco are generally not as big as in Parque Rucamanque by these measures, although crown area was greater for robles in the city (Table 5).

Table 5. Size of Robles in Rucamanque (DBH, Height, Crown Area)

Mean values of DBH were 123,5cm for Rucamanque and 101.7cm for Temuco. A significant difference was found, (p-value ＜0.001). Robles measured in Rucamanque are significantly larger (by DBH) than robles measured in Temuco.

Measure	Rucamanque	Temuco		Rucamanque	Temuco
Minimum DBH	101,7 cm	63,4 cm	**Minimum crown**	31,2 m²	7,65 m²
Average	123,5 cm	101,7 cm	**Average**	116 m²	155,7 m²
Maximum DBH	154,4 cm	161,2 cm	**Maximum crown area**	218,4 m²	323,58 m²
Minimum Height	37,5 m	19,1 m			
Average Height	46,8 m	27,3 m			
Maximum Height	60 m	39,3 m			

Figure 2. DBH Parque Rucamanque and Temuco. Trees in Temuco had a greater variety of diameters than those in Parque Rucamanque. Also, the tree with the largest DBH was located in the city.

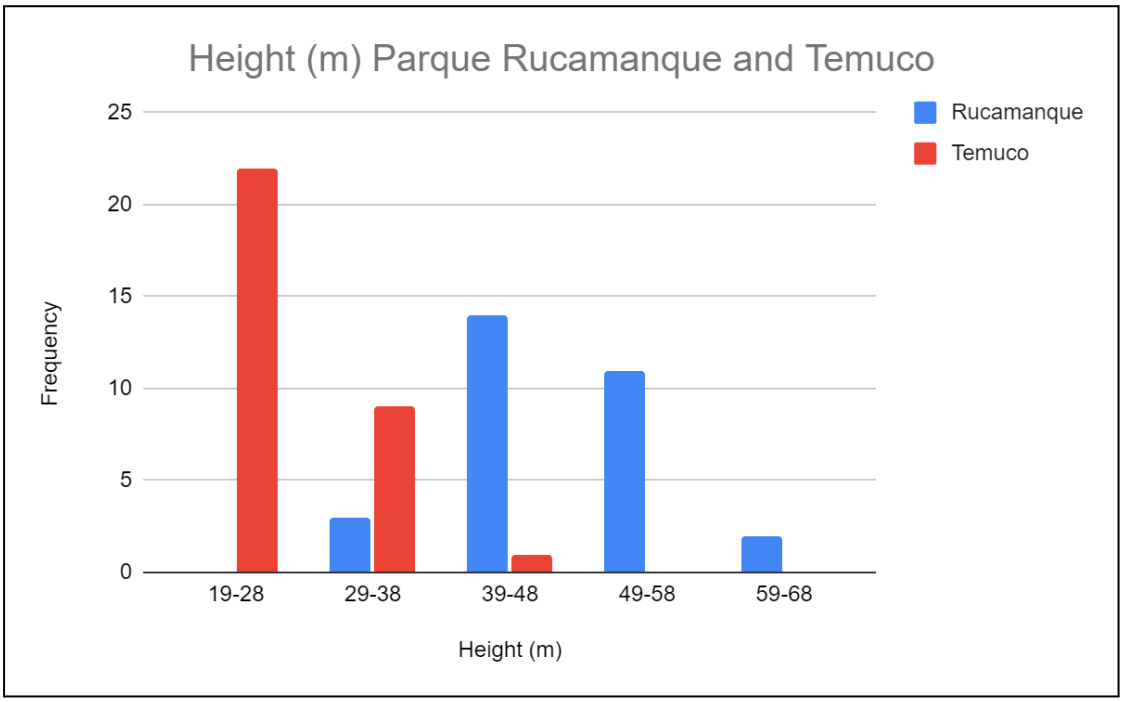


Tree perimeter, or circumference in Temuco ranged from 199,2-506,4 cm, with an average of 319,6 cm. The number of people that could wrap their arms around, hands linked, hugging the tree, ranged from 1-3 people. Mirroring diameter, the two robles with the greatest circumference were found near shopping center Portal de la Frontera (3 people, or 506 cm) and in Parque Estadio German Becker (3 people, or 449 cm).

In terms of height, robles measured in Rucamanque are significantly larger (by height) than robles measured in Temuco. The p-value was ＜0,001, which is less than the alpha value of 0,05.

The maximum height of robles in Parque Rucamanque (60m), was greater than the maximum known for *Nothofagus obliqua* (50m). Robles in Temuco appear to only reach 39,3 m (Figure 3).

Figure 3. Height Parque Rucamanque and Temuco. The tallest trees are in the reference ecosystem. There are many more trees above 30 m in height in Parque Rucamanque than in Temuco. Most trees in Temuco ranged from 19-28 m in height.



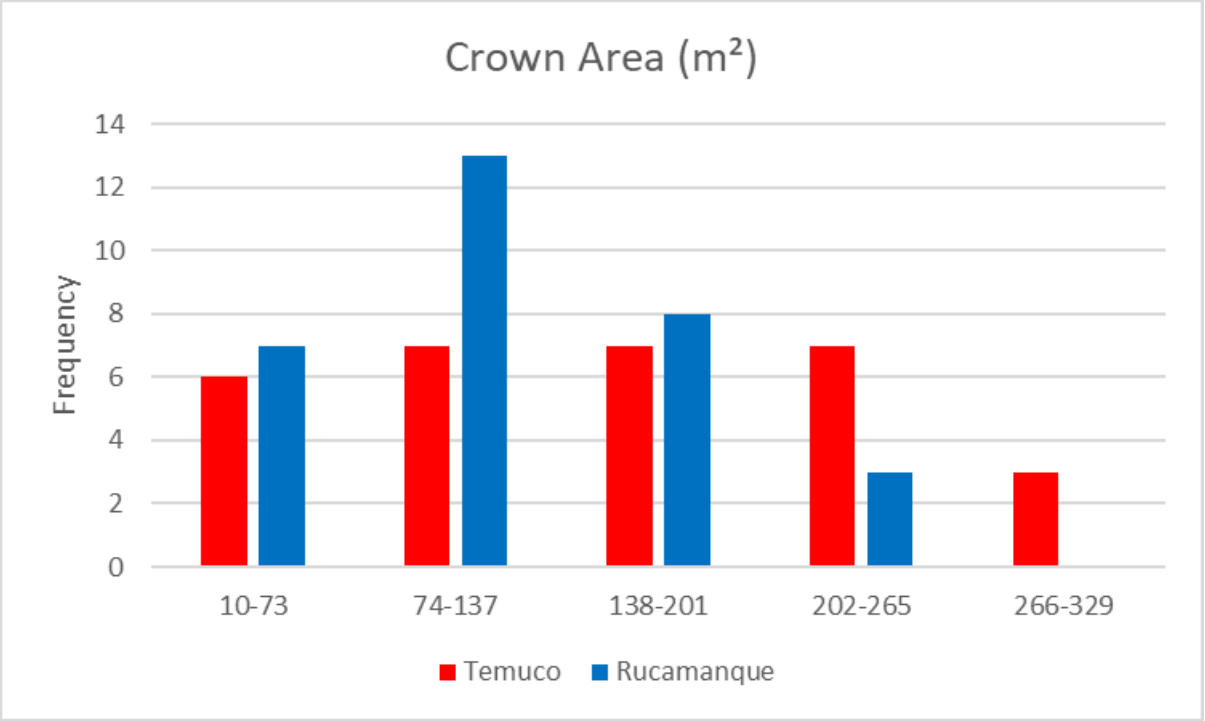
The average height in Rucamanque was 46,8m, while the average in Temuco was 27,3m.

In terms of how the trees´ heights compare to Torre Caupolicán, the highest building in Temuco, it was found that the robles in Temuco only measure a maximum of 0,53 towers,

while those of Parque Rucamanque measure a maximum of 0,81 towers. Almost all (31/32) of the robles measured in Temuco measured a quarter or less of the Torre Caupolicán. Equivalents for the heights of each of the top five trees in each location were included on their wayside signs.

Figure 4. Crown Area Parque Rucamanque and Temuco

There was a greater number of trees in Temuco with widespread crown areas than in Parque Rucamanque. Further, the trees with the largest crown areas were located in the city.

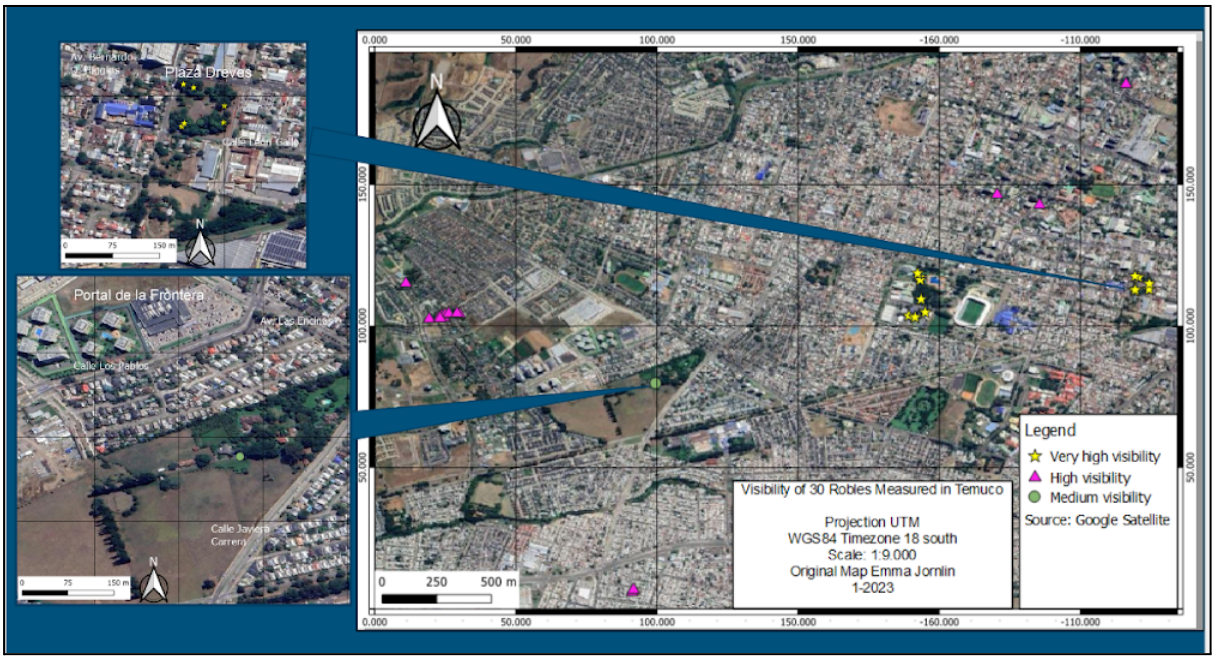


On average, the crown area was greater in Temuco (155,7m²) than in Rucamanque (116m²) (Table 1). In fact, Temuco´s crown areas were found to be significantly greater than those in Rucamanque, with a p-value of 0,035, less than alpha 0,05.

5.3 Visibility

Most of the robles were in very visible locations, and therefore have high ornamental value. The roble near Portal de la Frontera was the largest and perhaps oldest roble found in Temuco, however, is located on a less busy residential street and therefore had relatively low ornamental value and was not included in the top five robles.

Figure 5. Map with visibility of robles measured in Temuco. Robles at Plaza Dreves (top left) are highly visible. Although the roble near Portal de la Frontera had the largest DBH and minimum age, it was in a relatively hidden location, lowering its overall ranking.



5.4 Minimum age of Temuco´s robles

Due to many of the trees being rotten inside, many of the core samples came out of the tree incomplete. Also, many of the core samples crumbled in the process of taking them out of the tree, mounting them, and sanding them. Finally, most of the rings were too difficult to read by a novice researcher. Core samples from Temuco were given priority, as that location is the priority for the patrimonial tree route.

About 60% (18/32) of the core samples from Temuco had been measured by this study´s publication. The number of rings counted on the core sample using the software Coorecorder will be treated as their minimum ages. Minimum ages ranged from 33 to 132 years, with most robles falling in the range of 72-114 years old at minimum (Table 6).

Table 6. Estimated Age and Minimum Age (years) of robles measured in Temuco and Parque Rucamanque

	Temuco			**Rucamanque**		
	Min.	**Average**	**Max.**	**Min.**	**Average.**	**Max**
Age in years based on DBH equation 1*	175	334	511	341	412	496
Age in years based on DBH equation 2**	73,3	81,4	88,2	81,9	84,7	87,7
Minimum age (years) based on core samples	33	82	132	Not measured		

* Age =1024,862824*exp(-112,0580369/DBH) (Marinao, 2005, 37). The equation to estimate age based on DBH produced little variation in age. It also estimated a tree being 511 years old in Temuco, more than the estimated age of the oldest known roble in the world.

**Age= 1/(0,00984776+0,240063/DBH) (CONAF, 2013, 20). The equation to estimate age based on DBH produced little variation in age.

No core samples were able to be measured in Parque Rucamanque. In Temuco, 18 core samples were measured and their minimum age was estimated.

Minimum age produced by core samples suggests greater, more realistic, variation than age estimated by DBH (Table 6). Core samples can only be used to estimate minimum age at this point, as the total age has yet to be determined.

The minimum age is estimated to represent on average less than half of each roble´s life, due to the length of the core sample in proportion to their radii. The roble located near the shopping center Portal de la Frontera, is likely the oldest roble in the city. It has a minimum age of 132 years. On average, the minimum age of robles in Temuco is about 82 years old. Therefore, it is likely that many robles are older than the city itself.

5.5 Biocultural values

Only one person responded to the formal survey, Rodrigo Gutiérrez, the city representative in charge of the Urban Parks Department, la Unidad de Parques Urbanos del Municipio de Temuco. He did not have additional contacts who could be surveyed, and the rest of the individuals contacted did not respond.

Mr. Gutiérrez listed the following trees as most valuable:

Roble near Portal de La Frontera
Five robles in Plaza Dreves
Roble on Calle Recreo
Roble on Calle Hochstetter

He stated that these trees possess all the values listed in the survey (See Annex, values a-i).

Mr. Gutiérrez listed a number of descriptive values, which were not included on the signs for each patrimonial tree due to limited space, but which could be useful for the digital patrimonial tree tour (Anex 2). He stated that the robles are valuable for their historic, environmental and cultural value. For example, they tell the story of the location´s natural history and provide hope in the face of environmental disaster. He stated that wildlife depend on them, especially raptors, depending on them for perching sites. He also mentioned that the selected robles help give residents there a sense of identity.

Informal surveys revealed additional details (Anex 2). A group of city grounds crew workers at Parque Estadio German Becker stated that they support digüeñes, mushrooms endemic

to Southern Chile, in August and September. They also shared that the robles in the park provide nutrients to the soil through the leaves they drop.

At the Teatro Municipal, the security guard said that the roble in front of the theater helps regulate the temperature and is a site of recreation; young children play around it (Anex 3).

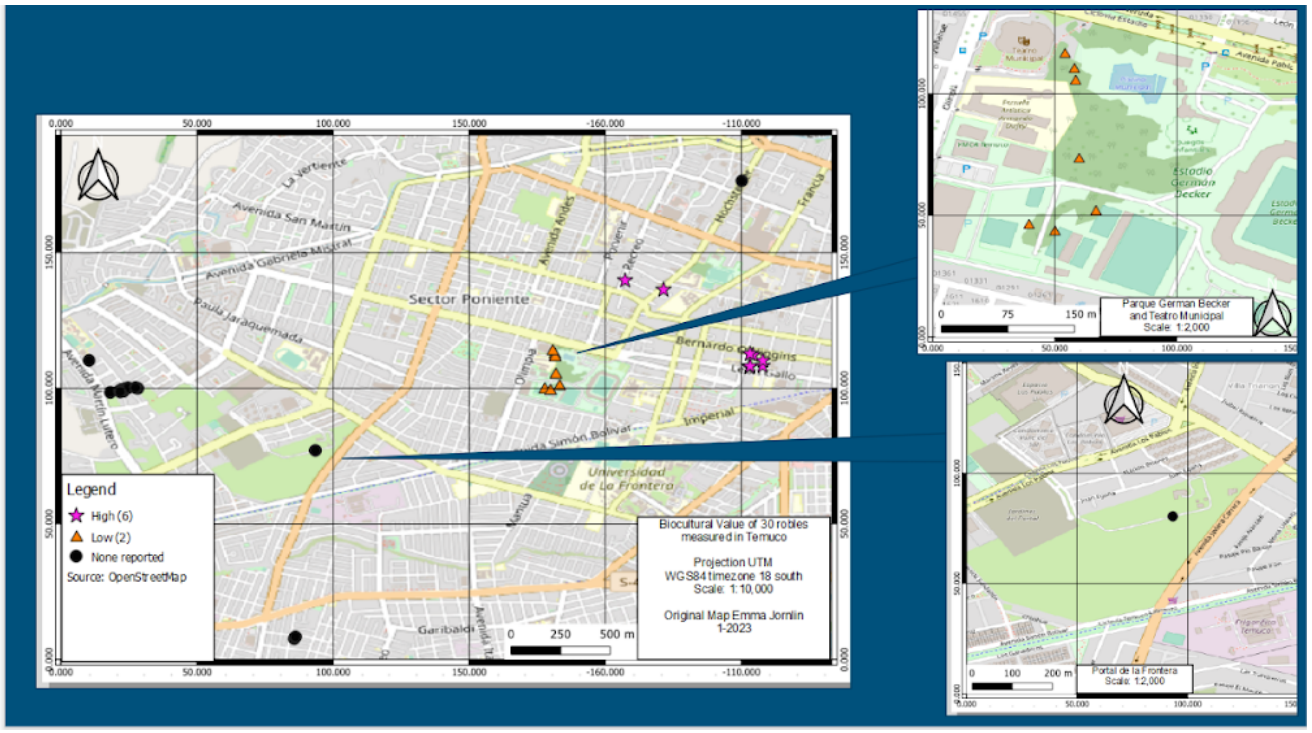
Overall, of the 30 robles measured in Temuco, about half (15) were cited as having cultural value (Table 4). The value most cited was the ability of the trees to provide shade/temperature regulation, with fifteen of the trees (50%) cited by survey respondents as providing this ecosystem service. Fourteen trees (47%) were listed as serving as habitat, meaning it supports plants and/or animals, and they were in relatively busy parts of the city. Nine trees (30%) were said to contribute to health/wellbeing. Eight (27%) were listed as having aesthetic value, meaning they provide beauty to the community. In terms of reducing contamination, only eight (27%) were named. There were also eight trees (27%) listed as providing erosion control. No trees were cited as serving as a historical relic of boundaries, avenues, ancient cemeteries, or providing support for economic development, or being of spiritual/religious value.

5.5.1 Biocultural Value Ranked

Trees measured in Plaza Dreves, Calle Recreo, and Calle Hochstetter, had the highest biocultural value, with 12 values cited. Robles located further north or to the west, such as those on the streets Martin Lutero, Venus and Neptuno, and Clínica Mayor, had the least biocultural value cited, with zero (Figure 6).

Those in Plaza Dreves boast a plethora of values: temperature control, beauty, ability to clean the air, erosion control, history, and wildlife support.

Figure 6: Map showing Biocultural Values of Robles in Temuco. Robles located in Plaza Dreves, Calle Hochstetter and Calle Recreo were reported to have greater biocultural value than those in the rest of the city



5.6 Overall Ranking

5.6.1 Rucamanque

The top valued robles in Parque Rucamanque were mostly located on Union, Pu Aliwen, and Triwe trails (Table 7).

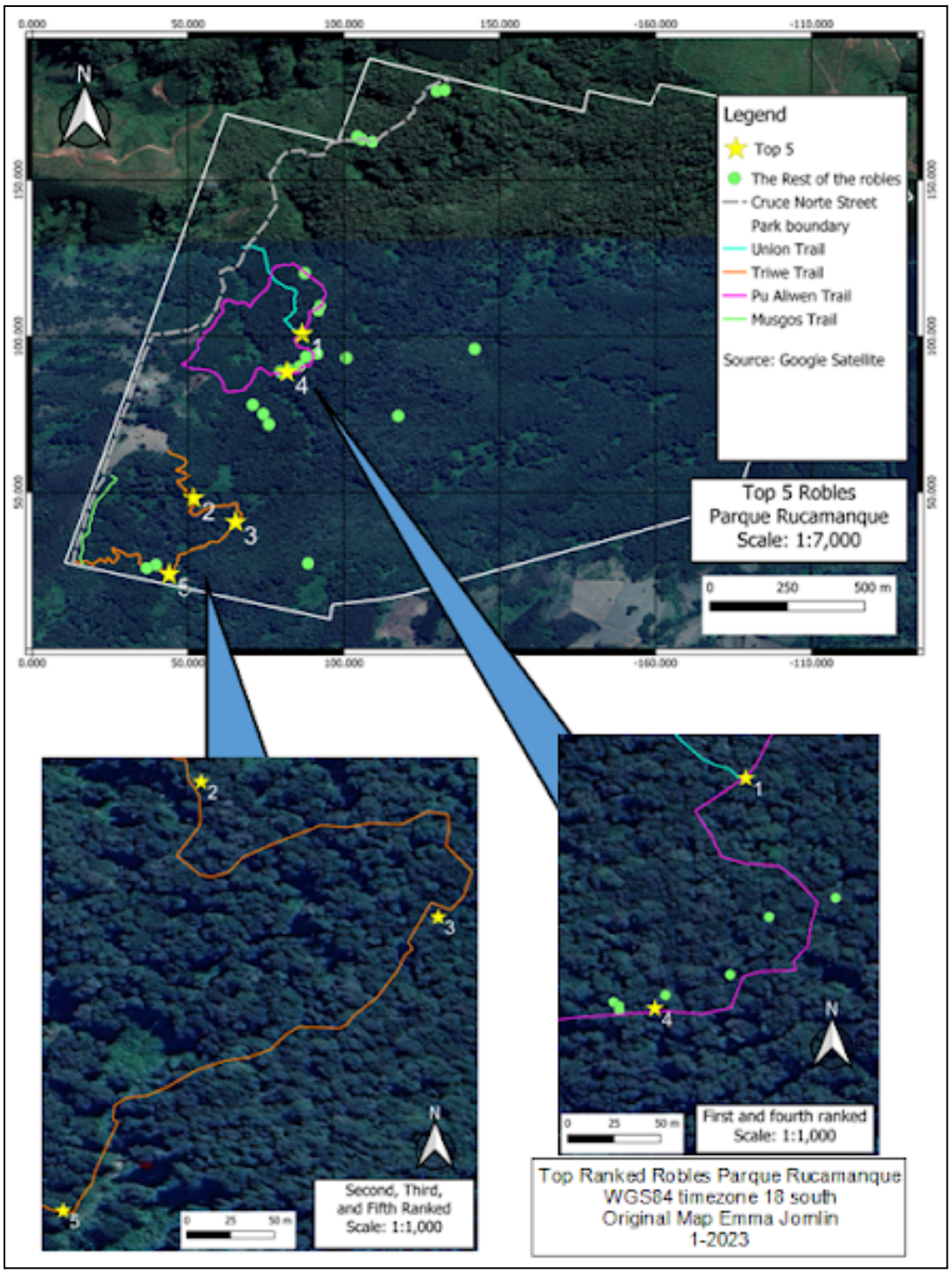
Table 7: Top 10 Recommended Robles for a Patrimonial Tree Route in Parque Rucamanque. The majority of the top ranked robles in Parque Rucamanque are located on the Pu Aliwen Trail, followed by Triwe Trail.

Rank	Point Value	Location	UTM E	UTM N
1	23	Union Trail and Pu Aliwen Trail	708874	5718519
2	22	Triwe Trail	708506	5717853
3	22	Triwe Trail	708639	5717751
4	21	Pu Aliwen Trail	708821	5718363
5	20	Triwe Trail	708419	5717543
6	19	Triwe Trail	708377	5717583
7	19	Near Pu Aliwen trail	708799	5718368
8	19	Near Pu Aliwen trail	708935	5718631
9	18	Near Triwe Trail	708347	5717570
10	18	Near Pu Aliwen trail	708889	5718768

The five most valuable trees in Parque Rucamanque are located close to one another, one could even walk the route in one day. Two of the trees can be accessed from the Pu Aliwen trail: the top tree is located on the intersection of the Union trail and the Pu Aliwen trail, and

the fourth tree is located further on the Pu Aliwen trail. The Triwe trail contains the second, third, and fifth top ranked trees (Figure 7).

Figure 7: Map showing Top Five Suggested Patrimonial Robles for Tree Route in Parque Rucamanque



5.6.2 Temuco

Ranking for the 30 robles in Temuco determined that the robles in Plaza Dreves had the highest overall value, with a point value of 28-36 (36 being the highest overall ranking in Temuco). The top two robles were in Plaza Dreves, while the third top ranked roble was in front of the Teatro Municipal, with 31 points. Other high ranked individuals were located in Parque German Becker, Call Hochstetter, Calle Recreo, and a site near Pumahue (Table 8).

Table 8: Top 10 Recommended Robles for a Patrimonial Tree Route in Temuco

Rank	Point value	Location	UTM E	UTM N
1	36	Plaza Dreves	707687	5709230
2	32	Plaza Dreves	707623	5709276
3	31	Teatro Municipal	706627	5709318
4	30	Plaza Dreves	707639	5709268
5	30	Plaza Dreves	707618	5709190
6	29	Parque Estadio German Becker	706580	5709072
7	29	Hochstetter St.	707197	5709703
8	28	Recreo St.	707004	5709768
9	28	Site near Pumahue	704451	5709116
10	28	Plaza Dreves	707622	5709196

The majority of the top ranked robles in Temuco are located in Plaza Dreves and Parque Estadio German Becker. Most of the top ranked robles were in plazas or parks, highly visible locations (Figures 5 and 8).

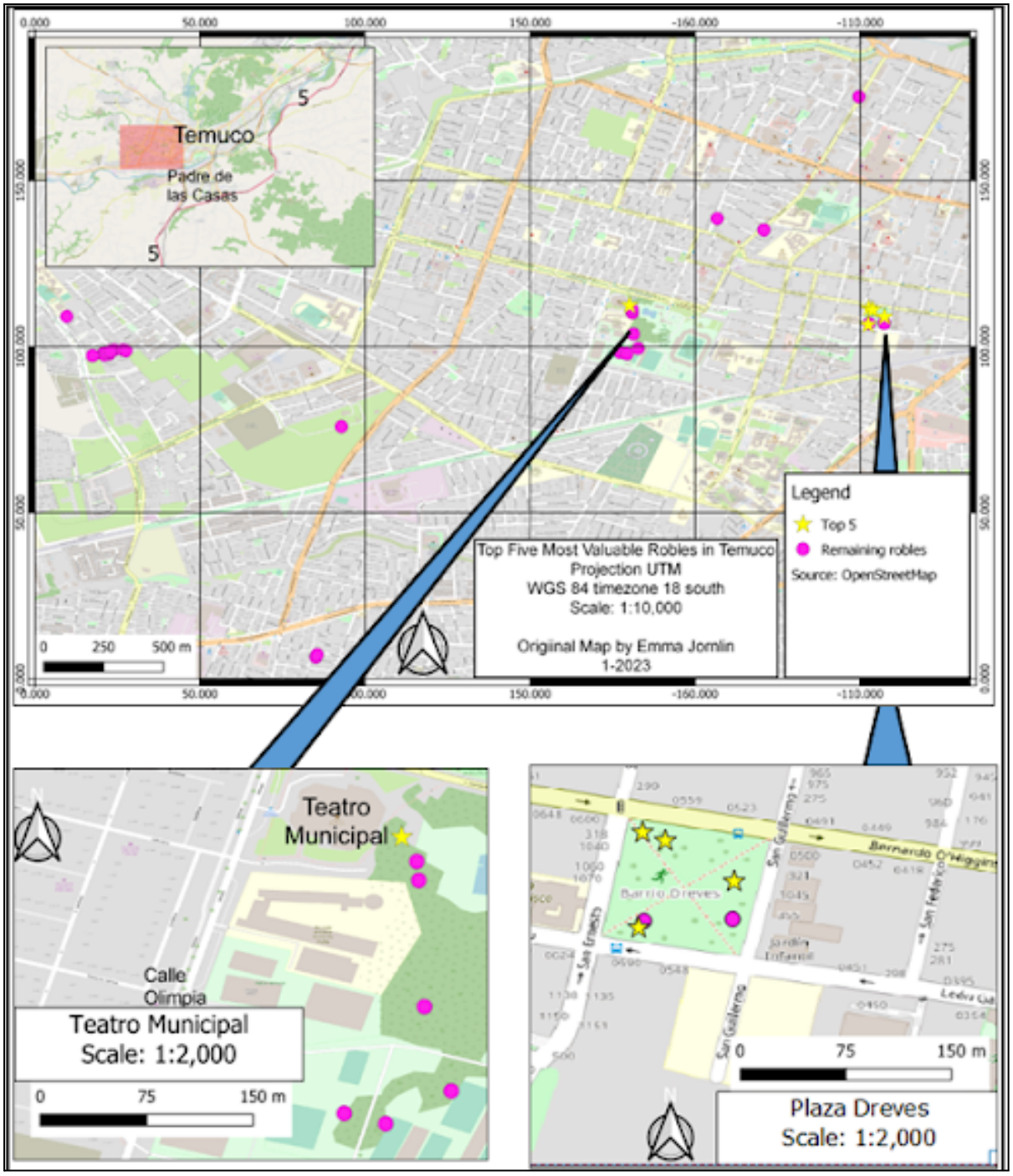
Neither the oldest estimated roble nor the largest roble in Temuco were selected as one of the top five patrimonial trees. The top five ranked robles in Temuco had a minimum age range of 49-99 years, while the oldest, estimated to be a minimum of 132 years old, was ranked seventh in patrimonial ranking. In fact, the average minimum age was 82, and only one of the top five was older than that. The DBH of the top five robles was mostly above the average of 101,7 cm, and ranged from 85-127 cm, compared to the maximum of 161 cm in Temuco.

The heights ranged from 26-35 m, compared to the tallest roble found in Temuco, 39 m. They were all except one taller than the average roble measured, 27,3 m.

While the top five ranked robles did not include individuals with the largest DBH or height, the method used did result in the tree with the largest crown area being included. The tree with the largest crown area, 323 m², was ranked the fourth most valuable patrimonial tree. Also, the top five had larger crown areas than the average for Temuco; crown area for the top five ranged from 206-323 m², all of which were greater than the average, 155,7 m².

The top five were also chosen for their biocultural value, for which all had four in Plaza Dreves had six biocultural values. The one in front of Teatro Municipal scored a two. In terms of aesthetics, the reverse occurred: the roble at Teatro Municipal scored the highest, as it is a quiet area, with less traffic, easy to get to and to walk around there. Those at Plaza Dreves did not have such high ranking, scoring a 4, as there is some traffic. Finally, all of the top five received the highest visibility score, another reason why they were selected as patrimonial trees.

Figure 8: Map showing Top Five Suggested Patrimonial Robles for Tree Route in Temuco. The majority of the recommended patrimonial trees are located in Plaza Dreves. A fifth tree is located in front of the Teatro Municipal next to Parque German Becker.



Groups of Robles

It would be easier to protect groups of trees growing close to one another. Groups with the greatest value measured include the robles located at:

1. Site close to Pumahue and Pedro Arias Davila Street (8 robles)
2. Parque Estadio German Becker and the Municipal Theater (7 robles)
3. Plaza Dreves (6 robles)
4. Venus and Neptuno Streets (2 robles)
5. Hochstetter and Recreo Streets, with Antumalal (2 robles)

Plaza Dreves and Parque Estadio German Becker feature the most robles with top ranking; Plaza Dreves has four of the five top robles, and Parque Estadio German Becker has the third ranked roble (Figure 9).

Figure 9: Map showing Plaza Dreves: Suggested area to focus Conservation Efforts on. Robles in Plaza Dreves with Diameter Listed.

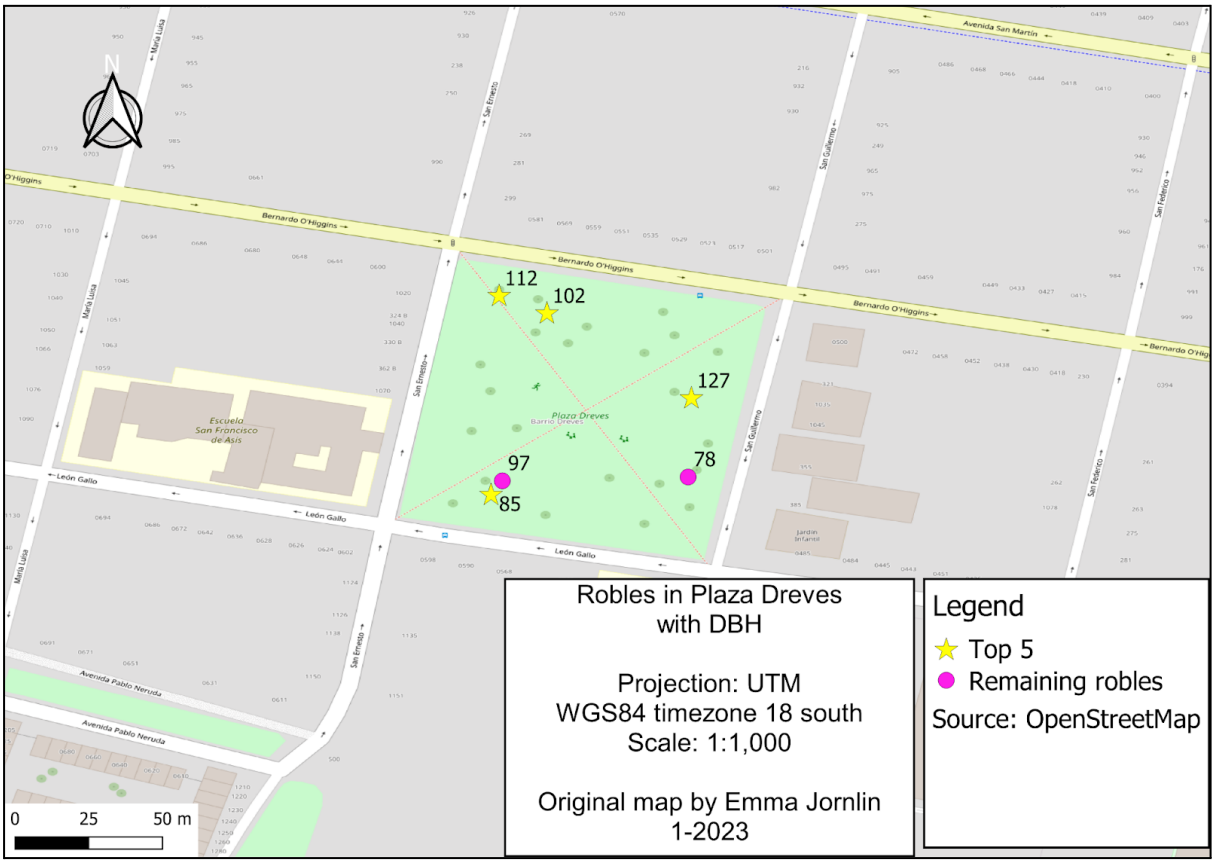


Figure 10: Parque German Becker: Suggested area to focus Conservation Efforts on

5.7 Educational materials

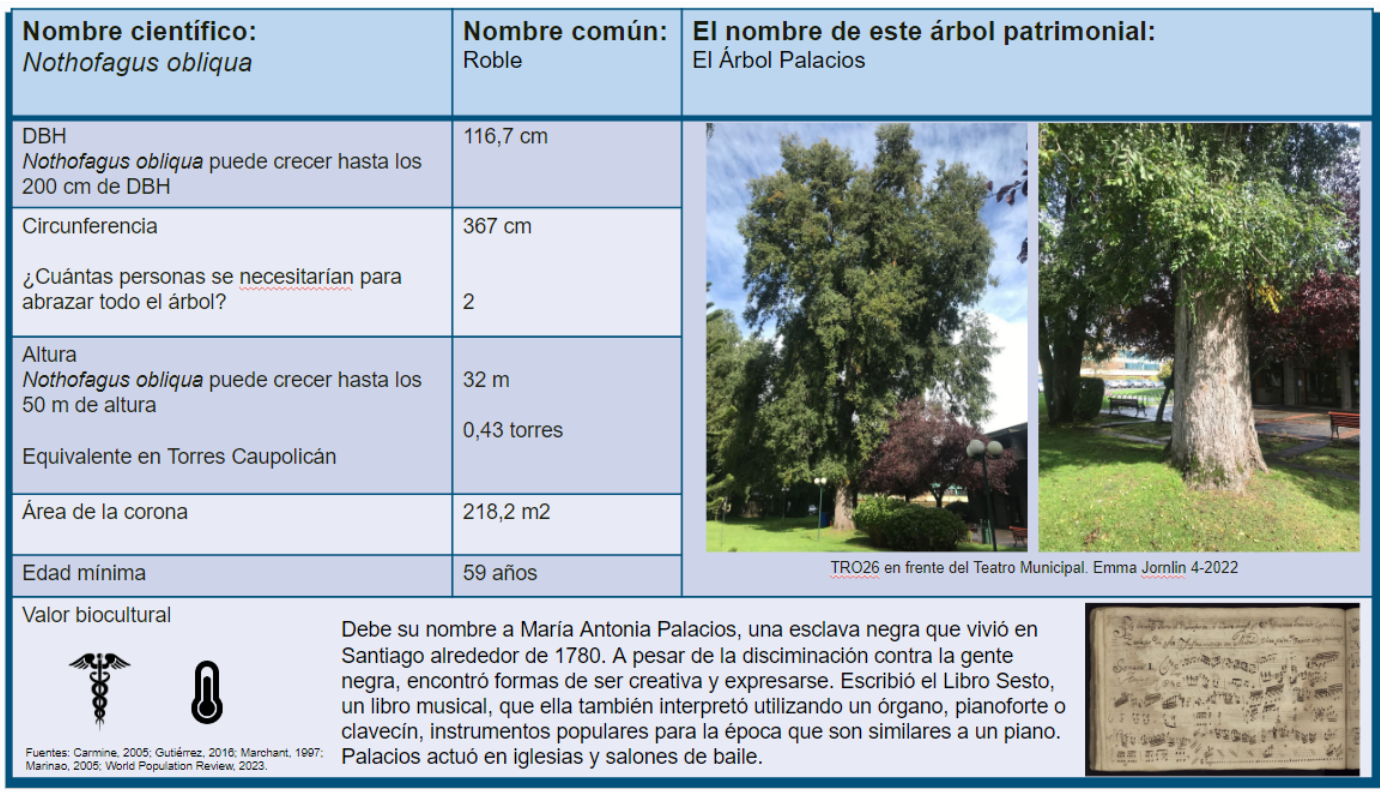
Patrimonial tree pages, or fichas in Chilean Spanish, were created for the top 5 robles in both Parque Rucamanque and Temuco.

In Parque Rucamanque, the top five trees were given names of animals that inhabit Parque Rucamanque: *Pumas, Pudu, Monito del monto, Zorro culpeo, and Chucao* (these names are only suggestions used to give an idea of what a wayside could look like).

In Temuco, trees were given names of historically famous Chilean women who have been a part of social movements. (These names are only suggestions used to give an idea of what a wayside could look like).

Example of a patrimonial tree page for Temuco:

Figure 13: Three Suggested Educational Wayside Signs for the Patrimonial Tree Route



Género: Nothofagus
Familia: Fagaceaes
Especie: *Nothofagus obliqua* (Mirbel) Oersted var. Obliqua
Nombres comunes: Roble, Hualle (roble jóven)
Pellín, coyam o coyán (nombres Mapuches)

Estado de conservación: **Vulnerable (V)**

Características: Árbol de hoja caduca. El tronco es de color marrón oscuro y, a menudo, se divide en dos grandes ramas. Las hojas se vuelven de color amarillo-naranja-marrón en otoño (marzo-mayo) y caen en invierno (junio-septiembre). Roble crece hasta 53,5 metros de altura, 2 metros de diámetro y 20 metros de diámetro de dosel. Puede vivir hasta 500 años.

Ecología:

Distribución y hábitat: Especie nativa de los bosques templados de Chile y Argentina. En Chile, se encuentra desde Valparaíso hasta Los Lagos. Crece hasta los 2.500 m.s.n.m., pero típicamente alrededor de los 600 m.s.n.m. Mezclas con raulí, lingue y laurel.

Requisitos: Se desarrolla en climas mediterráneos. Requiere disponibilidad hídrica. Prefiere suelos profundos y fértiles. Puede vivir en suelos de PH neutro a ácido.

Interacciones: Relación simbiótica con las abejas, que recogen el néctar de sus flores y las polinizan y con el digüeñe, hongo comestible que crece en sus ramas.

Fuentes: Marinao, 2005; Ibáñez, 2022; Ojeda *et al.*, 2013; Romero y Hauenstein, 2014; Ferreira *et al.*, 2018; Montenegro, 2000.

Crédito: Emma Jornlin

Crédito: Chris Valdes

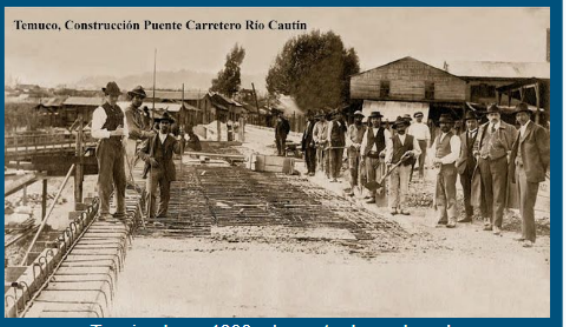
Digüeñe (*Cyttaria espinosae*),
Crédito: Helena Bricio

Historia de los Robles Patrimoniales en Temuco: Sobrevivientes

La zona que estás viendo solía estar cubierta por un impenetrable bosque templado caducifolio. Dentro del bosque había árboles de roble, raulí, coigüe y lingue.

Roble es considerado un árbol sagrado por los mapuches, y usaban la madera de roble para sus chemamull, o esculturas, y en los funerales.

A partir de 1889, los angloamericanos comenzaron a talar el bosque y crear lo que ahora es Temuco. El roble era la especie más comúnmente cortada, ya que se prefería la madera para construir estaciones, puentes y casas. Gracias a la abundancia de robles, la construcción fue barata. La población aumentó rápidamente.



Terminado en 1898, el puente de madera de roble permitía los cruces ferroviarios, la importación y exportación de mercancías desde y hacia la ciudad.
Fuente

¿Cuántos años piensas tenían los árboles cuando fueron cortados para construir Temuco?

Aparte de su valor en la construcción, ¿por qué son importantes los árboles grandes y antiguos?

Fuentes: Skewes y Guerra, 2015; González y Godoy, 2020

6. DISCUSSION

In this study, *Nothofagus obliqua* (roble) trees in Temuco were studied, as they are potentially the most bioculturally valuable and abundant of the large native trees in Temuco (Municipalidad de Temuco, November 2021; Riedemann and Aldunate, 2011). The goal was to determine which would be most deserving of patrimonial protection and inclusion in a tree tour. Of the top five robles recommended for patrimonial status in this study, most had relatively great DBH and height. They were all located in parks or greenspaces, specifically Plaza Dreves and Teatro Municipal, highly accessible and visible to the public.

Results from this study add to the existing knowledge about patrimonial trees, and the characteristics of robles in Temuco. According to the bibliographic review, in Chile, the concept of ´patrimonial tree´ is relatively new and there are very few studies on the subject (Facforen 2022). There has never been one before in Temuco. Therefore, this discussion will be limited to comparing this study to the national Chilean patrimonial tree project, a study in progress in Valdivia, Chile, and ones in Bogotá, Colombia, as well as in Quito, and Riobamba, Ecuador.

Chile's national patrimonial trees program focuses on culturally valuable patrimonial trees (Castillo Ibáñez, 2022), without giving much attention to the other characteristics typically included in patrimonial systems in other countries. More international values were given equal weight in this study: DAP, age, height, crown area, visibility, aesthetics of the area, perception of social value, comparison to robles in reference ecosystem.

Older trees are valuable because they contain information about climatic variability, fires, and other historic patterns. They serve as landmarks, and beacons of hope that humans can protect nature against dismal events such as climate change. The top ranked trees in this study were not the oldest, however two of the top five trees in this study had an estimated minimum age over 70 years, which is likely the minimum required to be as old as the city itself, as on average, core samples represented 50,24% of the radius and the city is 140 years old.

In terms of diameter, this study showed that there are individuals in Temuco as large as 161 cm DBH and 39 m height. It also found new large individuals to add to databases for the park. The largest height measured in Parque Rucamanque, 60 m, was possibly an error, as that would make it taller than the tallest measured roble in the world. However, this is the only error. The study found there are relatively large robles by DBH in the city and park. The average DBH for robles measured in the park in this study was 123,5 cm and the maximum

was 154,4 cm. This is larger than the 50 robles *Marinao et al.* (2005) measured, the average being 62,8 cm and maximum 125,5 cm.

In terms of age, this study also demonstrated that there is at least one tree that is a minimum of 132 years old, and half of the robles present minimum ages of more than 70 years, meaning their true age could very well be older than the city itself, 140 years, as the core samples generally represented about half or less of the total radius. Another reason to suggest that many of the robles measured are older than the city is the fact that in the reference ecosystem, a minimum age of 284 years was estimated from a core sample taken from a tree measured 81,5 cm (Marinao *et al.*, 2005). 93% (28/30) of the trees measured in Temuco had diameters over 81,5 cm. While diameter is not a sure test of age, it is likely that a tree twice the size (DBH) must be at least as old. For example, in Sequoia National Park, the General Sherman tree is the same age as another tree located in a less favorable part of the park. The other tree is half its size but is still 2,200 years old. Likewise, trees located in the city may be the same age as those in the reference ecosystem even when they are half the size because it simply takes them longer to grow in a poor environment.

In terms of size (DBH, height, crown area), this study found that there are many relatively large robles in Temuco. There were 17 trees measured that were over 100 cm in diameter, the requirement to be a part of Valdivia´s patrimonial tree system (Facforen, 2022). Information about the characteristics of trees included in Valdivia´s system has not yet been published, therefore it's unclear if 17 is a high number or not. What is known is that the largest diameters found in Parque Rucamanque (154.4cm) and Temuco (161.2) were both less than the record for robles, which is about 200 cm (Gutiérrez, 2016), but were still quite large. There were relatively tall robles found in Temuco, but nowhere near the heights of those found in Parque Rucamanque or other parts of the world. Crown area, on the other hand, was larger on average in the city than the forest, with an exceptionally large area in Temuco of 323,58 m². There is little information about crown area of robles published.This is an important variable to know, as most of the photosynthetic activity occurs in a tree´s crown area, meaning they likely produce a lot of oxygen for the city. Their crown area is also an important source of shade to be valued given the urban heat sink effect, exacerbated in Temuco by its location in a valley.

In terms of the physical dimensions of robles, the results found in Rucamanque were similar to those found by Marinao (2005) and Salas (2012) regarding DBH of trees: they had found DBH of about 111 cm-158 cm, while in this study, DBHs of 102-155 cm were recorded in Parque Rucamanque. However, this was the first study addressing which large robles in

Parque Rucamanque are valuable because of their visibility. As such, some of the largest trees were not able to be included in the final ranking because of their remoteness.

Although survey participants were given the option of electing cultural values for the individual trees, there were few reported. Only eight of the thirty trees in Temuco were said to provide aesthetic value, and none were said to provide a historical relic of boundaries, avenues, ancient cemeteries, or providing support for economic development, or being of spiritual/religious value. This was somewhat surprising, given that robles are not unattractive trees, and are known to be sacred to the Mapuche indigenous people. However, there weren't any robles cited by the national study as having these values, either. It´s possible that survey participants simply didn´t know about the cultural values associated with specific trees.

There don't appear to be any patterns about where trees with certain biocultural values are located. For example, in both this study and others, there are no striking findings about robles with more ability to provide habitat being located in the middle of a city versus on the outskirts, nor that they have more aesthetic value in certain locations. Nor do there seem to be patterns about where the oldest robles are located, suggesting that cutting down or conserving the trees was not concentrated solely in certain areas, but rather sporadic.

The principal limitation to the study was having such a small sample of survey participants. It was dubious whether citizens would have enough knowledge or interest to be able to participate. The goal in Temuco was also to achieve quality over quantity. But more responses are certainly needed. Civic participation in patrimonial tree projects has been cited as being important in Colombia and Ecuador, as it incorporates people's knowledge and can better guarantee sustainable management (Cortés Cortés, 2013; Vizuete, 2008). A survey about patrimonial trees in Riobamba, Ecuador, which has nearly half the number of residents as Temuco, included 400 people (Vizuete, 2008). In future studies, trees located on private land should also be included, if possible, surveying residents and/or neighbors familiar with the trees. This didn't happen in part because there were no existing connections to neighbors located near the robles selected for their DBH.

Minimum age is an important aspect in most patrimonial tree studies. Age was unable to be determined for nearly half the roble trees in this study. The equations from Marinao (2005) and CONAF (2013) for age based on DBH seemed quite erroneous. They produced a very small range for most of the values (estimates of 341-496 years for Rucamanque for the Marinao equation, 82-88 years for Rucamanque and 73-88 years for Temuco for the CONAF equation), and inaccurate results (the oldest tree found in Rucamanque was only 88 years

old (CONAF equation), but Marinao (2005) found a 500 year old roble). Core sampling can produce more accurate results. However, often the robles in this study were rotten in the center, the core samples crumbled, and by nature it is difficult to read the rings of core samples taken from this species. Future studies done by researchers at the Universidad de la Frontera will look at the true age of the trees.

The results of this study will hopefully assist decision makers by providing information about which trees possess the best traits for patrimonial designation and/or tree tours, as well as which trees/zones to prioritize in eventual management plans. It is expected that the education conducted through the self-guided patrimonial route will result in greater knowledge of, empathy for, and connection to robles included on the tour, and better conservation of all robles in Temuco (Ruchter *et al.,* 2010). The descriptions in the tour will serve as a reminder of how the local environment helped create and continues to support the culture and community that exists today, fostering desire for its protection. The project can even attract tourism, which can encourage conservation and economic gain (Taylor, 2016).

This study will also support educational efforts to increase knowledge of and appreciation for native trees in the area. Through the digital tour, more people are able to differentiate between a roble and a pine or eucalyptus tree (Carbó, 2018). Tree tours will increase visitation at Parque Rucamanque, in an effort to raise awareness and conservation of the robles studied there. In all informal conversations with people living locally in Temuco, and the neighboring towns of Pucón and Villarrica, no one had heard of Parque Rucamanque before. Also, it hardly receives any visitors, according to staff consulted informally. If it is important to the park to increase people's awareness of it, as the Management Plan says (Nuñez *et al.*, 2015), a patrimonial tree route could be an excellent way to do so.

Finally, this study can serve as a prototype for other parts of Chile because the genus *Nothofagus* has a large range in the country; it dominates the temperate and subarctic forests of Chile from 33° S to 56° S (González and Godoy, 2020). The species *Nothofagus obliqua* can be found in an extensive territory, from the Province of Colchagua (VI Region) to the Province of Llanquihue (X Region) (Donoso, 1987). The study methods and system used in this study for selecting and educating about patrimonial roble trees can serve as a model for other locations that seek to conserve members of this valuable genus and species by identifying patrimonial trees.

The findings of this study show that there are at least 30 robles in Temuco that would be deserving of patrimonial protections, and that five in particular stand out, mostly for their

diameters, in one case impressive height, for their accessibility, and in some cases for their age and/or what they offer for the human, animal, and fungal community. Furthermore, this study shows that a great number of urban robles in Temuco had impressive crown areas, relative to those in the reference ecosystem.

Further research could consist of more in depth research about biocultural values. For example, although only eight of the thirty trees were said to have aesthetic value, it is likely that a greater percentage do, which is likely part of the reason they haven´t been cut down. Other patrimonial tree systems, such as Quito and Riobamba, Ecuador, included a lot of citizen input and help in cataloging their trees (Polo *et al.*, 2017). Surveys could be conducted with neighbors in Temuco concerning the cultural value, history, folklore and stories of the trees. Specifically, surveying Mapuche people may add a lot to future studies. During the study in 2021, there were Mapuche people protesting outside Parque Rucamanque, claiming the land, including the park, as their own. Protests by the Mapuche people in other parts of the Araucania region are also fairly common, given the controversial colonization (Maturana *et al.*, 2021). They may have historic, or actual ties, to specific trees in these areas, and could talk about their biocultural values. Civic participation in designating patrimonial trees is key, as it leads to more complete information about the trees, can increase acceptance of policy, and can also increase the collective sense of responsibility for environmental protection(Benedetti *et al*. 2023).

One of the benefits of patrimonial trees is their ability to inspire awe, which can in turn promote trust and bonding in a community, and decrease stress (Reese, 2023). If there is a way to measure which trees are most awe-inspiring, without it being too subjective, this would be a study worthy investing in for the future.

Finally, different spatial studies could be conducted. For example, what percentage of patrimonial trees are located in low income neighborhoods vs. high income? How close are trees to current waterways? What about historic waterways? The health of the trees studied could also be measured, as this is commonly a variable in patrimonial tree studies (Cortés Cortés, 2013). In Bogotá, they found that trees in institutional spaces are in better sanitary condition than trees in public spaces (Cortés Cortés, 2013). Is this true in Temuco? This could help in creating a management plan for the trees´ long term conservation.

7. CONCLUSION

Though they are not as large by diameter and height as those in Parque Rucamanque, their reference ecosystem, the robles measured in Temuco are still relatively large for their species and many have high biocultural value. The finding of a minimum age of 132 years in Temuco means that it is likely that some of the trees are older than the city itself. The top ten robles identified in this study fit in well with Temuco´s concept of patrimonial trees and with Chile´s national register of patrimonial trees, and could be used in either or both systems. The top five robles that are recommended for the patrimonial tree route in Parque Rucamanque include individuals on the Union, Pu Aliwen, and Triwe trails, valuable for their size (DBH, height, crown area) and accessibility. The top five most valuable robles in Temuco are those located in Plaza Dreves and outside the Teatro Municipal. Those in Plaza Dreves boast a plethora of values: temperature control, beauty, ability to clean the air, erosion control, history, and wildlife support. The fourth most valuable roble, outside Teatro Municipal, is valued for its temperature control, recreational value, and size. It is recommended that these ten trees be designated as patrimonial and that they be included in a patrimonial tree route. In order to achieve the goal of protecting Temuco and Parque Rucamanque´s patrimonial trees, it will be important to conduct surveys before and after the creation of the patrimonial tree route, and any other educational initiatives, to determine their effectiveness.

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9. ANNEX

9.1 Formal survey

Encuesta sobre los *Nothofagus obliqua* (robles) patrimoniales en Temuco

Hola, me llamo Emma Jornlin y soy tesista en la Universidad de Chile, programa MASCN. Mi tesis se llama ¨Caracterización de los árboles patrimoniales de *Nothofagus obliqua* en la ciudad de Temuco.¨

Me interesa saber cuáles robles Usted cree que deberían ser designados como patrimoniales. Un árbol patrimonial en la ciudad de Temuco recibiría más protecciones, como multas más altas por daño infligido. La información puede ser utilizada para una ruta de árboles patrimoniales de Temuco.

El enfoque de este estudio es en robles en Temuco que son excepcionales primero por su tamaño (DBH), luego por razones culturales, historia, etc. Ya identificamos los 32 individuos más grandes; están en los mapas (adjuntos). Me gustaría que Usted elija cuáles de estos árboles cree que deberían ser considerados patrimoniales, e identifique los valores socioculturales y/o las historias de ellos. Nivel individual sería ideal, pero puede ser a nivel grupal, también.

Nombre: **Fecha:**

Municipalidad/Comunidad/Universidad (elige uno)

Definición de un árbol patrimonial

Un árbol puede ser considerado patrimonial porque uno o más de los siguientes razones:

a. Apariencia

b. Regulación de temperatura/sombra

c. Creación de hábitat

d. Reducción de la contaminación

e. Contribución a la salud/bienestar de los seres vivos

f. Control de la erosión

g. Reliquia histórica de fronteras, avenidas, cementerios antiguos

h. Apoyo para el desarrollo económico

i. Valor religioso/espiritual

Por favor, identifique cuáles robles de los identificados (en los mapas) en los siguientes lugares Usted elegiría como patrimoniales:

Calle Hochstetter

Calle Holandesa

Calles Martin Lutero St. y Los Tepúes

Near Portal de La Frontera

Parque Estadio Germán Becker

Plaza Dreves

Calle Recreo

Sitio cerca de Pumahue

Teatro Municipal

Calles Venus y Neptuno

En cuál(es) árbol(es) está enfocando Usted:

1. **¿Qué está haciendo la municipalidad/la comunidad ya/qué tienen planificado para conservar estos árboles, o los robles en general en Temuco?**

2. **¿Recuerdas cómo era la naturaleza antes en Temuco? (eg. cuando eras niño/a)**

3. **¿Por qué piensa Usted que los robles más grandes/antiguos siguen aquí?**

4. **¿Por qué se debe conservar estos árboles?**

5. **¿Usted conoce alguna relación positiva entre los robles grandes/antiguos de la ciudad y ciertas especies de plantas o animales? (un ave que apoya, etc)**

6. **¿Conoce alguna relación positiva entre los robles más grandes/antiguos y las personas?**

7. **¿Qué sabe Usted sobre la historia de este árbol/estos árboles?**

-¿Pudiera compartir fotos/documentos que tiene de ellos?

8. **¿Qué se considera valorable de estos árboles?**

(elige uno o más)

a. Apariencia
b. Regulación de temperatura/sombra
c. Creación de hábitat
d. Reducción de la contaminación
e. Contribución a la salud/bienestar de los seres vivos

f. Control de la erosión

g. Reliquia histórica de fronteras, avenidas, cementerios antiguos

h. Apoyo para el desarrollo económico

i. Valor religioso/espiritual

Comentarios/Detalles adicionales:

¿Usted conoce alguien más que tenga información sobre los robles que pudieran ser patrimoniales?

Nombre/información de contacto:

¡Gracias por su participación!

9.2 Results of formal survey

The following are the responses to the formal survey from Rodrigo Gutiérrez, the city engineer in charge of Temuco´s Urban Parks Department, la Unidad de parques Urbanos del Municipio de Temuco. He commented on the biocultural value of the robles in Temuco:

¨They are live indicators of the environmental state of the city and a register of climatic variations. In the context of climate change, they represent a flag of the survival of nature in the city.¨

¨Son indicadores vivos del estado ambiental de la ciudad y registro de las variaciones climáticas. En contexto de cambio climático representan una bandera de la sobrevivencia de la naturaleza en la ciudad.¨

He stated that wildlife depend on them:

¨Their presence is very important, they serve as perches and nesting sites for birds. Principally raptors that have very important roles as pest control.¨

¨Su presencia es muy importante, se constituyen como perchas y anideros para aves. Principalmente rapaces que cumplen roles muy importantes en el control de plagas.¨

He also mentioned that the selected robles help give residents there a sense of identity:

¨They give identity to the sector they develop in.¨

¨Le dan identidad al sector donde se desarrollan.¨

-Rodrigo Gutierrez, MSc. Forestry Engineer, Head of the Urban Parks Department

-Rodrigo Gutierrez, MSc. Ingeniero Forestal, Encargado Unidad Parques Urbanos

9.3 Results of informal surveys

The following are the responses from informal surveys with grounds crew workers at Parque Estadio German Becker about the biocultural value of the robles there:

¨There are digüeñes (mushrooms endemic to Southern Chile) in August and September. All the trees here have them.¨

¨Hay digüeñes (hongos endémicos del sur) en agosto-septiembre. Todos aquí dan.¨

¨In April/May, they lose their leaves and the leaves provide a lot of nutrients for the soil. We can make compost. We can't do that with the álamo or pine leaves, their leaves are too acidic.¨

¨En abril/mayo botan sus hojas y las hojas aportan muchos nutrientes al suelo. Podemos hacer compostaje. No podemos hacer eso con las hojas de los álamos o pinos, son demasiado ácidas sus hojas.¨

-Jardineros/Funcionarios, Parque Estadio German Becker

The following are responses from an informal survey with a security guard at Teatro Municipal about the biocultural value of the roble in front of the theater:

¨It offers shade for people, especially those that sit on the benches in summertime.¨

¨Ofrece sombra para la gente, especialmente los que se sientan en las bancas en el verano.¨

¨Kids run around the tree.¨

¨Los niños corren alrededor del árbol.¨

-Security Guard, Teatro Municipal