Session 3.4

Some Like it Hot: Creating and sharing new knowledge and supporting education on the contribution of forests and trees to adaptation and mitigation to climate change

Chair: Jacob Hendee
Which Plant Where - climate-ready plant selection for resilient urban forests

Michelle Leishman, Alessandro Ossola, Samiya Tabassum, Gwilym Griffiths
BENEFITS OF URBAN GREEN SPACE

- Reduces obesity levels by increasing physical activity including walking and cycling
- Manages stormwater, keeps pollutants out of waterways, and reduces urban flooding
- Increases neighbourhood property values
- Reduces stress by helping interrupt thought patterns that lead to anxiety and depression
- Filters up to a third of fine particle pollutants within 300 yards of a tree
- Cools city streets by 2-4°F, reducing deaths from heat and cutting energy use
- Reduces rates of cardiac disease, strokes, and asthma due to improved air quality
- Protects biodiversity including habitat for migrating birds and pollinators

The Business Standard https://www.tbsnews.net/thoughts/urban-green-space-and-well-being-281461
But our urban green spaces face many challenges
...including climate change

Australia’s climate has warmed since 1910.

Rainfall has been very low over parts of southern Australia during April to October in recent decades.

Heatwaves have become hotter, lasting longer, and happening more often.

- Darwin: number of heatwave days have more than doubled
- Brisbane: heatwave days start 8 days earlier
- Canberra: number of heatwave days have more than doubled
- Sydney: heatwave days start 19 days earlier
- Melbourne: hottest heatwave day is now 2°C hotter; heatwaves start on average 17 days earlier
- Hobart: number of heatwave days have more than doubled
- Perth: number of heatwave days have increased by 50%
- Adelaide: hottest heatwave day is 4.3°C hotter; number of heatwave days have almost doubled

Some of our common species are feeling the heat

*Platanus acerifolia*
London planetree, Richmond 9th Jan. 2018

*Banksia serrata*
Old Man Banksia, Sydney
10th Mar. 2019
Extreme temperatures can result in leaf scorch

Measured in W. Sydney on 10th Feb. 2017, 14:00 AEDT, Air T = 40.7 °C, 32% RH
Western Sydney extreme heat 2019-20
Visual canopy assessment of 5591 tree stems along 92.3 km of road.

Four categories of canopy damage:
(A) undamaged, 0-5% canopy damaged
(B) lightly damaged, 6-30% canopy damaged
(C) heavily damaged, 31-90% canopy damaged
(D) defoliated, 91-100% canopy damaged.
97% of all native trees assessed as ‘undamaged’ compared with 82% of exotic trees
### Economic impact on the urban forest

#### Breakdown of costs of replacement for heavily damaged and defoliated trees under the low cost and high cost scenarios. The low cost scenario involved replacement with juvenile trees while the high cost scenario involved replacement with advanced trees. Note that maintenance and cost of mortality were calculated for the first five years.

<table>
<thead>
<tr>
<th>Cost type</th>
<th>Low cost scenario</th>
<th>High cost scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost (AUD)</td>
<td>Proportion (%)</td>
</tr>
<tr>
<td>Establishment</td>
<td>$268,809</td>
<td>46 %</td>
</tr>
<tr>
<td>Maintenance</td>
<td>$292,682</td>
<td>50 %</td>
</tr>
<tr>
<td>Cost of mortality</td>
<td>$23,260</td>
<td>4 %</td>
</tr>
<tr>
<td>Total</td>
<td>$584,751</td>
<td>100 %</td>
</tr>
<tr>
<td></td>
<td>$407,656</td>
<td>50 %</td>
</tr>
<tr>
<td></td>
<td>$334,635</td>
<td>41 %</td>
</tr>
<tr>
<td></td>
<td>$74,906</td>
<td>9 %</td>
</tr>
<tr>
<td></td>
<td>$817,197</td>
<td>100 %</td>
</tr>
</tbody>
</table>

Tabassum et al. (2021) *Urban Forestry & Urban Greening*
Tree inventory lists from 60 Local Government Areas across Australia:

- 1.2 million trees
- 1,200+ species

The 30 most common species make up 53% of the urban forest
Are our urban forest species future climate-proof?

By 2070, climatically suitable habitat in Australia’s significant urban areas is predicted to decline for 73% of species assessed.

We need better species selection
• Increase diversity
• Tolerance to low water availability
• Tolerance to extreme heat
• Tolerance to pests & pathogens

We need tools and resources
• Support species selection
• Facilitate successful planning
• Support effective management
We built a climate-ready species selection tool

**Bioclimatic models** to estimate areas of climatic suitability for each species under a changing climate in 2030, 2050 and 2070.

**Trait database** that includes information for >2500 species & cultivars on species’ attributes (biology, tolerances, site context, hazards)
We built a climate-ready species selection tool

Species attributes and bioclimatic suitability

Successes & Failures

Survive & Thrive

Lilly pilly (Syzygium wilsonii)
Heat sensitive

Heat sensitive

35 °C

27 °C

Soil WVC (%)

Date

Mar 19 Mar 26 Apr 02 Apr 09 Apr 16

Control
Drought

Air T (°C)

Hour

0 5 10 15 20

35 40 45

20 25 30 35
We built a climate-ready species selection tool

Species attributes and bioclimatic suitability

Successes & Failures

Survive & Thrive

Climate ready street tree trials
A best practice guide

How to successfully establish your new trees

How to measure your Urban forest
A best practice guide to establishing a tree inventory

What tree growers need from you
We built a climate-ready species selection tool

Future proof urban landscape projects with climate-ready species

Underpinned by the latest scientific research

Which Plant Where is a culmination of 5 years of research investigating which horticultural species will survive in Australian urban landscapes, not only now but under future climates. This plant selection tool is underpinned by the latest scientific evidence, providing growers, nurseries, landscape architects and urban green professionals with integrated tools and resources to develop resilient and sustainable urban green spaces for the future.

https://whichplantwhere.com.au
We built a climate-ready species selection tool.

- **Lophostemon confertus**
  - Brisbane Box
  - Tree
  - Climatic Suitability: 2030, 2050, 2070

- **Angophora floribunda**
  - Rough Barked Apple
  - Tree
  - Climatic Suitability: 2030, 2050, 2070

- **Agonis flexuosa**
  - Burgundy Western Australian
  - Weeping Peppermint
  - Shrub
  - Tree
  - Climatic Suitability: 2030, 2050, 2070
We built a climate-ready species selection tool

Lophostemon confertus

Species
- Tree

Family
- Myrtaceae

Crown
- Lophostemon acuminatus, Trachilostemon, Trachilostemon

Common names
- Whitelaw River Brushbox, Whitelaw River Brushbox, Queensland Brushbox, Scrub Box

Climatic Suitability

Location
- Cherrybrook (NSW 2083)

Climate Suitability

<table>
<thead>
<tr>
<th>Year</th>
<th>2030</th>
<th>2050</th>
<th>2070</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Suitable</td>
<td>Suitable</td>
<td>Suitable</td>
</tr>
</tbody>
</table>

Form
- Height in cultivation: 10 - 20 m
- Spread in cultivation: 4 - 5 - 20 m

Origin
- Native

Flower period
- Spring, Summer

Leaf type
- Evergreen

Canopy shape
- Pyramid, Rounded, Spreading

Site
- Urban space type: Garden, Park, Street, Water
- Sensitive Urban Design

Use
- Erosion Control, Feature, Preserves Fire Resistant, Screen, Shade, Timber, Windbreak

Soil texture
- Clay, Loam, Sand

Soil pH
- Acidic, Alkaline, Neutral

Performance
- Shade tolerance: Full sun
- Port shade

Tolerance
- High drought
- Moderate Frost
- High coastal

Drought strategy
- Avoider

Heat
- Tolerant

Growth rate
- Fast, medium

Biodiversity
- Bird
- Insect

Planting & Maintenance
- Peat-lite Soil, Poorly Drained Soil, Well Drained Soil

Use the slider to see how climate suitability for this species is changing over time across Australia (2030, 2050 and 2070)
With a species palette co-benefits tool

<table>
<thead>
<tr>
<th>Palette</th>
<th>Total Canopy Area</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perth</td>
<td>1050 m²</td>
<td></td>
</tr>
</tbody>
</table>

**Climatic Suitability**

Location: 6000

**Co-benefits**

- **Planting Diversity**: High
- **Biodiversity**: High
- **Carbon Value**: Moderate
- **Shade Value**: High
Learn About the Science Powering Which Plant Where

The Which Plant Where selection tool contains lots of useful information including where species will be climatically suitable in the future as well as benefits that species can provide in urban areas (e.g., attracting biodiversity, proving shade, carbon storage, etc). Below are links to technical guides that contain in-depth information on how these parameters were calculated.

- How we calculated planting co-benefits in Which Plant Where (PDF, 157 KB)
- How we calculated canopy cover in Which Plant Where (PDF, 92 KB)
- How we calculated climate suitability in Which Plant Where (PDF, 162 KB)
- How we measured drought and heat tolerance in Which Plant Where (PDF, 294 KB)
- How we calculated planting diversity in Which Plant Where (PDF, 1 MB)
- How we identified weed species in Which Plant Where (PDF, 3.9 MB)
What were the main challenges?

- Varieties, hybrids, cultivars can’t be modelled
- Natural distributions vs managed urban environments
- Obtaining good quality plant images
- Identifying weed species – location specific
- Long-term sustainability of the online tool – commercialisation vs accessibility
What is next?

- Trial of free access with new adoption plan development & implementation
- Expand species list
- Urban site requirements – soil volume, microclimate preference, maintenance requirements
- Improve co-benefits calculator (plant water use, carbon storage, cooling, biodiversity)
- Locally indigenous function
- Integration with other urban greening tools and resources (eg tree planting costs calculator, Gardening Responsibly)
2nd World Forum on Urban Forests 2023
Now, More than Ever
How Open Access Research is Helping Urban Forestry Professionals Face a Rapidly Changing World

Presented by
Lindsey E. Mitchell
Managing Editor, Arboriculture & Urban Forestry
International Society of Arboriculture
Research accessibility is a frustration for both researchers and the public

- Affects public perception of the reliability of science
- Affects the initial impact of research upon publication
- Affects the reputation of publishers and their values

https://doi.org/10.1038/356739a0
What is Open Access?

• **Accessibility**
  
The content is freely available immediately upon publication as opposed to being released behind a paywall (subscription)

• **Reproducibility**
  
Commonly, a copyright license is applied that allows for free use of the content without permissions from the authors or publisher
Seems Like a Good Idea! What’s the Catch?

- Article Publishing Charges (APCs)
  Instead of passing on the costs of publication to the subscriber, the cost is passed on to the author or their institution via APCs

**Elsevier**
- $2,703 avg
- $10,100 max

**Wiley**
- $3,159 avg
- $6,540 max

**Oxford University Press**
- $3,375 avg
- $7,256 max

**Wolters Kluwer**
- $3,297 avg
- $4,429 max

**Springer**
- $3,278 avg
- $11,690 max
Tension!

Publisher Costs
- Staff Salaries/Editorial Board Fees
- Peer Review Systems
- Copyediting, Layout, Proofreading
- Printing and Distribution
- Online Platforms
- Industry Partnerships

Researcher Challenges
- Academic Pressures
- Limited Funding
- Funder Requirements
- Submission Barriers
- Publishing Timelines
- Research Accessibility
ISA’s Mission and *Arboriculture & Urban Forestry*

- Through research, technology, and education, the International Society of Arboriculture promotes the professional practice of arboriculture and fosters a greater worldwide awareness of the benefits of trees.
- In support of this mission, *Arboriculture & Urban Forestry* transitioned to an Open Access model in September 2022 with no included APCs.
- This transition was also made in anticipation of the launch of AUF’s new online publishing platform, which became available spring of 2023.
What the Data Shows Us

AUF Transitions to Open Access in September 2022

• September 2021–August 2022
  46,600 DOI* Interactions

• September 2022–August 2023
  63,873 DOI Interactions

• 37% increase in activity

AUF Online Platform Launches May 2023

• January 2023–April 2023
  15,823 DOI Interactions

• May 2023–August 2023
  31,276 DOI Interactions

• 98% increase in activity

*DOI (Digital Object Identifier; https://www.doi.org)
Top Articles in 2021

• Urban Tree Mortality: A Literature Review
  https://doi.org/10.48044/JAUF.2019.015

• Urban Resources Initiative: A University Model for Clinical Urban Forestry Education
  https://doi.org/10.48044/JAUF.2021.004

• How Tree Risk Assessment Methods Work: Sensitivity Analyses of Sixteen Methods Reveal the Value of Quantification and the Impact of Inputs on Risk Ratings
  https://doi.org/10.48044/JAUF.2020.030

Top Articles in 2022

• Grassroots Citizen Science in Urban Spontaneous Vegetation
  https://doi.org/10.48044/JAUF.2018.010

• Tree Measurements in the Urban Environment: Insights from Traditional and Digital Field Instruments to Smartphone Applications
  https://doi.org/10.48044/JAUF.2022.009

• The Influence of Biochar Soil Amendment on Tree Growth and Soil Quality: A Review for the Arboricultural Industry
  https://doi.org/10.48044/JAUF.2022.014
Most Read Articles* since Platform Launch

- Which Plant Where: A Plant Selection Tool for Changing Urban Climates
  https://doi.org/10.48044/jauf.2023.014

- A Literature Review of Resilience in Urban Forestry
  https://doi.org/10.48044/jauf.2020.014

- Examining Species Diversity and Urban Forest Resilience in the Milwaukee, Wisconsin (USA) Metropolitan Area
  https://doi.org/10.48044/jauf.2023.017

- Sustainable Smart Park Management—A Smarter Approach to Urban Green Space Management?
  https://doi.org/10.48044/jauf.2022.006

- Urban Tree Mortality: A Literature Review
  https://doi.org/10.48044/jauf.2019.015

*Articles with a focus on urban forestry and urban climate pressures
Thank you

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auf@isa-arbor.com
2nd World Forum on Urban Forests 2023
Some Like It Hot

Strange Paths to Paradigm Shift: How Steve Jobs Helped California Adapt To Climate Change

Presented by
Dave Muffly

www.oaktopia.org
dave@oaktopia.org
Apple Park's Tree Whisperer

Steve Jobs had a vision to resurrect pre-tech Silicon Valley in his new HQ. It was up to this hippie arborist to make it happen.
Caution
Wildlife Afoot
Take Care When Opening Outside Doors
Annual Global Average Surface Temperature for Land and Ocean

Temperature difference from 20th century average (°F)

- Warmer
- Cooler

1880 1900 1920 1940 1960 1980 2000 2018

1901-2000 Average
Climate: the impact on cities in 2050

- The climate in Paris will be more similar to Canberra in 2050
- Seattle will be more similar to San Francisco
- Pretoria will be more similar to Cordoba
- Nairobi will be more similar to Maputo
- Moscow will be more similar to Sofia
- Stockholm will be more similar to Budapest
- In Europe, cities will be hotter by 3.5°C in summer, 4.7°C in winter

77% of cities will experience a striking change in climate conditions

Source: Crowther Lab
Shifting Cities
How Hot Will Summers Be By 2100?
Summer highs in Los Angeles, United States could be more like San Jose, Costa Rica by 2100 with moderate emissions cuts.
Madrean Pine-Oak Woodlands
Preparing for Climate Change: Forestry and Assisted Migration

Mary I. Williams and R. Kasten Dumroese
<table>
<thead>
<tr>
<th>Inches of Annual Precipitation</th>
<th>Vegetation Community</th>
<th>Feet Above Sea Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.5&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26.0&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24.5&quot;</td>
<td>Mixed Conifer Forest</td>
<td>8000'</td>
</tr>
<tr>
<td>23.0&quot;</td>
<td>Ponderosa Pine Forest</td>
<td>7000'</td>
</tr>
<tr>
<td>21.5&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20.0&quot;</td>
<td>Pine-Oak Woodland</td>
<td>6000'</td>
</tr>
<tr>
<td>18.5&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.0&quot;</td>
<td>Oak Woodland and Chaparral</td>
<td>5000'</td>
</tr>
<tr>
<td>15.5&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.0&quot;</td>
<td>Semi-Desert Grasslands</td>
<td>4000'</td>
</tr>
<tr>
<td>12.5&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.0&quot;</td>
<td>Sonoran Desert</td>
<td>3000'</td>
</tr>
</tbody>
</table>
Why We Should All Be Chasing Acorns

Oct. 17, 2022
Thank you

Dave Muffly

www.oaktopia.org

dave@oaktopia.org
2nd World Forum on Urban Forests
2023
Clean Air Calculator: Bridging Science and Practice

Presented by

Alan White

Climate Adaptation Chair- Canadian Nursery Landscape Association
Chairman-Green Cities Foundation
The Clean Air Calculator
Partners

Collaborative approach:

• Climate Adaptation Committee-Canadian Nursery Landscape Association-CNLA

• Dr. Eric Lyons, Director of the Guelph Turfgrass Institute- University of Guelph

• Environmental Systems Research Institute-Esri
The Clean Air Calculator

• A web application tool built on ArcGIS Software (Environmental Systems Research Institute - ESRI).
• The literature reviewed (key published studies and sources).
• Our goal is to create awareness about the benefits of plants in urban areas and their value in sustaining life in Canadian communities while mapping the planted urban environment.
What are the parameters measured?

- \(\text{CO}_2\): Carbon dioxide sequestration
- Number of people benefited
- Clean air
- Car emissions offsets
How to use the Clean Air Calculator?

• Step 1 - Find Your Location.

• Step 2 - Choose Your Land Cover - Lawns, Trees, and Shrubs

• Step 3 - Define Your Area

• Step 4 - Explore Your Clean Air Results
Our 2023 achievements so far

- **Total of Urban Green Space**
  - Target: 930,000 m²
  - Achieved: 5,159,680 m²
  - Progress: 555%

- **Total of Clean Air**
  - Target: 5,463 m³
  - Achieved: 12,512 m³
  - Progress: 229%

- **Population Positive Impacted**
  - Target: 5,082 people
  - Achieved: 11,785 people
  - Progress: 232%

- **The total of submissions**
  - Target: 100 submissions
  - Achieved: 31 submissions
  - Progress: 31%
Why The Green Cities Foundation?

● GCF is a community connecting plants & people for a greener, healthier urban environment. The foundation recognizes the importance of engaging individuals at the grassroots level, whether it's through their personal efforts in their yards or balconies or by participating in community initiatives like #GreenMyCity.

● By involving people at both the individual and group levels, the foundation empowers them to play an active role in making their communities greener and healthier.

● The tool allows people to measure and quantify the positive impact of plants, shrubs, understory landscapes, grass, and green spaces on the environment.
When people have the tools to measure their contributions, they are more likely to take ownership of their role in creating a healthier and more sustainable urban climate.

In summary, the Green Cities Foundation's work is not only about creating greener urban spaces but also about empowering people to take an active role in achieving this goal. Through tools like the clean air calculator, they are providing individuals and communities with the means to measure and understand their contributions, ultimately leading to a more hopeful and engaged populace committed to creating healthier urban environments.
Clean Air Calculator Research & Methodology

• Net Primary Production
• Development of formulas
• Intentional simplicity

Clean Air Calculator Model

Green Space = (Area) (Carbon Sequestration rates)

Literature Review
## Literature Review

### Applicable Studies

<table>
<thead>
<tr>
<th>Article</th>
<th>Authors</th>
<th>Year</th>
<th>Type of crop Type of grass Mean</th>
<th>Units</th>
<th>Measurement</th>
<th>Gross or Net</th>
<th>Location</th>
<th>Conversion to Mg C ha⁻¹ year⁻¹</th>
<th>Mean</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Carbon Sequestration Potential and Emissions in Home Lawn Turfgrasses of the United States</td>
<td>Selhorst and Lai</td>
<td>2013</td>
<td>Homelawn cool season 2.8</td>
<td>0.9</td>
<td>5.4</td>
<td>(Mg C ha⁻¹ year⁻¹)</td>
<td>Mean SOC sequestration gross</td>
<td>Multiple US Sites</td>
<td>2.8</td>
<td>0.9</td>
<td>5.4</td>
</tr>
<tr>
<td>The residential landscape: fluxes of elements and the role of household decisions</td>
<td>Fissore et al.</td>
<td>2002</td>
<td>Homelawn cool season 0.51</td>
<td>-</td>
<td>-</td>
<td>(g C m⁻² year⁻¹)</td>
<td>Total C input gross</td>
<td>Minnesota, USA</td>
<td>5.1</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Carbon budgeting in golf course soils of Central Ohio</td>
<td>Selhorst and Lai</td>
<td>2011</td>
<td>Golf Course cool season 0.44</td>
<td>-</td>
<td>-</td>
<td>(Mg C ha⁻¹ year⁻¹)</td>
<td>Net Sequestration gross</td>
<td>Ohio, USA</td>
<td>0.44</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Assessing Soil Carbon Sequestration in Turfgrass System Using Long-Term Soil Testing Data</td>
<td>Qian and Falleet</td>
<td>2002</td>
<td>Golf Course cool season 0.90</td>
<td>0.9</td>
<td>1</td>
<td>(t C ha⁻¹ year⁻¹)</td>
<td>Change in SOC gross</td>
<td>Colorado and Wyoming, USA</td>
<td>0.95</td>
<td>0.9</td>
<td>1</td>
</tr>
<tr>
<td>Biogeochemical cycling of carbon and nitrogen in cool-season turfgrass systems</td>
<td>Law and Patton</td>
<td>2017</td>
<td>Homelawn cool season 1518.3</td>
<td>1408</td>
<td>1629</td>
<td>(g C m⁻² year⁻¹)</td>
<td>Net Carbon accumluating gross</td>
<td>Indiana, USA</td>
<td>1.07</td>
<td>0.86</td>
<td>1.29</td>
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<tr>
<td>Modeling Carbon Sequestration in Home Lawns</td>
<td>Zirkle et al.</td>
<td>2011</td>
<td>Homelawn cool season 1518.3</td>
<td>46</td>
<td>235.1</td>
<td>(g C m⁻² year⁻¹)</td>
<td>Net SOC including HCC gross</td>
<td>Multiple US Sites</td>
<td>1.45</td>
<td>0.46</td>
<td>2.35</td>
</tr>
<tr>
<td>Carbon sequestration and greenhouse gas emissions in urban turf</td>
<td>Townsend-smith and C.</td>
<td>2010</td>
<td>Homelawn cool season 0.14</td>
<td>-</td>
<td>-</td>
<td>(g C m⁻² year⁻¹)</td>
<td>Accumulated Organic C gross</td>
<td>California, USA</td>
<td>1.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Soil Organic Matter Accumulation in Creeping Bentgrass Greens: A Chronosequence with Implications for Conley et al.</td>
<td>Townsend-smith and C.</td>
<td>2011</td>
<td>Golf Course cool season 0.59</td>
<td>-</td>
<td>-</td>
<td>(g C m⁻² year⁻¹)</td>
<td>Estimated Soil Carbon gross</td>
<td>North Carolina, USA</td>
<td>0.59</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Trees

<table>
<thead>
<tr>
<th>Article</th>
<th>Authors</th>
<th>Year</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
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<th>Mean</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon storage and sequestration by trees in urban and community areas of the United States</td>
<td>Nowak et al.</td>
<td>2013</td>
<td>0.28</td>
<td>0.128</td>
<td>0.513</td>
<td>(kg C m⁻² year⁻¹) Sequestration gross</td>
<td>Multiple US Locations</td>
<td>2.8</td>
<td>1.28</td>
<td>5.13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon storage and sequestration of Urban Street Trees in Beijing, China</td>
<td>Tang et al.</td>
<td>2016</td>
<td>1.3</td>
<td>-</td>
<td>-</td>
<td>(mg ha⁻¹ year⁻¹ C Sequestration gross</td>
<td>Beijing, China</td>
<td>1.3</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Carbon storage and sequestration by urban forests in Shenyang, China</td>
<td>Liu and Li</td>
<td>2012</td>
<td>2.84</td>
<td>1.16</td>
<td>4.78</td>
<td>(t ha⁻¹ year⁻¹ C Sequestration gross</td>
<td>Shenyang, China</td>
<td>2.84</td>
<td>1.16</td>
<td>4.78</td>
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<tr>
<td>Impacts of urban forests on offsetting carbon emissions from industrial energy use in Hangzhou, China</td>
<td>Zhuo et al.</td>
<td>2010</td>
<td>1.66</td>
<td>0.82</td>
<td>3.02</td>
<td>(t ha⁻¹ year⁻¹ C Sequestration gross</td>
<td>Hangzhou, China</td>
<td>1.66</td>
<td>0.82</td>
<td>3.02</td>
<td></td>
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<tr>
<td>Comparison of carbon storage, carbon sequestration and air pollution removal by protected and maintaial Martin et al.</td>
<td>Zhuo et al.</td>
<td>2012</td>
<td>-</td>
<td>219</td>
<td>758</td>
<td>(g C ha⁻¹ year⁻¹ C Sequestration gross</td>
<td>Alabama, USA</td>
<td>1.02</td>
<td>0.29</td>
<td>1.76</td>
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<tr>
<td>Carbon reduction and planning for urban parks in Seoul</td>
<td>Jo et al.</td>
<td>2013</td>
<td>3.5</td>
<td>1.2</td>
<td>8.4</td>
<td>(t ha⁻¹ year⁻¹ C Sequestration gross</td>
<td>Seoul, Republic of Korea</td>
<td>3.5</td>
<td>1.2</td>
<td>8.4</td>
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### Shrub Article

<table>
<thead>
<tr>
<th>Article</th>
<th>Authors</th>
<th>Year</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Measurement</th>
<th>Gross or Net</th>
<th>Location</th>
<th>Conversion to Mg C ha⁻¹ year⁻¹</th>
<th>Mean</th>
<th>min</th>
<th>max</th>
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<tr>
<td>Vegetation ecology and carbon sequestration potential of shrubs in tropics of Chhattisgarh, India</td>
<td>Jhariya</td>
<td>2017</td>
<td>1.7</td>
<td>0.7</td>
<td>1.57</td>
<td>t ha⁻¹ ye⁻¹</td>
<td>net carbon sequestration net</td>
<td>India</td>
<td>1.14</td>
<td>0.71</td>
<td>1.57</td>
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<tr>
<td>The Application of Stem Analysis</td>
<td>Beets</td>
<td>2014</td>
<td>1.15</td>
<td>0.15</td>
<td>3.23</td>
<td>t ha⁻¹ ye⁻¹</td>
<td>carbon stock increase net</td>
<td>New Zealand</td>
<td>1.15</td>
<td>0.15</td>
<td>3.23</td>
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<tr>
<td>Carbon sequestration and growth of six common tree and shrub shelterbelts in Saskatchewan, Canada</td>
<td>Amichev et al.</td>
<td>2015</td>
<td>1.31</td>
<td>0.31</td>
<td>6.64</td>
<td>Mg ha⁻¹ ye⁻¹</td>
<td>carbon stock increase net</td>
<td>Saskatchewan, Canada</td>
<td>3.98</td>
<td>1.31</td>
<td>6.64</td>
<td></td>
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</tbody>
</table>
Clean Air Calculator Research

• Oxygen Production by Urban Trees in the USA. David J. Nowak, Robert Hoehn, and Daniel E. Crane. 2007
• Carbon storage and sequestration by urban trees in the USA. USDA Forest Service. Nowak, D; Crane, D. 2013
• Air Pollution Removal by Urban Forests in Canada and its Effect on Air Quality and Human Health. David J. Nowak, Mark Mcgovern. 2017
• Net Carbon Sequestration Potential and Emissions in Home Lawn Turfgrasses of the United States. Selhorst, A; And Lal. 2013
Development of an Urban Turfgrass and Tree Carbon Calculator for Northern Temperate Climates

by Corey Flude, Alexandra Ficht, Frydda Sandoval and Eric Lyons

1 Department of Plant Agriculture, University of Guelph, 50 Stone Road East, Guelph, ON N1G 2W1, Canada
2 Canadian Nursery Landscape Association, 7856 Fifth Line South, Milton, ON L9T 2X8, Canada
* Author to whom correspondence should be addressed.

Sustainability 2022, 14(19), 12423; https://doi.org/10.3390/su141912423

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Thank you

Alan White|CNLA

alan.white@canadanursery.com

Link to the CAC website: https://www.experiencebuilder.gardenconnect.com/ExperienceBuilder/?page=Map
2nd World Forum on Urban Forests
2023
How healthy, diverse urban forests can support threatened trees in the wild and mitigate the impacts of climate change

Presented by
Murphy Westwood, PhD
Vice President of Science and Conservation
The Morton Arboretum
Global Tree Assessment (GTA):  
Assessing the extinction risk of all ~60,000 tree species by 2020

- Launched in 2015
- > 60 institutional partners
- > 500 tree experts from around the world
The U.S. effort for the GTA

• Christina Carrero, Bard College and The Morton Arboretum
• Emily Beckman Bruns, The Morton Arboretum
• Anne Frances, USDA Agricultural Research Service
• Diana Jerome, The University of Edinburgh
• Wesley Knapp, NatureServe
• Abby Meyer, Botanic Gardens Conservation International U.S.
• Ray Mims, United States Botanic Garden
• David Pivorunas, USDA Forest Service
• DeQuantarius Speed, The Morton Arboretum
• Amanda Treher Eberly, NatureServe
• Murphy Westwood, The Morton Arboretum

… and dozens of other botanists and plant experts!
The starting point for U.S. trees (2017)
Two threat assessment frameworks in the U.S.

- Est. in 1964, used globally
- GTA assessment platform of choice
- Assessments compiled by global network of scientists and conservationists
- <300 U.S. tree species assessed

- Est. in 1978, used in N. America
- Assessments compiled by its network of Natural Heritage Programs
- ~97% of species assigned Global Rank, but 75% of those were >10 years old

Carrero et al., 2022. Plants, People, Planet
IUCN Red List categories and NatureServe global ranks

- Extinct (EX)
- Extinct in the Wild (EW)
- Critically Endangered (CR)
- Endangered (EN)
- Vulnerable (VU)
- Near Threatened (NT)
- Least Concern (LC)
- Data Deficient (DD)
- Not Evaluated (NE)

- Critically Imperiled
  - Global: G1
  - National: N1
  - Subnational: S1
- Imperiled
  - Global: G2
  - National: N2
  - Subnational: S2
- Vulnerable
  - Global: G3
  - National: N3
  - Subnational: S3
- Apparently Secure
  - Global: G4
  - National: N4
  - Subnational: S4
- Secure
  - Global: G5
  - National: N5
  - Subnational: S5
U.S. Tree Assessment Goals

• Address the lack of U.S. tree species on IUCN Red List and out of date NatureServe global ranks
• Ensure U.S. was contributing to Global Tree Assessment initiative
• Create easily accessible checklist of U.S. tree species (for the contiguous 48 states)
• Develop a comprehensive picture of the state of extinction risk of U.S. trees
• Streamline data sharing between IUCN Red List and NatureServe
Results: The state of U.S. trees

Data sharing for conservation: A standardized checklist of US native tree species and threat assessments to prioritize and coordinate action

Christina Carrero1,2* | Emily Beckman Bruns1,6 | Anne Frances3* |
Diana Jerome4* | Wesley Knapp5* | Abby Meyer6 | Ray Mims7 |
David Pivorunas8 | DeQuantarius Speed1 | Amanda Treher Eberly5 |
Murphy Westwood9

1The Morton Arboretum, Lisle, Illinois, USA
2Bard College, Annandale-On-Hudson, New York, USA
3United States Department of Agriculture (USDA) Agricultural Research Service, Beltsville, Maryland, USA
4The University of Edinburgh, Edinburgh, UK
5NatureServe, Arlington, Virginia, USA
6Botanic Gardens Conservation International U.S., San Marcos, California, USA
7United States Botanic Garden, Washington, D.C., USA
8United States Department of Agriculture (USDA) Forest Service, Washington, D.C., USA

Correspondence
Christina Carrero, The Morton Arboretum, Lisle, IL, USA

Societal Impact Statement
Understanding the current state of trees within the United States is imperative for protecting those species, their habitats, and the countless communities they support, as well as the ecosystem services they provide. We present an updated checklist of all tree species native to the contiguous United States, their state distribution, extinction risk, and most common threats. Knowledge of national threat “hotspots” and conservation priorities facilitates efficient conservation efforts and the allocation of resources to safeguard the 11–16% of US tree species that are threatened. These results lay the groundwork for tree and ecosystem conservation efforts in the United States that contribute to achieving critical international conservation goals, including the United Nations Decade for Ecosystem Restoration and the Global Tree Assessment.

Summary

Received: 31 January 2022 | Revised: 27 June 2022 | Accepted: 28 June 2022
DOI: 10.1002/ppp.31005
The checklist of U.S. trees
Data included:

• Family
• Genus
• Species
• Taxonomic authority
• Country-level and state-level distribution

• Endemicity to the contiguous U.S.
• IUCN Red List and NatureServe assessment and year
• Endangered Species Act listing
• Number of ex-situ collections
The checklist of U.S. trees

- Checklist contains: 79 families, 269 genera, 881 species of trees
- 294 species endemic to the contiguous 48 states
- Oaks (Quercus; 85 species) and hawthorns (Crataegus; 84 species) dominate tree flora
- Nine other genera with >10 tree species
Native tree hotspots

Native Trees

Contiguous U.S. Endemic Trees

Carrero et al., 2022. Plants, People, Planet
Threat assessments completed

563 species
(3-fold increase)

109 species

96.7%
of U.S. tree species assessed

96.3%
of U.S. tree species assessed

Developed crosswalk methodology to facilitate data sharing between IUCN and NatureServe databases

Carrero et al., 2022. Plants, People, Planet
Threat assessment results

94 species (11%) threatened

135 species (16%) threatened

165 species (19%) threatened
**Federal protections for trees**

<table>
<thead>
<tr>
<th>Species name</th>
<th>Federal Listing Status</th>
<th>IUCN Red List Category</th>
<th>NatureServe Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asimina tetramera</td>
<td>Endangered</td>
<td>EN</td>
<td>G1</td>
</tr>
<tr>
<td>Betula uber</td>
<td>Threatened</td>
<td>NE</td>
<td>G1</td>
</tr>
<tr>
<td>Cercocarpus traskiae</td>
<td>Endangered</td>
<td>CR</td>
<td>G1</td>
</tr>
<tr>
<td>Chionanthus pygmaeus</td>
<td>Endangered</td>
<td>EN</td>
<td>G2</td>
</tr>
<tr>
<td>Consolea corallicola</td>
<td>Endangered</td>
<td>CR</td>
<td>G1</td>
</tr>
<tr>
<td>Fremontodendron mexicanum</td>
<td>Endangered</td>
<td>EN</td>
<td>G2</td>
</tr>
<tr>
<td>Torreya taxifolia</td>
<td>Endangered</td>
<td>CR</td>
<td>G1</td>
</tr>
<tr>
<td>Ziziphus celata</td>
<td>Endangered</td>
<td>EN</td>
<td>G1</td>
</tr>
</tbody>
</table>

**Compare to**

<table>
<thead>
<tr>
<th>IUCN Red List: 94 spp. Threatened</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>NatureServe: 135 spp. At-risk</th>
</tr>
</thead>
</table>

Carrero et al., 2022. Plants, People, Planet
Most common threats facing U.S. trees

- Invasive & other problematic species, genes & diseases
- Climate change & severe weather
- Natural system modifications
- Biological resource use
- Agriculture & aquaculture
- Residential & commercial development
- Human intrusions & disturbance
- Pollution
- Energy production & mining
- Transportation & service corridors
- Other options

Carrero et al., 2022. *Plants, People, Planet*
Phylogenetic patterns of threat
Genera with the most threatened species

<table>
<thead>
<tr>
<th>Genus</th>
<th>Number of species threatened/at-risk</th>
<th>Total number of native US tree species</th>
<th>% of genus threatened/at-risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crataegus</td>
<td>29</td>
<td>84</td>
<td>34.5%</td>
</tr>
<tr>
<td>Quercus</td>
<td>17</td>
<td>85</td>
<td>20.0%</td>
</tr>
<tr>
<td>Fraxinus</td>
<td>7</td>
<td>15</td>
<td>46.7%</td>
</tr>
<tr>
<td>Pinus</td>
<td>6</td>
<td>38</td>
<td>15.8%</td>
</tr>
<tr>
<td>Arctostaphylos</td>
<td>4</td>
<td>10</td>
<td>40.0%</td>
</tr>
<tr>
<td>Cupressus</td>
<td>4</td>
<td>6</td>
<td>66.7%</td>
</tr>
</tbody>
</table>

77 out of 269 tree genera have at least one threatened and/or at-risk species

Carrero et al., 2022. Plants, People, Planet
Threatened tree hotspots

Native threatened trees

Endemic threatened trees
How can urban forestry save threatened trees in the wild?
Healthy urban forests benefit all trees

Taking action

- Trees are a nature based solution to combat climate change
  - Higher canopy cover → cooler temps, mitigates runoff
  - Trees are a carbon sink
  - A diverse urban canopy is more resilient to new pests/diseases
- Create forest preserves and connect habitat with corridors
- Engage and support private landowners to plant trees
- Partner with local gardens and arboreta to join conservation efforts and share knowledge and best practices
- Ensure threatened tree species are included in habitat restoration and reforestation efforts ("near situ" conservation)
- Advocate for and build awareness of the importance of trees
- Help reduce “plant blindness” so trees aren’t taken for granted
Case Study:
Chicago Region Trees Initiative at The Morton Arboretum

CRTI is a partnership of communities, individuals, organizations, green industry, businesses, and governments working together to develop and implement strategies for a healthier, more diverse, more equitable urban forest.
A city that is an accredited arboretum is actively working to conserve the endangered species *Quercus acerifolia*.

Establishing at least four urban “conservation grove” sites.

Planting both seed-derived groves and grafted trees that represent the four known sites where this species exists in Arkansas.

Goal: to develop a complete collection of *Q. acerifolia*, by capturing the maximum amount of genetic variability across the species as possible, while also planting the urban forest.

**Case Study:**
City of Columbia, MO - Stephen’s Lake Park Arboretum
Maple leafed oak conservation
Become an Accredited Arboretum

- Arboreta come in all shapes and sizes!
- Take your urban and community forestry efforts to the next level, recognizing the educational and conservation value of the trees in your care.
- Be recognized for achievement of specified levels of professional practice.
- Earn distinction in your community, university, or government agency.
- Leverage funding.
- Identify opportunities for collaboration with other arboreta for scientific, collections, or conservation activities.
Thank you

Murphy Westwood, PhD | The Morton Arboretum
Other information

mwestwood@mortonarb.org
www.mortonarb.org
www.chicagorti.org

U.S. trees paper:
2nd World Forum on Urban Forests
2023
From Hardscape to Welcoming Greenscape:

Grass and Diverse Trees Transform a Highway in Nairobi, Inspiring Replication

Presented by
Kate Chesebrough
Landscape Architect (NYS)
Urban Forestry Research Fellow, CIFOR-ICRAF
Cornell University Masters of Landscape Architecture ‘24
A Watershed Moment for Trees in Nairobi

- **Link Road Trees Case Study**
  - Led by Catharine Watson, CIFOR-ICRAF
- **CIFOR-ICRAF Urban Forestry Research Fellows**
- **Always in collaboration with Kenyan youth and scientists**
Link Road Trees Case Study: Why Here, Why Now?

- Room for new ideas about native trees, in contrast to exotics planted earlier in history
- 3,500+ trees removed by expressway – widespread disappointment, sparked activism
- Much attention to tree planting nationwide
- An opportunity – KURA approached for help improving environment in otherwise vacant road reserves
- Intended to promote and demonstrate effectiveness of native trees
- Tangible expertise, collaboration

Expressway construction caused much tree removal, and preservation of a large ficus

Kenyan President Ruto announced plans to plant 15 billion trees by 2032

Peter Greensmith, Nairobi Parks Superintendent 1947-1965, pictured here with the Queen Mother
Link Road Trees: How it Started

- Eroding bare soil on very steep slopes
- Employed people from nearby informal settlements – energy poverty
- Site preparation
- Taken on as personal project
Link Road Trees: How it’s Going

- 50+ species of native trees
- A park-like, attractive environment
- Dense plantings create canopy closure reducing pressure from weeds
Link Road Trees: Commitment to Care

- Maintenance is key to success
- Over 75% of funds toward labor
- Drought during 2021-2023
- Unofficial motto: *Grow slower, better*
Link Road Trees: Growing Knowledge

- Tree count and identification: Staff become tree experts
- Pedestrian footfall throughout day counted by staff
- Beneficial insects identified by local and visiting entomologists
- Testing the Regreening Africa phone app in urban setting reveals new potential use
- Road reserves can be less contested than other urban spaces
Scaling Up?

- KURA road reserves throughout country include over 19,000ha of potential urban forestation – of which Nairobi appx. 7,000ha
- Forested roadways as multi-functional, dynamic infrastructure
- Corridors for habitat, biodiversity, pedestrian connectivity
- Meets definition of UN Habitat 2022 Public Space Inventory as ‘linear public space’
- Attractive and appreciated
Urban Forestry Research Fellows

- First-ever at CIFOR-ICRAF
- **Kate Chesebrough**
  - Master of Landscape Architecture ‘24, Cornell University College of Agriculture and Life Sciences
- **Alice Gerow**
  - Master of Forestry ‘24, Yale University School of the Environment
- Summer 2023 in-person in Nairobi
- Hosted urban forestry seminar at CIFOR-ICRAF with outside guests
- A new direction – open to collaboration

At CIFOR-ICRAF after urban forestry seminar, with Bolurin Adepipe (MIT M.Arch), myself, Cathy, Sam Dindi (Mazingera Yetu Environmental Magazine), Alice, Lawrence Wachira (KURA), José Chong (UNHabitat Public Space)
Urban Forestry Research Fellows

- **Alice Gerow**
  - Studying street tree distribution in Nairobi
  - Examines socioeconomic and spatial inequalities in distribution of urban greenspace
  - Investigates differences in street tree abundance, size structure, species diversity, and composition between selected residential neighborhoods
  - Study rests on a ground-based inventory of nearly 2,000 street trees in 12 neighborhoods.
  - Objective: to characterize the distribution of street trees and address a knowledge gap on a critical layer of Nairobi’s urban forest to inform formal and informal urban greening initiatives.
Urban Forestry Research Fellows

- **Kate Chesebrough**
  - Studying urban forestry through design with focus along riverways, roadways in selected informal settlements
  - Focus on care-grown trees, not planting
  - Image of city transformed
  - Shift from untended to cared for, safety, pride
  - Flood-prone areas and ongoing adaptation
  - Assembling palette of urban/climate-adapted tree species appropriate to site conditions
  - Knowledge-sharing and partnership-building
  - Objective: urban forestry approach that values maintenance, creates new collaborations for impactful climate adaptation for more livable cities
Informed by Networks

- Many organizations are stakeholders in urban forestry in Nairobi
  - Organizers and urban planners Slum Dwellers International, Muungano wa Wanavijiji
  - Youth groups in Mathare, Korogocho, Lucky Summer, Kibera, and Mukuru
  - Botanists at CIFOR-ICRAF, Kenya Forestry Research Institute, Darubini, Museums of Kenya
  - Policymakers at Nairobi City-County Sustainability, Parks & Recreation, and Planning Departments, as well as UN Habitat Public Space Programme

- Goal: help share knowledge between
Action-Oriented Design Research

- Illustrating trees to make them more visible
- Sketching live during all site visits
- Ongoing coordination for site- and neighborhood-specific plans
- Trees are about time - tenure, maintenance, long-term climate goals
- Preparing tree species matrix based on performances – food, timber, medicine, habitat, ornamental, etc.
- Potential workshops in January
Uniquely Nairobi, With Broad Themes

- Transferal of rural knowledge to urban settings due to population shift
- Medicinal use of trees – important to health of residents, few plans discuss
- Addressing plant blindness
- A shift in identity with native trees
- Health benefits of public green space
- Huge potential for collaboration
- Tangible green spaces maintained and loved by people bring climate goals to life

Large vendor stalls of traditional medicines for sale in the Mathare informal settlement, many of which are sourced from native tree bark, seeds, fruit, etc.

Transforming from dump sites to green spaces – tangible differences that require systemic change for the longer term.
Thank you

Kate Chesebrough | Landscape Architect
CIFOR-ICRAF | Cornell University

kic22@cornell.edu
CEUs

Session 3.4: Some Like it Hot: Creating and sharing new knowledge and supporting education on the contribution of forests and trees to adaptation and mitigation to climate change

PP-23-3572