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INSTITUTIONAL MEMBERS OF TREENET 2016

ASSOCIATIONS
Arboriculture Australia Ltd
Council Arboriculture Victoria
Institute of Australian Consulting Arboriculturists (IACA)
Local Government Tree Resources Association (NSW)
Nursery & Garden Industry SA Inc (NGISA)
Victorian Tree Industry Organisation (VTIO)

GOVERNMENT
ACT TAMS and Parks & City Services
Albury City Council
Campbelltown City Council
City of Belmont
City of Boroondara
City of Burnside
City of Charles Sturt
City of Glen Eira
City of Holdfast Bay
Ipswich City Council
City of Melbourne
City of Melville
City of Mitcham
City of Newcastle
City of Onkaparinga
City of Playford
City of Port Adelaide Enfield
City of Sydney
City of Unley

CORPORATE
Active Tree Services
ArborCarbon
Arbor Centre
Arborman Tree Solutions
Arbortrack Australasia Pty Ltd
Austral Tree Services
Botanix Plant Supply Pty Ltd
Enviro Frontier
Greenwood Consulting
Homewood Consulting
HR Products

Click here to visit the TREENET website to find out more about our Institutional Members
TREETNET MANAGEMENT COMMITTEE AND ADVISORY BOARD 2016

TREETNET MANAGEMENT COMMITTEE

Chairperson:  Dr Greg Moore
Director:  Glenn Williams (ex officio)
Director:  David Lawry OAM (ex officio)
Treasurer:  Darryl Gobbett  (ex officio)
Members:  Judy Fakes
          Dr Jennifer Gardner / Dr Kate Delaporte
          Tim Johnson
          Cameron Ryder
          Rob Bodenstaff
          Lyndal Plant

TREETNET ADVISORY BOARD

Glenn Williams  Director TREETNET  SA
David Lawry OAM  Director, Avenues of Honour  SA
Darryl Gobbett  Honorary Treasurer TREETNET / 1915-2015 Avenues of Honour Project  SA

Educational and Research Institutions

Prof Chris Daniels  Professor of Urban Ecology University SA  SA
Dr Jennifer Gardner  Curator, Waite Arboretum, TREETNET Management Committee  SA
Dr Greg Moore  Research Assoc. Burnley School of Resource Management & Geography,
          Chair, TREETNET Management Committee  VIC
Dr Dean Nicolle  Director, Currency Creek Arboretum  SA
John Zwar  TAFESA Urrbrae Campus, TREETNET Management Committee  SA
Lyndal Plant  The University of Queensland, TREETNET Management Committee  QLD

Nursery Industry

John Fitzgibbon  Metropolitan Trees  VIC
Hamish Mitchell  Specialty Trees  VIC

Community

Hon Michelle Lensink  Liberal Member Legislative Assembly  SA

Landscape Architects and Urban Planners

Michael Heath  Chair National Trust SA Significant Tree Team  SA

Arboricultural & Allied Professions

Jan Allen  Terra Ark  QLD
Peter Bishop  Bunya Solutions  QLD
Rob Bodenstaff  Arbor Centre, TREETNET Management Committee  WA
David Galwey  Tree Dimensions  VIC
Peter Lawton  Trentcom  VIC
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<tr>
<th>Name</th>
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<tr>
<td>Ben Kenyon</td>
<td>Homewood Consulting</td>
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<td>Phillip Kenyon</td>
<td>Kenyon’s Quality Tree Care</td>
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<tr>
<td>Cameron Ryder</td>
<td>C &amp; R Ryder Consulting, TREENET Management Committee</td>
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<td>Kym Knight</td>
<td>Tree Environns</td>
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<td>Mark Willcocks</td>
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<td>Quentin Nicholls</td>
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<td>Sue Wylie</td>
<td>Tree Talk Arboricultural Consulting</td>
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<td>Tim Johnson</td>
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<tr>
<td>Christopher Lawry</td>
<td>Mount Barker District Council</td>
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<td>Jason Summers</td>
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<td>Karen Sweeney</td>
<td>City of Sydney</td>
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<td>Vic Bijl</td>
<td>City of Belmont</td>
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<td>Lee Anderson</td>
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<td>Judy Fakes</td>
<td>Commissioner, Land &amp; Environment Court NSW, TREENET Committee</td>
<td>NSW</td>
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TREENET INCORPORATED CONSTITUTION

1. NAME

The name of the Association is “TREENET Incorporated”

2. DEFINITIONS


2.2 “Association” means the above named Association.

2.3 “Management Committee” means the committee referred to in Rule 11.

2.4 “Advisory Board” means the Board referred to in Rule 12.

3. VISION AND AIMS

3.1 Vision

The vision of the Association is to enhance the role of trees in the urban forest and to engage the community in this endeavour.

3.2 Aims

The aims of the Association are:

3.2.1 To develop and maintain an interactive web application to facilitate the exchange of information relating to urban forests.

3.2.2 To promote research and education relating to urban forests including holding symposia.

3.2.3 To broaden the body of knowledge that exists about street trees and foster research, distribute applicable information, facilitate cooperation and enlist community support concerning the protection, preservation and enhancement of the urban forest.

3.2.4 To establish and maintain a public fund to be called TREENET Fund for the specific purpose of supporting the environmental purposes of TREENET Inc. The Fund is established to receive all gifts of money or property for this purpose and any money received because of such gifts must be credited to its bank account. The Fund must not receive any other money or property into its account and it must comply with subdivision 30-E of the Income Tax Assessment Act 1997.

4. POWERS

The Association shall have all the powers conferred by Section 25 of the Act.
5. MEMBERSHIP

5.1 Membership
When an organisation or person has agreed to become a member of the Association and has paid the Association’s membership fee where it applies, then that organisation or person will be admitted to membership pursuant to the Constitution, and their name shall be entered in the Association’s Register of Members.

5.2 Classes of Member
There shall be five classes of member:

5.2.1 Management Committee Member
This class shall consist of all members of the Management Committee as described in Rule 11.1. Management Committee Members will have the right to receive notice of and attend all meetings.

5.2.2 Advisory Board Member
This class shall consist of natural persons who have been invited by the Management Committee to be on the Advisory Board and agreed. Advisory Board Members will have the right to receive notice of, and attend, the Annual General Meeting and other General Meetings as called. The term of appointment will be for the calendar year.

5.2.3 Associate Member
This class shall consist of natural persons who register an interest in joining the Association and who subscribe to the aims of the Association.

5.2.4 Institutional Member
This class shall consist of research and educational institutions, government bodies, businesses and associations who are financial members. Institutional Members will have the right to receive notice of, and attend, the Annual General Meeting and other General Meetings as called.

5.2.5 Honorary Life Member
This class shall consist of natural persons who have been granted Honorary membership at the discretion of the Management Committee. Honorary Life Members will have the right to receive notice of and attend the Annual General Meeting and other General Meetings as called.

5.3 Votes
Members may exercise the following voting entitlements:

5.3.1 Management Committee Member – 1 vote
5.3.2 Advisory Board Member – 1 vote
5.3.3 Associate Member – members of this class shall have no votes
5.3.4 Institutional Member – financial members – 1 vote by representation or proxy
5.3.5 Honorary Life Member – 1 vote
5.4 **Register of Members**
A Register of Members shall be kept which contains the name, postal or electronic address, class of membership and subscription details of each Member and the date of joining the Association.

5.5 **No Transfer of Rights**
The rights and privileges of a Member shall not be transferable and shall cease upon such an organisation or person ceasing to be a Member.

6. **MEMBERSHIP FEES**
The Management Committee shall from time to time set the terms and conditions of membership fees, if any, for the different classes of membership.

7. **CESSATION OF MEMBERSHIP**
Membership may cease by resignation, expulsion or non-payment of fees.

7.1 **Resignation**
Members shall cease to be a member by notifying the Association by whatever means the Management Committee might direct from time to time.

7.2 **Expulsion**
If any Member wilfully refuses or neglects to comply with the provisions of the Constitution, or is guilty of any conduct which in the opinion of the Management Committee is unbecoming to a Member or prejudicial to the interests of the Association, the Committee shall have the power to expel the member from the Association PROVIDED THAT at least one month before the Committee Meeting at which a resolution for the Member’s expulsion is to be considered, the Member shall have been given notice of such meeting and what is alleged against them and of the intended resolution for their expulsion, and they shall at such meeting and before the passing of such resolution have had an opportunity to give oral or written explanation for their defence.

7.3 **Non-payment of Fees**
If a Member has not paid fees as agreed in the terms and conditions and has been notified in writing by the Association of this failure, then the Member shall cease to be a Member of the Association unless the prescribed fee is paid by the date as notified.

8. **PROPERTY AND FINANCE**

8.1 The funds and other property of the Association shall be managed and controlled by the Management Committee and shall be used only for the vision and aims of the Association.

8.2 All cheques, negotiable instruments and orders drawn by the Association shall be signed by two persons designated by the Management Committee.

8.3 Subject to Rule 8.1, the surplus funds of the Association may be invested in such manner as the Management Committee sees fit, except direct equities.

8.4 The accounts of the Association shall be audited annually.

8.5 The financial year of the Association shall be from 1 July to 30 June.

8.6 The Association shall prepare financial accounts at the end of each financial year.
9. **NOT-FOR-PROFIT**

The assets and income of the Association shall be applied solely in furtherance of its above-mentioned vision and aims and no portion shall be distributed directly or indirectly to the members of the Association except as bona fide compensation for services rendered or for reimbursement for expenses incurred.

10. **MEETINGS OF THE ASSOCIATION**

10.1 The Annual General Meeting shall be held at such time as the Management Committee shall determine.

10.2 Any Motion that any voting Member proposes to move at the Annual General Meeting including a proposal to alter the Constitution shall be given in writing to the Management Committee at least four weeks before the meeting.

10.3 At least 21 days before the Annual General Meeting or any other General Meeting, notice shall be given by written or electronic form sent to all members of the Association entitled to vote, but any accidental omission to give notice to any voting member shall not invalidate the meeting.

10.4 At the Annual General Meeting, ordinary business shall be the presentation of the audited financial accounts, election of the Management Committee and the appointment of an auditor.

10.5 Each voting member present shall be entitled to one vote. In case of an equality of votes, the Chair shall have a second or casting vote.

10.6 A Special General Meeting may be requested by ten voting members presenting an agenda to the Management Committee, the agenda being signed by all ten members. The Management Committee must within 14 days give notice of a Special General Meeting to be at least 21 days from the notice date. The Special General Meeting will be limited to the agenda items plus other items of which the Committee gives notice. Once the agenda items have been resolved by consensus, resolution or vote they cannot be used again to call a Special General Meeting for 52 weeks from the meeting date.

10.7 An Advisory Board Member shall be entitled to appoint in writing a natural person, who is also an Advisory Board Member of the Association, to be his or her proxy, and to vote on his or her behalf at any general meeting of the Association.

11. **MANAGEMENT COMMITTEE**

11.1 **Membership of the Management Committee**

The Management Committee will comprise six elected members drawn from education and research, business and government sectors of the community and three *ex officio* members as follows:

11.1.1 An academic from a tertiary educational institution

11.1.2 A member of Local Government

11.1.3 Four other members

11.1.4 The Director of Waite Arboretum will be a member *ex officio* and may also represent The University of Adelaide with consent from the University

11.1.5 The Directors of Treenet and the Treasurer of Treenet will be members *ex officio*. 

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*The 17th National Street Tree Symposium 2016*
11.2 Elections

11.2.1 The elected members of the Management Committee shall be elected annually by voting members of the Association at the Annual General Meeting.

11.2.2 Where the number of candidates for membership of the Management Committee exceeds the maximum number, elections shall be held by secret ballot of members at the Annual General Meeting entitled to vote. In the case of an equality of votes, the Chair shall have a second or casting vote.

11.2.3 The nomination of a candidate for membership of the Management Committee must be in writing, signed by a proposer (who must be an Advisory Board member) and by the nominee. The nomination must be delivered to the Director of the Association before such time as the Management Committee shall determine.

11.2.4 Subject to Rule 11.1, the Management Committee shall have the power to co-opt further Committee members and to fill casual vacancies.

11.3 Office Bearers

The Office Bearers of the Association shall be:

- Chair
- Directors & Public Officer ex officio
- Treasurer ex officio

11.4 Procedures Generally

The Management Committee may meet in person or confer by video or telephone conferencing, email or by other electronic means for the dispatch of business and subject to the Constitution, otherwise regulate its meetings as it thinks fit.

11.5 Calling of Committee Meetings

11.5.1 The Management Committee shall meet or confer at least four times per year as described in 11.4. Notice of the meeting or conference shall be given in writing to each Committee Member.

11.5.2 The position of any Committee member absent for three consecutive meetings or conferences without leave of absence shall automatically become vacant. Acceptance of an apology shall be deemed grant of such leave.

11.6 Chair

The Chair shall take the chair at meetings. In his or her absence, the Committee shall appoint a member of the Committee to chair the meeting.

11.7 Decisions of Questions

Questions arising before a meeting of the Committee shall be decided by a majority vote. In case of an equality of votes, the chair shall have a second or casting vote.

11.8 Reporting

The Management Committee shall be responsible to the Association and shall present an annual report, including the audited financial accounts, to each Annual General Meeting.

11.9 Auditor

The Management Committee shall appoint an auditor of the Association, who will hold office until the next Annual General Meeting of the Association.
12. **ADVISORY BOARD**

12.1 There shall be an Advisory Board of the Association.

12.2 The Advisory Board will comprise persons who are competent and willing to provide advice to the Association in their individual areas of expertise, and to liaise with other bodies and institutions for the purpose of facilitating the flow of information between the Association and those other bodies and institutions, and facilitating the implementation of projects which the Association undertakes in furtherance of its aims.

12.3 Members of the Advisory Board shall have no power or authority to represent the Association in any dealings between the Association and third parties.

12.4 The Advisory Board shall meet at such times and places as the Management Committee shall determine.

12.5 The Chair of the Management Committee will take the chair at meetings of the Advisory Board.

13. **QUORUMS**

13.1 The quorum at general meetings of the Association shall be six members entitled to vote.

13.2 The quorum at Management Committee meetings shall be three members.

14. **AUTHORITY TO ENTER INTO CONTRACTS OR AGREEMENTS**

The Association shall not be committed to any binding contract or Agreement except pursuant to a resolution of the Management Committee and the instrument shall be signed by at least two members of the Committee.

15. **DISSOLUTION**

15.1 The Association shall be dissolved if a resolution to this effect is carried by a three-quarters majority voting in person or by proxy at a general meeting, 21 days notice of the proposed resolution having been given to all members entitled to vote.

15.2 In the event of the Association being dissolved, the amount that remains after such dissolution and the satisfaction of all debts and liabilities shall be transferred to the University of Adelaide, for expenditure on the Waite Arboretum only.

16. **ALTERATION TO THE CONSTITUTION**

This Constitution may be altered by resolution of a majority of three-quarters of members entitled to vote and who cast a vote in person or by proxy at a general meeting. Written notice of amendments shall be posted to all members entitled to vote at the same time as the notice of the meeting.

17. **REQUIREMENTS OF THE PUBLIC FUND**

The organisation must inform the Department responsible for the environment as soon as possible if:

- it changes its name or the name of its public fund; or
- there is any change to the membership of the management committee of the public fund; or
- there has been any departure from the model rules for public funds set out in the Guidelines to the Register of Environmental Organisations.
18. MINISTERIAL RULES

The organisation agrees to comply with any rules that the Treasurer and the Minister with responsibility for the environment may make to ensure that gifts made to the fund are only used for its principal purpose.

19. CONDUIT POLICY

Any allocation of funds or property to other persons or organizations will be made in accordance with the established purposes of the organisation and not be influenced by the preference of the donor.

20. WINDING-UP

In case of the winding-up of the Fund, any surplus assets are to be transferred to another fund with similar objectives that is on the Register of Environmental Organizations.

21. STATISTICAL INFORMATION

Statistical information requested by the Department on donations to the Public Fund will be provided within four months of the end of the financial year.

An audited financial statement for the organisation and its public fund will be supplied with the annual statistical return. The statement will provide information on the expenditure of public fund monies and the management of public fund assets.

22. RULES FOR THE PUBLIC FUND

22.1 The objective of the fund is to support the organization’s environmental purpose.

22.2 Members of the public are to be invited to make gifts of money or property to the fund for the environmental purposes of the organisation.

22.3 Money from interest on donations, income derived from donated property, and money from the realisation of such property is to be deposited into the fund.

22.4 A separate bank account is to be opened to deposit money donated to the fund, including interest accruing thereon, and gifts to it are to be kept separate from other funds of the organisation.

22.5 Receipts are to be issued in the name of the fund and proper accounting records and procedures are to be kept and used for the fund.

22.6 The fund will be operated on a not-for-profit basis.

22.7 A committee of management of no fewer than three persons will administer the fund. The committee will be appointed by the organisation. A majority of the members of the committee are required to be ‘responsible persons’ as defined by the Guidelines to the Register of Environmental Organizations.
SPEAKER AND PANELIST PROFILES

Dr Colin Butler
Colin is Visiting Fellow, National Centre for Epidemiology and Population Health at the Australian National University and until very recently was Professor of Public Health, University of Canberra. He qualified in medicine from the University of Newcastle, NSW, in 1986. His academic work has, for many years, principally involved interactions between society, health and the environment. In 2009 Colin was named as one of a hundred doctors for the planet. Colin has published about 130 articles and book chapters and given over 70 invited talks internationally. He is sole editor of “Climate Change and Global Health” and senior editor of “Health of People, Places and Planet”.

Colin has twice been arrested defending the environment, first at the campaign to protect the Franklin river in Tasmania from flooding in 1983, and again in 2014, near the Maules Creek coal mine in NSW, to protest the lack of high level Australian leadership over climate change.

In doing so, Colin became the first Australian contributor to the Intergovernmental Panel on Climate Change (IPCC) to be arrested for climate disobedience, and one of very few, globally.

Dr Thomas Astell-Burt
Dr Thomas Astell-Burt’s research is located at the interface between population, well-being and environmental studies, using a range of quantitative approaches (e.g. Geographic Information Systems).

Thomas is leading a National Health and Medical Research Council-funded project to identify built and natural environments that support better diabetes care. He is interested in building multisectoral partnerships, enhancing evidence for decision makers and in particular, developing the business case for investing in more and better quality green spaces for health purposes.

He is working with Dr Xiaoqi Feng to co-direct the Population Wellbeing and Environmental Research Lab (PowerLab).

Dr Xiaoqi Feng
Dr Xiaoqi Feng is a Chief Investigator on a National Health and Medical Research Council grant and the National Heart Foundation of Australia Fellow in Built Environment and Health at the University of Wollongong.

Xiaoqi has strong research interests in understanding what types of green space promote the best start in life for children, and how much green space is needed to help keep people healthy and out of hospital in older age.

This research is conducted in Australia (e.g. with the Western Sydney Local Health District and Diabetes NSW) and in China (e.g. with the China Centre for Disease Control and Prevention (China CDC). She is working with A/Prof Astell-Burt to co-direct the Population Wellbeing and Environmental Research Lab (PowerLab).
Vicki Martin

Vicki is a landscape architect with a passion for urban design. Her role since 2010 is Principal Urban Design at Brisbane City Council. The Urban Design Unit delivers a wide ranging portfolio of urban design and public art policy and projects; including the management of the delivery of Suburban Centre Improvement Projects (SCIPs), the Vibrant Laneways program, public art collection and strategic urban design advice and policy. These initiatives are the fine grain implementation of key Brisbane City Council strategies and policies. They create vibrant, distinctive and culturally rich places that attract people to live, work and invest.

Vicki studied landscape architecture at the Queensland University of Technology and has also worked extensively in consultancy in the United Kingdom specialising in landscape planning, assessment and design, and design of major infrastructure and urban regeneration projects.

Paul Barber

Paul is the Managing Director of ArborCarbon Pty Ltd, Adjunct Associate Professor at Murdoch University, and Vice-President of the not-for-profit Men of the Trees (MOTT). Paul completed his PhD in forest pathology, and has described more than 17 new species of fungal pathogen associated with diseases of trees. He established ArborCarbon in 2009 to provide clients with services and products for the diagnosis, monitoring and sustainable management of vegetation. Since then Paul has completed projects for government and private clients in Australia, Asia, the USA and the Middle East. Paul has a particular interest in providing land managers with the tools to easily map, monitor and measure urban forest cover and condition, and the benefits these forests provide to people.

Dr Brenda Lin

Dr Lin's research examines how natural systems or components of natural systems can be maintained or integrated into an increasingly developed landscape to provide ecosystem services that optimise both environmental and human well-being. Her primary research is focused on global environmental drivers of landscape change and the resulting effects on ecosystem services, especially climate regulation services. One area of focus has been in urban ecological systems where she examines the relationships between vegetation cover, environmental services, and human health.

After completing her doctoral research, Dr Lin joined the Earth Institute at Columbia University as a Postdoctoral Research Fellow working on interdisciplinary issues of sustainable development and food security in agricultural systems under climate change.

Prior to joining CSIRO, Dr Lin was a Science & Technology Policy Fellow with the American Association for the Advancement of Science in Washington DC, USA. During this time she worked for the United Stated Environmental Protection Agency within the Global Change Research Program in the Office of Research and Development. Her research at the US EPA focused on climate change impacts within the natural and built environment and examined potential climate change adaptation strategies at the national scale. Dr. Lin joined CSIRO in November 2010 working within the Climate Adaptation Flagship. She is now working within the Sustainable, Liveable and Resilient Cities Program within the Land and Water Flagship.
**Associate Professor Cris Brack**  
Cris has an academic background in forestry with a B.Sc. (Forestry) (Hons) and a PhD, but has also worked in the native forests as well as the plantations across Australia, New Zealand and the Asia-Pacific. In the 1990's he began to focus on urban forests and urban green spaces when he developed a decision information support system for managing urban trees (DISMUT). This system integrated an effective streetscape survey of all urban trees in the Canberra urban estate along with a series of growth models to estimate how the trees grow and become stressed. Over the following two decades he has been developing new ways of measuring these urban forests and predicting their values and future management needs. He is now the Associate Professions for forest measurement and management at the Fenner School of Environment and Society at the Australian National University. He is also involved in research and management at the National Arboretum, Canberra.

**Tuesday Udell**  
Tuesday Udell is Senior Policy Advisor for the Heart Foundation, with a keen interest in creating healthy environments and making South Australia a better place to live. Tuesday has worked for many years in South Australian public health roles for government and non-government organisations after studying and working in London for 11 years.

In 2006, after finishing a Masters of Science, Tuesday joined the Heart Foundation’s National food supply team where she led the development of nutritional evidence reviews, policy and position papers.

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She is the lead author of the discussion paper *Does Density Matter?*, the co-author of *Good for Business* and is currently leading the reformed South Australian Active Living Coalition.

On weekends you will see her cooking, gardening, walking her dog and walking her children.

**Dr Danielle Shanahan**  
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Dr Greg Moore

Greg Moore was Principal of Burnley College of the Institute of Land Food Resources at Melbourne University from 1988 to 2007. Prior to this he was a Senior Lecturer and Lecturer in Plant Science and Arboriculture at Burnley from 1979. He was Head of the School of Resource Management at the University from 2002 to 2007.

Apart from a general interest in horticultural plant science, revegetation and ecology, Greg has a specific interest in all aspects of arboriculture. He has contributed to the development of Australian Standards in pruning and amenity tree evaluation and continues to be a major speaker at conferences worldwide and in Australia.

He was the inaugural president of the International Society of Arboriculture, Australian Chapter. He is a much sought after guest for talk-back radio and regularly invited to contribute comment for television and print media.

He has been a member of the National Trust of Victoria’s Register of Significant Trees Committee from 1988, chairing the committee since 1996. He has chaired TREENET since 2005.

Greg continues to supervise post-graduate students and pursues an active research profile in any matters that relate to trees in the urban environment and revegetation.

Kat Ryan

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"At first I thought I was fighting to save rubber trees, then I thought I was fighting to save the Amazon rainforest. Now I realise I am fighting for humanity." (Chico Mendes)

Abstract

This paper seeks to place the issue of forest protection within a wider context of regard for Nature. It starts with a brief review of urban forests and health, including air pollution, “green space” and “nature deficit disorder”. It then discusses climate change, in conjunction with other evidence of disregard for nature and its effect on heatwaves, floods and ecosystems, including the habitat of the Monarch butterfly. Evidence is then presented linking disrespect for nature, minorities and other limits to growth with climate change, refugees, conflict and population policy.

We face multiple crises. High income nations feel besieged by refugees and asylum seekers. Many low income nations are wracked by insurgency, division and in some cases open war. The two spheres interact, generating xenophobia, fences, walls and detention camps at the barriers. At the same time, the climate has warmed and wilded, as humanity treats the atmosphere as a sewer, oblivious to the harm we are doing it as our predecessors were to the filth they poured in the river Thames. We are a species of primate, descended from trees, but so entranced with our technological progress that too many of us think we no longer need Nature.

On the whole, in the last ten thousand years (the Holocene) Nature has been benign, forgiving and abundant. Humanity has flourished. However, unless we quickly alter our path, on a scale that today seems almost unimaginable, we will leave this sweet spot behind. Future Nature will not be so benign. We risk a new Dark Age.

In this context, it is imperative that we value and protect Nature that remains, including our forests. Australians have, in recent decades, almost led the world as carbon criminals. Our record on biodiversity is also poor. This behaviour has to change, from the bottom up and the middle out. Politicians like Bob Such are unfortunately rare, but even the lawyers and unionists who dominate our parliaments and who largely appear indifferent to Nature, will listen to people if we show we care enough. As the multiple global crises deepen, this is the only chance we have.

Introduction

Although I have written on global deforestation (1) and about human health and forests (2), as well as other aspects of ecosystem “services” (3) (4) and on biodiversity change and human health (5), this paper takes a different track. It attempts to place deforestation within the broader sphere of harm and loss of respect (and reverence for life) (4) and Nature. It covers a large territory and is not intended to be comprehensive.

It starts with a brief review of health and urban trees, before then linking climate change and loss of respect for nature with the evolving refugee crisis and the potential for conflict.

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2 https://www.theguardian.com/environment/amazon-rainforest
4 http://www.hummingbirdworld.com/spiritnature/Schweitzer.htm
Human health, forests and trees

Air pollution

Preservation and enhancement of forests is beneficial to reduce air quality (rural and urban), climate change and also provides valuable erosion and flooding control.

Trees in cities reduce the urban heat island effect (6) and give crucial habitat to insects, birds and mammals.

Trees are especially effective at reducing levels of particulate matter (PM$_{10}$), an important component of air pollution from vehicles, industry and (where used) the burning of biomass including wood, for cooking and heating. In turn, PM$_{10}$ is an important cause of lung and heart disease (7).

However, the relationship between trees and air pollution is complex. For a start, tree lined avenues may increase local air pollution from cars, by reducing ventilation (8). Furthermore, some tree species (including Mediterranean plants, both deciduous and coniferous trees, such as elder, elm, spruce and pine) emit volatile organic compounds (VOC) which may in some cases and seasons worsen urban ozone concentrations in combination with traffic and other sources of air pollution (9).

Green Space and “Nature Deficit Disorder”

There is a growing appreciation that regular contact with nature, including when young, may benefit human well-being and lower anti-social behaviour. Richard Louv has coined the term “nature deficit disorder” for what may be a syndrome more common among people deprived from much contact with nature (10). In support, a study undertaken in Munich, Germany, found that boys living further than 500 m away from urban green spaces had more behavioural problems compared to those living within 500 m of urban green spaces (11).

However, debate remains about cause and effect. Specifically, more affluent people, who in general have better health, access to more resources and who adopt more health protective behaviour, such as lower smoking rates, are more likely to live in leafier areas and to be closer to parks, where property prices are higher. Could the reported behavioural benefit of access to parks for boys be actually because they get more physical exercise? Or, perhaps, they have more leisure and feel more energetic, due to a nicer home life? Or is the experience of being in nature – even a fairly bland urban park – inherently beneficial?

Perhaps all of these explanations have some validity. The great planetary ecologist, René Dubos (credited by some with coining “think globally act locally”) commented in the 1950s on the reduced human contact with nature that was then evolving, especially in urban areas. Dubos speculated that this would trigger a demand for artificial forms of stimulation, including through drugs (12). It is possible that Dubos may also have anticipated a growth in electronic stimulation as partial compensation for the loss of contact with nature: the early forms of electronic games and virtual reality were evolving when Dubos was still alive (13).

Dubos warned:

”... people adapt so unconsciously to their surroundings, ... that they would no longer mind the stench of automobile exhausts, ugly urban sprawl, "starless skies, treeless avenues, shapeless buildings, tasteless bread, joyless celebrations.” "We do not live on the planet earth but with the life it harbours and within the environment that life creates” (12)

Could people who are poorer benefit from exposure to more green space (and blue space – water views), even if their other risk factors for poor health remain unchanged? It seems worth a try, but policy makers are likely to require additional evidence before converting pts of densely populated urban areas to green space.

In general, in Australia, as in many nations, rural people are poorer, less educated and less healthy than their urban cousins. Yet rural people have, on average, significant exposure to green space. This suggests, if there is a benefit from such exposure, that it is not sufficiently powerful to overcome many other disadvantages.

Some risks from the wrong tree species

Not all trees benefit health; some species are highly allergenic, causing severe symptoms in vulnerable people, including asthma (14) and, possibly mood changes. There are credible claims that exposure to allergens is a factor underpinning the long observed rise in suicides in spring (15).
Trees frequently shed leaves and twigs; their debris blocks gutters and adds to maintenance costs. Especially in winds and storms, trees drop branches and can fall, crushing cars and even houses. Trees give shade and reduce noise but their shade in urban areas may hide views, reduce photovoltaic energy production and lessen valuable sun access to Vitamin D deprived people in winter. But, of course, shade is appreciated in hot weather. In some settings, urban forests can fuel catastrophic urban fires, such as those which swept through much of Canberra in 2003 (complete with fire tornadoes) (16). Considerable thought, research and expertise is therefore needed to choose the optimal mix of tree species, especially in urban areas. Although this is the background paper for the keynote lecture, I am not going to offer a more detailed opinion!

Sacred groves

Finally, it is worth mentioning that contact with trees, especially ones that are old, appears nourishing psychologically and spiritually, at least to people with high “biophilia” (a love of nature) (17). In many traditional societies sacred groves are worshipped and maintained (18). The Buddha was enlightened beneath a Bodhi tree (Ficus religiosa).

Climate change, loss or respect for nature, and our slow emergency

The world faces multiple crisis. In this section, I am treading firmer ground, having written and warned of these issues for 25 years (19, 20). High income nations feel besieged by refugees and asylum seekers. A large number of low income nations are wracked by insurgency, division, and in some cases ruinous and vicious war. The two spheres (fear and war) interact, generating xenophobia, fences, walls and detention camps at the barriers. Periodically, news reports announce new crossings of people across boundary, unwanted by most and generally regarded as incursions, if not invasions. The issue of asylum seeking has become central to many election campaigns, including in Australia.

Climate change: heat and flooding

The climate is steadily warming (21) and we are perilously close to the target set in the Paris climate conference of December 2015 (see Figure 1) (22).

Figure 1 Climate change is accelerating, credit Prof Stefan Rahmstorf, using NASA data. 12-months running average, including the new July (2016) value, the hottest month ever recorded. In 2016 average temperature increase is perilously close to the 1.5 degree target, announced only in December 2015. This target is in comparison to “pre-industrial” levels (1850-1900). Although this figure suggests a recent anomaly of 1 degree C, it is more like 1.2 degrees C compared to the 1850-1900 level.
The climate is also “wilding”, including an apparent increase in the recently named phenomena “rainbombs”\(^5\). While this term might seem dramatic (an article in Bloomberg suggested that “climate change is weaponizing the atmosphere”)\(^6\) there is evidence, where good records exist, of increased rainfall intensity in the U.S., \((23)\) and possibly in Australia, too \((24)\). Heavier rainfall (and flash flooding) is consistent with our understanding of climate change; a warmer atmosphere can hold (and release) more water. There have been many spectacular examples in recent months (see figure 2-4).

Figure 2 Flooded homes in Hammond, Louisiana, USA on Saturday, August 13, 2016. Image via AP. http://jezebel.com/the-historic-flooding-in-louisiana-is-looking-pretty-da-1785299122?utm_campaign=socialflow_jezebel_twitter&utm_source=jezebel_twitter&utm_medium=social flow See caption for Figure 4

\(^5\) http://metro.co.uk/2015/08/20/watch-rare-rain-bomb-explode-over-arizona-at-150mph-5351672/
Figure 3  Flooding in Khartoum, Sudan, August 2016. See caption for figure 4.  
http://camuudmedia.com/archives/2016/08/75540

Figure 4  Flooding in Khartoum, Sudan, August 2016. This picture gives an insight into the hardships endured in low income settings. Although a single flood is not “proof” of climate change, our understanding of climate change is that such floods will become more frequent and severe.  
http://camuudmedia.com/archives/2016/08/75540
Climate and ecological change

Climate and other forms of ecological change are also causing a profound alteration to the nature of many forests, as eloquently described by Dave Lindorff (see Box 1)

Box 1: Spoting the Havoc Wreaked by Climate Change and Development is, Sadly, a Walk in the Park | This Can't Be Happening!7

I took a long hike today through a local nature preserve. It was a humid 96° F with the heat index, thanks to the humidity making it feel like 110° — too hot to work on the stone re-pointing job I’m doing on our old stone house. I needed some nature, though, after spending the last few weeks reading and writing about our insane political situation.

Wandering down a path into the woods and following a local stream, though, I found myself getting more troubled than before. These woods, where I’ve walked for years, used to be filled with myriad species of birds — water birds, hawks, songbirds and others, and insects — dragonflies, butterflies, bees and flies of all kinds, as well as frogs, turtles and snakes. I’d usually return from such walks to report having seen a baltimore oriole, a blue heron, a garter or a water snake, a large snapping turtle or one or another kind of hawk. I wouldn’t even report on the butterflies, as they were myriad.

Today though, the forest was quiet. Occasionally I’d hear the sound of some unidentifiable bird, probably a starling or sparrow, but bird sounds were rare. Sightings too. I heard no cries from bluejays or crows, saw no hawks or waterbirds — not even mallard ducks, and heard no songbirds. I saw one small painted turtle sunning itself on a fallen tree in a dammed up part of the stream — a spot that used to be covered with turtles on a day like this. And I heard no frogs, which might explain the lack of any herons or other wading birds. The two creatures I did see were a deer (these apex mammals seem to have made the suburbs home, with no available predator except the automobile to diminish their numbers, and with grass and suburban flower gardens providing abundant food) and a beautiful solitary orange Monarch butterfly (see figure 5), which was flying with more purpose, in almost a straight line down the pathway, than I’ve ever seen a butterfly fly (perhaps it is on it’s lonely way to Mexico hoping to find a mate?). Other than that, there were almost no bugs too. That’s really scary, since bugs, besides pollinating plants, provide that basic protein source for most larger animals up the food chain. I had read that bugs of all kinds are in a dramatic decline all around the globe [1], and it certainly looks like it if they aren’t even pervasive in a nature preserve where there is no insecticide being used, where grass isn’t cut, and undergrowth is left alone.

I had noticed this decline earlier when we were up in the Catskills where we have a summer house. The streetlight in front of our property, which used to be enveloped in literally thousands of moths, flies and flying beetles during late spring and early summer months, to the delight of the brown bats that dive into the cloud again and again filling their bellies each night, these days is devoid of insects, which is astonishing and, when one thinks of it, terrifying.

As I walked through the nature park, where biting creatures — deer flies and horseflies — used to harass me in years past, I was only visited by one horsefly, which I dispatched as it landed on my arm, thereby worsening the dearth of insects and causing me to feel a little guilty about it.

President John F. Kennedy, looking out the Oval Office window on a rainy day during the depths of the Cold War, asked his science advisor if the rain outside was contaminated by radioactive fallout. Upon hearing a “yes,” he decided, to the shock of his military advisors, to unilaterally call a halt to open-air nuclear testing, and to get the Russians to do the same — which they did. But I’m afraid both the major party candidates running for president this year are such power-hungry narcissists that they are incapable of doing the one thing that might save us, which would be to wake up one morning in the White House next year and, recognizing the looming disaster of climate change, to call for a halt to any further removal of hydrocarbons from the ground. That monarch butterfly I saw — the only one I’ve spotted all summer here in south-eastern Pennsylvania or up in the Catskills,

7 http://thiscantbehappening.net/node/3264
both places they used to be rampant only a few years ago — had the right idea, I suppose: get the hell out of here!

But then, if it manages somehow to make it to the monarch meeting place in Michoacan, a province in Mexico’s central highlands, it may find the ancient pine forest where its forebears used to gather, turning the trees orange with their multitudes, gone (see Figure 5). It turns out that local farmers, desperately poor as NAFTA has destroyed their local subsistence farm economy, are cutting and burning the pine forest there and planting avocado trees [2], in hopes of earning a better income from that high-priced fruit than from the corn that for generations they used to grow for local consumption. But included among the forest they are destroying to satisfy insatiable first-world guacamole demand in the US and Europe is the butterfly reserve that the monarchs rely on.

![Figure 5 Monarch butterflies, against a background of pine trees.](http://www.evolutionnews.org/2011/12/monarch-butterfly053751.html)

Rachel Carson kicked off the environmental movement back in 1962 with her book Silent Spring. She was focusing then on the destruction of songbirds by the pervasive use of pesticides. But what I saw on my park stroll was a silence even deeper. It’s not just the birds that are gone now, it’s almost every living creature in the woods! The plants are still there, but as the pests that threaten them — many of them invasive results of globalized trade like the ash borer, the gypsy moth, oak wilt fungus, etc. — attack trees that are also being stressed by climate change with its season-changing warm periods and its periodic droughts — that may not be true for long.

1. [http://e360.yale.edu/feature/insect_numbers_declining_why_it_matters/3012/](http://e360.yale.edu/feature/insect_numbers_declining_why_it_matters/3012/)
2. [http://mashable.com/2016/08/16/illegal-avocado-deforestation/#XJcnQzTTgsqw](http://mashable.com/2016/08/16/illegal-avocado-deforestation/#XJcnQzTTgsqw)

**Climate change and forests**

The clearance and burning of forests, mostly to grow food, has been an important contributor to climate change; essentially, less carbon is stored in the soil, roots and leaves of crops (or livestock) than in the biomass of forest and the animal life it supported. Excess carbon, formerly held in the forests, shifts to the air and ocean, though some is taken up by non-forest biomass. Peat fires associated with forest clearance and burning, including in South East Asia are another lethal feedback (25). Harmful, reinforcing (positive) amplification of climate change involving forests is also predicted to add to our peril, such as from drying and burning of the Amazon forest (26, 27).
Refugees, climate change and increasing warnings

The issues of refugees and climate change are related, although poor governance, inequality and long nurtured grievances are additional elements that contribute to the violence, hunger and search for opportunity that drive people to flee or migrate. Despite wearing clothes, humans are largely governed by ancient instincts. This is not meant as a criticism; it is unsurprisingly difficult to collectively avoid or evade our biological heritage.

Our genes and culture have enabled humans to colonise much of the planet and even venture into space. But unless we evolve a new culture of planetary governance our fate appears perilous, as we confront our most fearsome predator; ourselves. The number of high level warnings that we are in trouble, as a global civilisation, is rising (28).

In the last ten thousand years, known as the Holocene (the period since the last Ice Age), Nature has been relatively benign and abundant. It is true that sea level rose rapidly and substantially at the dawn of the Holocene, as glaciers melted and oceans warmed, cutting off numerous islands from their respective continental masses, including Kangaroo Island, Tasmania, New Guinea and the British Isles. This was disruptive to humans (leading, after several thousand years of struggle, to the extinction of people on Kangaroo Island (29)), but there was at that time little if any permanent human coastal settlement. The level of coastal disruption then seems trivial in comparison to the impending crisis of coastal inundation that is already emerging, especially in low-lying regions such as Florida (30), Bangladesh and many deltas (31, 32). Sea level rise, conservatively estimated to approach a metre by 2100 is predicted to cost billions of dollars, to displace millions, and to reduce global food security.

Despite numerous famines, wars, earthquakes, plagues and other forms of hardship, humanity has, collectively, flourished during the Holocene, enabling an explosion in our numbers from fewer than ten million to about 7.5 billion today. However, unless we quickly alter our path, on a scale that today seems almost unimaginable, we may leave this “sweet spot” behind. Future Nature will not be so benign. Some fear that civilisation will collapse (33, 34). We may to risk a new Dark Age

Regional and planetary overload

I have mentioned that civilization is in an emerging crisis. However, many readers will dispute this, especially in Australia, which is still largely protected from these global forces, despite the increasing expenditure of our tax revenue on “border security” including “offshore processing”. In total, such expenditure – separate to defence spending – now exceeds that which Australia contributes to foreign aid. This increasing expenditure is one symptom of the emerging crisis. It may reassure those of you are skeptical that although “crisis” is often interpreted as something evolving very rapidly, it is more likely that the crisis of “planetary overload” (35) will unfold over several more decades, and perhaps longer. But we cannot be complacent, events could turn very violent much more quickly. For tens of millions of people, the crisis has already commenced.

Pope Francis has stated several times that we are in the early stages of World War III, including in 2014 and again in July 2016 when he warned “when I speak of war I speak of wars over interests, money, resources, not religion.” Also in July 2016, former New Zealand Prime Minister Helen Clark, a candidate for UN secretary general, stated that the United Nations “must do a better job at combating the root causes of violent extremism and global insecurity”.

Inequality, terrorism and the failure of globalisation

Links between inequality, resentment, double standards and terrorism have long been identified as important by analysts critical of capitalism and western “exceptionalism”, but until recently, these critiques have had with little impact. However, events including the popularity of anti-establishment politicians including Bernie Sanders, Donald Trump, and in Australia, the rise of opponents of free trade including the teams led by Nick Xenophon and Pauline Hansen are consequences of growing inequality, as was Brexit, when UK voters to leave the European Union.

There is a grudging realisation by many for whom globalisation has delivered increased bounty not only that this wealth has been unfairly distributed, but that, sooner or later, this growing gap is untenable, causing unliveable reductions in social cohesion. There is, as yet, less understanding that global inequality is a driver of terrorism and insecurity, but it is encouraging that both Pope Francis and Helen Clark are urging consideration of this possibility.

**A world record of refugees**

Perhaps the most convincing evidence of an emerging global crisis, even beyond the increasing frequency of Islamist-inspired violence in many countries, is the explosion in the number of refugees. On World Refugee day, June 20, 2016, the United Nations High Commission for Refugees announced that at the close of 2015 there were over 65 million displaced people on the planet, the majority of whom are children. This represents an increase of over 50% from the end of 2011 (36). Links between this increase, global environmental change and piecemeal “planetary overload” (35) are rarely made, but in fact the increase in refugee numbers is neither random nor coincidental.

Instead, this increase is a largely foreseeable consequence of planetary scaled “eco-social” (socio-ecological) factors. These deep factors, which operate in several pockets of “regional overload” (see table 1) are largely ignored, not only by journalists, but by spokespeople for governments, United Nations agencies and even for aid and environmental organisations.

**Table 1:** Examples of “regional overload” which contribute to current and future refugee production. Fertility rates (for 2015) are from the CIA Factbook. 11

<table>
<thead>
<tr>
<th></th>
<th>Climate change influence?</th>
<th>Other environmental influence?</th>
<th>Government</th>
<th>Fertility influence?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syria</td>
<td>Worsening drought (climate change related)</td>
<td>Aquifer depletion (drought, high population)</td>
<td>Lack of equitable governance</td>
<td>Comparatively high</td>
</tr>
<tr>
<td>Burundi</td>
<td>Not obvious</td>
<td>Scarcity of fertile land (per person)</td>
<td>Long history of ethnic tension</td>
<td>Very high (6.1)</td>
</tr>
<tr>
<td>Somalia</td>
<td>Drought</td>
<td>Fisheries plundered by other states</td>
<td>Chaotic – failed state</td>
<td>Very high (6.0)</td>
</tr>
<tr>
<td>Sahel (eg Niger)</td>
<td>Drought</td>
<td></td>
<td></td>
<td>Very high (Niger 6.8)</td>
</tr>
<tr>
<td>South Sudan</td>
<td>Drought</td>
<td></td>
<td>Civil war, distrust, new state</td>
<td>Very high (5.3)</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>Recent El Niño famine</td>
<td></td>
<td></td>
<td>Very high (5.2)</td>
</tr>
<tr>
<td>Myanmar</td>
<td>Not apparent</td>
<td></td>
<td>civil wars, hatred and fear of Rohingya</td>
<td>Moderate (2.2)</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>Sea level rise</td>
<td>Land scarcity</td>
<td>Increasing Islamism</td>
<td>Now slowing (2.4)</td>
</tr>
</tbody>
</table>

Instead, there is a form of conspiracy of silence in which commentators act as though there are no regional (or global) limits to human population size, even when areas are shared by rivalrous groups with marked differences in allegiance and, sometimes, appearance, ethnicity, culture, economic status and religion. But the growth in refugee numbers is not just from intolerance; it is also a consequence of our species’ disrespect and disconnect for Nature, as well as scanty willingness for more affluent and powerful groups to dilute their relative advantages.

**Human Population size**

For over fifty years there has been concern about the size of the growing global population (37). Although many fears were expressed, prior to the heyday of the Green Revolution, that humanity faced the prospect of very serious famine, there is consensus today that humans today can grow enough food to keep far more than even the current population alive, were it evenly distributed.

However, resources, including of food, are not evenly distributed. Furthermore, humans seek far more than basic nutritional subsistence. Human “carrying capacity” (38) is determined by far more than food supply. Our species also crave affluence, prestige and luxuries, whether country houses at the seaside, or coconuts on tiny Pacific islands (39). The supply of these luxuries is far more restricted than of staples. The social anthropologist Mary Douglas gives several compelling examples (see Box 2).

**Box 2: The complexity of human numbers**

The Ndembu are a tribe, in Zambia, who (at least at the time of the study) lived at a population density of 3-6 per square mile and who relied on cassava as their staple crop. Douglas comments that cassava is very easy to grow, and does not require labour-intensive cultivation. She also reports that the Ecological Survey of Northern Rhodesia (sic) estimated that using traditional techniques their tribal area could support at least three times its population density. However, although cassava is their staple, Douglas states that they are not very interested in cassava (do you blame them?) Instead, they are passionately interested in hunting. But game is scarce in their region; were their population higher, game would be even more scarce.

At the time of Douglas’s research, a trade-off seems to have been found. The population of the Ndembu is higher than possible from reliance on hunting alone (for the area they dominate). However, the number of Ndembu is lower than theoretically possible, due to their collective appreciation of hunting, which can be considered a scarce luxury for this group.

**Tikopia**

This tiny (5 sq kms) Pacific island is 700 miles from the nearest big island, and has for centuries produced all of its own food. In 1929 Douglas reports that its population was about 1,300 and that it was fully conscious of pressure on resources, with strong social disapproval for couples who reared families of more than two, or at most three children. Population numbers were restricted by contraception, abortion, infanticide and an ancient custom of pushing out to sea undesirables such as thieves.

Their staples were fish, root crops (taro and yams) and tree crops (breadfruit and coconuts). Pigs, once kept, had been removed, apparently as people realized more humans could be fed without them. Of these crops, coconuts were the most valued, producing cream which enhanced the palatability of all the other available food.

Like the Ndembu, the population of Tikopia, could have been larger – but there would be fewer coconuts to share. Furthermore, Tikopia (like most locations) is vulnerable to climatic events, such as cyclones, which can damage crops, including coconuts. Douglas argued that Tikopians consciously avoided a higher population not only to ensure a sufficient supply of coconuts, but also to have some spare, in case of disasters; a form of insurance. Nonetheless, of course, the Tikopians could not have supported a much larger population.

**Trading Nature for people**

I recently had a conversation with an Australian Aboriginal woman who mentioned, without prompting, how selfish humans have been to increase our population at the expense of Nature. She went on to describe the respect Indigenous people have for many natural elements.
I cannot speak for her people, but I believe that there is a great deal we could learn from them, especially from their traditional customs and knowledge. There is, for example, convincing evidence that many Australian Aboriginal tribes – perhaps almost all – had various methods, including customs and taboos, which slowed human population growth, enabling adequate, even abundant resources, for people, even during climatic extremes (40, 41). Slowing human population growth also reduces the chance of other species being driven towards extinction, although it is clear that many species did vanish due to the impact of Australia’s small Indigenous population, including megafauna (42), the thylacine and the devil (Sarcophilus harrisii), though each of the latter survived for a while on Tasmania; one still does.

**How distrust of the other drives us near the cliff**

These three examples (the Ndembu, the Tikopians and the Australian Aboriginals) give insight into the global crisis that exists of both overpopulation, overconsumption and damage to Nature. But the global population problem appears insoluble, without changes in attitude which seem currently implausible.

Humans do not seek or willingly accept to behave like bricks in a wall, content to be crammed into one spot, acting politely until their natural death, even if regularly fed a poor diet and given minimal other necessities, such as basic shelter, even if some people do behave a little like this when forced to, particularly if conditioned to endure scarcity from birth. An example is the inhabitants of Gaza, with a population density of almost 5,000 per square km (Australia has about 3 people per square km). This is not the highest in the world; Macao, Monaco, Hong Kong and Singapore are higher. However, inhabitants in those places have a far higher standard of living and more mobility.

Instead, humans use their ingenuity and co-operate with similar groups to form alliances, seeking to increase their chance of additional resources. If it is accepted that most (if not virtually all) humans will seek and accept living standards that are greater than needed to simply maintain existence then it follows that competition for scarce resources is inevitable, even if basic resources (such as nutrients) are abundant. Such competition can be reduced by population restricting strategies adopted by Australian Aboriginals (living traditionally) and the Tikopians, and the Ndembu.

In theory, global competition over scarce resources (likely to become increasingly scarce, as a result of climate change as well as population increase) could be tempered by an accelerated global demographic transition (a switch from above replacement fertility to below 2.1 children per woman). In reality, this is unlikely, due to the many forms of inequality which exist, such as of wealth, income, life expectancy and access to leisure and opportunity (see Box 3).

**Box 3: The demographic dividend**

Although regional demographic transitions can deliver “demographic dividends” (43) which accelerate the accumulation of wealth and development several factors operate to obstruct this, especially in non-homogenous societies. Of course, if each group were to co-operate by slowing fertility in parallel then both groups might win, illustrating an example of the prisoner’s dilemma (44) and avoiding what Hardin called “the tragedy of the commons” (45). Over sufficient time, populations which reap the demographic dividend (e.g. Japan, Thailand, Taiwan and China) are likely to be more powerful on a per capita basis than populations which fail to undergo the transition (e.g. Nigeria and many other African nations). There are exceptions, such as Saudi Arabia, a population which has considerable wealth and influence, despite a comparatively high fertility rate. But this wealth is not because of the demographic dividend, but instead its enormous natural resource base (46).

In much of the world, especially in most of Africa and the Middle East, the lack of cultural and other forms of homogeneity helps to thwart a rapid and widespread demographic transition. In such places, any group which lowers its birth rate (even if to seek long-term per capita benefits) appears to face (and perhaps does initiate) short term risk at the hands of its main competitor, whose population will continue to rise at a higher rate. This differential in population growth rate (and perhaps of total population size) creates the perception, and possibility the reality of vulnerability.

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12 [http://www.indexmundi.com/g/r.aspx?v=21000](http://www.indexmundi.com/g/r.aspx?v=21000)
Conclusion: fighting for humanity
Chico Mendes, Bob Such and René Dubos

Chico Mendes, the Brazilian union leader and rubber trapper, is an icon for environmentalism, especially in Brazil. His murder occurred because of competition over resources that in turn underpinned the livelihood of other groups. Although some experts challenge the scarcity arguments, claiming (curiously) that conflict often arises instead from abundance (47), this is surely less plausible than the converse. Competition over limited resources is the heart of evolutionary theory (48). Parents, martyrs and saints may sacrifice themselves for another individual, but such events are very rare.

Humans have invented opera, nuclear weapons and spaceflight, remarkable for a species of primate, descended from trees. At its higher level of achievement humanity has made incredible technological and organisational progress. However, collectively, we seem to be so entranced by this technology, including of virtual reality, that many of us have forgotten our absolute dependence on Nature. While new technology such as photovoltaic cells and electric cars are promising to slow the rate of climate change changes in attitude are required if civilisation is to survive the challenges which our cavalier attitudes to the protection of Nature have set in place.

It is imperative that we value and protect the Nature that remains, including our forests, both urban and otherwise. Yet, Australians have, in recent decades, almost led the world as carbon criminals, on a per person basis. Our record on biodiversity protection is also poor. The Great Barrier Reef, still a natural wonder of the world, is increasingly affected by coral bleaching, from a combination of warmer temperatures (49) and farming runoff (50). Australian government policies are trying to reduce the latter, but at the same time perversely support a massive expansion of coal mining, which of course will exacerbate climate change. High sea surface temperatures are also attributed as the main cause in the recently observed, unprecedented in scale die-off of mangrove forests13 in the Gulf of Carpentaria.

Political double standards like this have to shift, but are unlikely to do so from the “bottom up”, on a global scale. The poorest fraction of humanity (at least 25%, perhaps 50%) lack the means to have much influence, especially when so many politicians are flagrantly non-democratic and corrupt. If we are to survive as a civilisation then beneficial change must be driven by "middle out" strategies – led by people with education and means of influence, such as people reading this.

Politicians who value Nature, like the late Bob Such (1944-2014) are rare. Even so, the lawyers and unionists who dominate our parliaments, and who largely appear indifferent to Nature, must listen if enough people show they care enough.

The final word is to René Dubos. He called on individuals to initiate actions that would ‘put fundamental needs of life before claims of profit, prestige or power.’ Solutions would not come from "the official proclamations made in great universities, policy statements from governments nor recommendations from expert panels. Rather it is all the motivated individuals of the world who can save it (12).

References


URBAN GREENING FOR HEALTHIER AGEING: GAPS IN KNOWLEDGE AND HOW WE CAN PLUG THEM TOGETHER

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Abstract
Green space is increasingly prominent in public health research, but many important details remain unknown. In this presentation, we outline the state of evidence on green space and health. We identify three of the bigger issues currently vexing some epidemiologists that are also important to the wider green space enterprise. Finally, we suggest some avenues in how we can plug these gaps in knowledge together.

Epidemiology now
Why would two epidemiologists be interested in trees? Other than for their uncanny ability to brighten up practically any streetscape with their natural beauty? Epidemiology, according to the British Medical Journal, concerns the understanding of how often diseases occur in different groups of people and why. Information from epidemiological studies has been used to plan and evaluate strategies to prevent illness 1. Epidemiologists have also worked with clinicians to contribute to guidelines on the management of patients in whom diseases have already developed 2. So once again, why the interest in trees?

First let us consider two figures who are, or were until fairly recently, mainstream in popular culture. Take Sherlock Holmes, for example, and his attempts to thwart an evil genius who was seemingly hell bent on doing major harm (or worse) to one or many people. Gregory House MD is another popular rogue who would appear to stop at little (other than seemingly any opportunity to berate a colleague) to diagnose a condition and save the life of a patient. Disclaimer: neither Sherlock Holmes nor Gregory House are epidemiologists. But their common pursuit of an answer to a question that could save lives through scientific observation, pattern detection and hypothesis testing is precisely what epidemiologists do. Except whereas the two aforementioned mavericks tend to focus on one patient at a time, we are more interested in entire communities, cities and countries, protecting the health of millions at a time 3.

A vicious cycle
As epidemiologists we are interested in identifying, measuring, describing, evaluating and helping to optimise access to phenomena that helps to keep people healthy and out of hospital. You may think that is what the health sector is for, but you’d only be partially right. If a person visits an emergency department for a heart attack, receives world class care and recovers sufficiently to be discharged, that is an excellent result. But the downright abominable news is that once that person leaves hospital for home, they are often returning to the very same circumstances that contributed to their need to go to hospital in the first place 4. Deprivation. Stress. Pollution. Sedentary lifestyles. Loneliness. Discrimination. Bad food. It’s a vicious cycle. A cycle that the health sector can’t break on its own 5. Not only do we need to think outside the square to solve this question, but unless you happen to wake up one fine Australian morning with a startling epiphany that Holmes or House would be proud of, we clearly also need to work together as a society 6,7.

Breaking the cycle
This is where trees come in. A great deal of scientific research (including our own) has been conducted for over 20 years now that suggests evidence for what you may already hold true. That is, trees support our wellbeing 8-11. We are enhanced, psychologically and physiologically, by exposure to trees and green spaces more generally
Green salubrious landscapes to go for a nice quiet stroll. To push a pram. To walk a dog. To take a brisk jog. To shelter from the heat. To take a breath of fresh air. To think. To play. To relax and marvel. To have a gathering with family. To meet new friends. To escape from the madding crowd.

So while reality television shows report the latest dietary fads, national guidelines prescribe the minimum amount of physical activity we should be doing and the President of the Australian Medical Association suggests we should all take more responsibility for our health, it’s a Pythonian statement of the bleeding obvious – but we shall say it anyway – that the circumstances we are in affect what we can and cannot choose to do. Difficult to choose to benefit from a park if there isn’t one located nearby. To promote healthier people, we cannot put all of our eggs in one basket; we need to consider health and wellbeing implications in decision-making in all sectors, not just the health sector.

Accessing green space – does everyone have a fair go?

Our research shows that people living in lower income neighbourhoods in Sydney, Melbourne, Brisbane, Perth and Adelaide tend to have less access to green space nearby where they live. Communities living in Western Sydney, known for socioeconomic disadvantage and serious health challenges like type 2 diabetes, also tend to have less green space nearby than their counterparts in the affluent North Shore and Eastern suburbs. What this means is that for many communities where chronic diseases are more common and the odds of repeat hospitalisation are higher, the availability of green space tends to be lower. More trees will not be the panacea for all of society’s problems, but an equalisation of access to quality green spaces is likely to give everyone a fairer go at gleaning all those benefits from trees et al.

How much green for healthy ageing?

Now we could stop there, but as epidemiologists, we not only care about the big picture, but we care about the details too. There is actually much about the relationship between green space and health that we just do not know enough about yet. The recent Harvard Natural Environment Initiative position statement summed up many of the holes in the evidence base. A big one, from the point of view of urban planning and people in green space-related industries, and increasingly from our point of view too, is how much green space is needed to elicit a health benefit? It is probably not a straight line relationship. Think of income. An extra $100 a year for a person earning just $50,000 annually is unlikely to make much difference, but an extra $10,000 could make a potentially very significant difference to their quality of life. An extra $10,000 a year for a person already earning $500,000 annually may, on the other hand, be largely inconsequential.

It might be the same with trees and green spaces more generally. For people with very little green space nearby, a little addition may be tokenistic with respect to health, but it may not actually take a huge amount of new greenery to stimulate a meaningful health response. A reasonable investment with a potentially big benefit for the community. Even more greenery in communities where green space is already abundant may, on the other hand, may yield only marginal returns for health; ergo the ‘law of diminishing returns’. The effect of increasing the quantity of green space on community health could, we suspect, be curvilinear. Some research has already shown that the association between green space and mental health varies between men and women by age group. But there just isn’t much evidence on how much green space is the optimal amount for health gain and whether this varies within the population at the moment.

Same quantity, different arrangement?

This then leads to an issue of formation. In terms of the health of an entire community, is it better to have lots of tiny pocket parks, or the same amount of green space clustered within a smaller number of larger parks that are easily accessible within a short walking distance? Evidence suggests that bigger green spaces are more likely to offer the types of surroundings that enable physical activity. But if the many pocket parks spread across a suburb are well-connected by properly maintained pathways, decent street-lighting and reasonable visibility, could this provide a substitute in contexts (e.g. downtown city centres) where land values are prohibitive for the development of new larger green spaces?
Again, not much evidence so far, but clearly it is not particularly useful for researchers to suggest that there needs to be a minimum of 40% green space, for example within an inner city neighbourhood that is already very densely composed and difficult to change (at least in the short term). We need to understand more clearly, with better evidence, how different patterns of green land use can give the same health benefit and under what conditions we can optimise those benefits for everyone.

**Green space as preventive healthcare?**

Finally - and this is a big one for many people in the health sector – if trees and green spaces really are consequential for the health of the population, to what extent can we say that the dollars invested in green space help us to break the vicious cycle of repeated hospitalisation for reasons that we know can be avoided? That is, are dollars invested in green space having a trickle-down effect, saving health sector dollars in the long-term that could then be reallocated to other health issues? Remember, it is not a case of saving money **per se**, but using money efficiently to get an even better health-focussed ‘bang for buck’.

If levelling up the inequity of green space availability within Australian cities helps to break the cycle of repeat hospitalisation by providing people with opportunities to choose, if they so wish, to visit places where they can relax, socialise, participate in outdoor recreation and feel great, regardless of their socioeconomic circumstances, then that would constitute an important element of a whole of society preventive health strategy. But have there been many studies linking up spatial indicators of green space provision with health service use, cost and quality of life data? Unfortunately, there have not.

**Data and collaboration is needed to plug these gaps**

Fortunately, the slowly creeping, incremental improvements in data availability within Australia and other countries suggests that these studies may well be possible in the hopefully not too distant future. In the Population Wellbeing and Environment Research Lab, or what we call the “PowerLab” at the University of Wollongong (see Figure 1), our team of epidemiologists, biostatisticians and geographic data scientists are dedicated to finding the answers to the three questions posed and more. We have recently been awarded research funding to begin to answer some of these questions from the National Heart Foundation of Australia and the National Health and Medical Research Council. We are enthused by the challenge of identifying how much and what formation of green space might contribute in a small, but significant way to keeping people healthy and out of hospital.

*Figure 1*

Data availability cannot come soon enough and it is clear that while satellite imagery can inform us on how much greenery is available within a particular area, this tells us little about what is in the green space and how well connected it is with other aspects of the built environment that people value. This not only includes things like retail and services, but also psychosocial factors such as feeling safe to walk outdoors in the evening. This type of information is crucial, but difficult to get from one source. It is likely to come from the communities living and the organisations and companies working in those areas. We do not need the genius of Sherlock Holmes or a maverick stylings of Gregory House. We need to work together, in partnership, to find the solutions that will benefit the whole of society; millions at a time.
The PowerLab has a strong track record of working with the local health sector, such as the Diabetes Initiative with Western Sydney Local Health District and Primary Health Network. We have also conducted some of the largest studies of green space and health in the world here in Australia. We now want to reach out to all members of TREENET, to local councils, garden centres, the park and leisure industry, landscape architects and others who are similarly enthused with the benefits of green space, to develop a green space geospatial data-sharing alliance the likes of which have not been seen before in Australia. An alliance with a common purpose, that is, to develop better evidence on the benefits of green space for public health. To develop evidence-based guidelines on how much green space is needed and maps of where investments ought to be targeted. On September 1st 2016, at the 17th National Street Tree Symposium, let’s get started.

References
SUBURBAN CENTRE IMPROVEMENT PROJECTS (SCIPS) – Making Liveable Local Centres

Vicki Martin
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Introduction

Brisbane City Council has delivered a very successful suburban initiative; the Suburban Centre Improvement Projects (SCIPs) program for over 20 years, in partnership with property owners and the local community. During this period - 48 SCIPs have been completed, with an investment of over 53 million dollars. This successful initiative has transformed Brisbane’s rich suburban fabric and assisted in the creation of some of Brisbane’s most popular suburban hubs. They celebrate local character and subtropical outdoor lifestyle and provide places where residents can meet to socialise, shop, conduct business and entertain.

Figure 1: Banyo SCIP. Open Door by Hew Chee Fong and Loretta Noonan

The aim of a SCIP is to improve the commercial vitality of a suburban centre by delivering infrastructure improvements that:

- creates a distinctive sense of place for local residents, visitors and businesses;
- provides a high-quality, attractive public space where people want to visit and shop; and
- improves the attractiveness, comfort, accessibility, connectivity and safety of a centre.
Key attributes of a SCIP include quality pavement, street trees, garden beds, gathering nodes, furniture and public art.

The incorporation of street trees provides one of the most significant benefits to a centre; but also presents one of the greatest design and consultation challenges in the delivery of a SCIP.

This paper focuses on SCIPs as a project and the contribution of trees as an urban design outcome and as a key element to enhancing the liveability of local centres. It also shares some of the challenges faced when delivering a SCIP.

**SCIPs in Brisbane**

There are a number of key Brisbane characteristics that shape how SCIPs are developed and maintained across the city. It is a city with a subtropical climate, which provides an enviable indoor – outdoor lifestyle. It has high humidity, with a few discomfort days per year; when temperatures and humidity are high and the cooling breezes are limited.

Key to Brisbane’s character is its wide range and high number of suburban centres outside of the city centre that are the heart of community life. Unlike other Australian capital cities; Brisbane City Council is responsible for a wider metropolitan area, in addition to the central business district and inner neighbourhoods.

The Brisbane City Plan 2014 includes four centre types. SCIPs are predominantly undertaken in two types of suburban centres, which have a more local focus, including the District Centre and the Neighbourhood Centre. The District Centres are capable of servicing a wider area and are often the location of a key attractor and are typically located on more major road corridors. Neighbourhood Centres include small-scale convenience shopping, which directly support the immediate community and are typically located on the more minor road corridors.

![Wide distribution of SCIPs across Brisbane](image)
Brisbane has a streetscape hierarchy in the City Plan 2014. This hierarchy is about the verge layout; not about the road corridor. It includes Subtropical Boulevards, Centre Streets and Neighbourhood Streets. It provides design advice on the footpath layout, tree species and materials that are typical of these streets. This advice guides both Council delivered outcomes and private development contributions. In locations such as SCIPs, a Locality Street typology is applied, to reflect the bespoke and higher quality outcomes in these centre locations.

To build upon a sub-tropical streetscape character, street tree planting does not always have a species monoculture. Outside of Brisbane’s CBD, the streetscape hierarchy provides for more than one tree species to be planted in a street corridor and with the planting layout either singular or clustered trees to suit site conditions, centre characteristics and to contribute to the subtropical image of the city.
SCIP Partnerships and Consultation

SCIPs are suburban centre public domain improvement projects that are delivered in partnership. This includes property owners, who contribute financially and the local community, which includes local residents, property owners, traders and community members.

Special Benefitted Area Rate

The City of Brisbane Act 2010 allows Council to charge special rates and charges for services, facilities and activities that have a special association with particular land, because the land or its occupier specially benefits from the service, facility or activity.

SCIPs are subject to a special rate to partly fund the delivery of the project and to establish ownership of the centre improvements. In the first stage of the project, SCIPs are launched to property owners. They only proceed to design development, wider community consultation and construction in locations where there is majority property owner support for the SCIP and the payment of a Benefitted Area special rate.

In locations where SCIPs proceed; Council pays the upfront costs to plan, design and build the SCIP and recoups a percentage of the costs from property owners via a Special Benefitted Area Rate. The special rate is repaid over a ten year period as part of the quarterly rates bill, starting in the financial year following completion of construction. There is no adjustment for CPI or any interest charged on the special rate.

SCIP consultation

SCIPs involve extensive consultation with the community to ensure that the end result is a reflection of the characteristics and needs of the local community. The community is involved in the planning and design process to ensure a sense of ownership and to identify what is important to those who work in or use each local centre.

SCIPs take approximately 18 months to complete an average sized centre. In the first phase of the project, Council works with property owners to gain their support. Once supported, Council forms a Community Representative Group or CRG to work on the planning and design of the project. The CRG is made up of a broad cross section of the community and plays an important role by providing local knowledge, input into the design and feedback from the local community. The CRG includes property owners, local businesses, community groups and residents. This broad range of members assists with delivering a design that covers the broad range of competing needs in a centre.

Incorporating trees into new SCIPs

From an urban design and liveability perspective, trees in SCIPs perform a wide range of valuable functions and provide enormous benefits to a centre. They are broadly appreciated at two different scales: by pedestrians or people in the centre using public seating, dining in private venues or in views from shops and offices, or from vehicle users travelling through a centre. Trees make a key vertical addition to a centre and can mark its entrance and characterise it as a vibrant, rich and well-established location.
Trees value a SCIP in the following ways, which contribute to centre’s attractiveness, pedestrian amenity, and also local identity by:

- providing shade, a cooling effect and increased comfort for centre users;
- delivering seasonal change through the incorporation of flowering trees;
- making a visual contribution and enhancing local identity and the subtropical character of a centre;
- contributing to the centre’s attractiveness;
- providing gateways to a centre, which are key to marking people’s journeys;
- establishing landmarks to assist with wayfinding; and
- framing views.

The following key considerations and challenges of planting new trees are typically part of delivering new SCIPs.

**Locating trees in a centre**

Streets have numerous constraints that need to be balanced with the design intent when incorporating trees into a SCIP.

Constraints to designing a street tree layout and species selection can include; the location of underground and overhead services, setbacks from kerb alignments to prevent conflict between trees and road users, vertical clearance of tree branches to pedestrians and cyclists, awning locations, vehicle and pedestrian sight lines, parking layout, dining permits and public lighting and signage.

Existing views are another key consideration and can be a constraint or an opportunity. Maintaining visibility to signs is one of the most contentious issues with centre traders. Every effort is made through tree species selection, placement, spacing and clearances to maintain views. In some centres, views are worthy of framing through the selective placement of trees.

Another consideration is about footpath dining, which is a characteristic of Brisbane’s suburban centres and its subtropical lifestyle. The preferred location is on the kerbside of the footpath. This is to allow all people including visually and physically impaired persons to comfortably use the property boundary line, the building edge in the majority of locations as a continuous point of reference when moving along the footpath. Footpath dining layouts need to accommodate existing and proposed trees as part of a SCIP layout, to accommodate the business’s need and negotiate a new layout that benefits both the businesses and also the local community.

![Figure 5: New tree planting at Kenmore and Graceville SCIPs](image)
Species selection

The selection of preferred tree species is one of the key workshop tasks for the SCIP Project’s CRG. The SCIP team develops a shortlist of tree species that suit the site planting conditions, site constraints and project design objectives. The list will include a range of trees that will perform different functions in a centre; for example, shade trees and feature trees, including seasonal and locally distinctive trees. The CRG’s role in the tree selection assists with developing community ownership of the SCIP project outcomes.

Species selection is also guided by the inclusion of low risk species in terms of seed pod and limb and frond drop and limited maintenance requirements. Tree planting in SCIPs does not deliver a mono-culture in the streetscape. The range of selected tree species provides a variety and delivers a design outcome that creates a well-designed and subtropical outdoor lifestyle suburban centre.

Before and after photomontages are a key tool used during the consultation workshops to assist with species selection and to allow members to visualise the benefits.

![Figure 6: Before and after images of a new meeting node with tree planting and furniture](image)

Planting details

Wherever possible trees are planted in garden beds and provide a physical and visual separation from traffic and on-street car parking. The garden beds also contribute to the attractiveness of a centre and provide a greater surface area to capture rainwater run-off. Where space is more constrained, trees planted in grates make a valuable addition to a SCIP.

Footpaths are often very constrained and conflicted spaces, providing facilities for a wide range of uses and users. Water Sensitive Urban Design (WSUD) trials have been undertaken in SCIPs, but have delivered little benefit to centres, when measured against other project objectives. From our experience in delivering SCIPs, WSUD requirements can preclude the planting of suitable trees, which are key to a SCIP outcome. The construction details can create significant changes in level and occupy large sections of public footpath, constraining use and requiring the incorporation of safety fences to protect pedestrians.

From our learnings, we have adapted and redesigned the WSUD approach to the often contested public footpath within the centre. This approach has identified the opportunities for reducing water demand by providing alternative sources such as connecting stormwater down pipe from private building into the adjacent garden beds before the stormwater discharge into the drain. This was implemented in the Alderley SCIP.

**Figure 7:** WSUD outcome at the Greenslopes SCIP

**Trees and vegetation providing themes for artwork**

Public art provides a platform for expressing local values, innovation, memory, meaning, creativity and beauty in each neighbourhood. SCIPs use public art to create a point of difference through improving a centre’s identity, providing a community focal point and celebrating local history and character.

Each SCIP engages a curator to develop the artwork strategy, which includes the local themes, outcome types, artist shortlist and locations that deliver on the design intent for a centre. Trees and vegetation often influence the theme of a local centre that celebrates local history and character. This was the case for recently delivered SCIPs at Kenmore and Cannon Hill.

The curatorial rationale for Kenmore SCIP is: Interwoven. One of the common threads and core values that influenced this rational was the surrounding high quality natural environments of leafy streets and gardens, parks and natural bushland corridors.

The resulting artwork ‘Growth’ by Matthew Harding was inspired by the rhythms and patterns of nature in Kenmore, which can be reflected in the growth and aspiration of community. The lineal form of the sculpture creates a trellis of light and shadow akin to the flicker of sunlight through a forest canopy, acting as a metaphor for our daily movements and interactions; capturing a filigree of our modern mobility.

This art sculpture has a scale and visual presence that engages passing views from vehicles and also serves as a place-marker and precinct anchor as human scale. From urban design perceptive, by placing the artwork in a more pedestrian-focussed location and incorporating a level of detail, SCIP centre visitors engage close-hand viewing experience and promote gathering and interaction.
At Cannon Hill, the curatorial rationale for the SCIP is Urban Folly. The commissioned artwork ‘Tree’ by James and Eleanor Avery is inspired by the history of Cannon Hill, where it makes reference to the naming of the suburb from the early settlers who saw fallen trees and thought they looked like cannons.

The resulting work ‘Tree’ represents a symbolic of renewed energy and vibrancy from the Cannon Hill history and also bring a dynamic and playful quality to the centre. The artwork is a stylised tree, fabricated from facets of sheet aluminium and finished with high gloss paint. It provides a landmark at the entrance to the centre on the busy Wynnum Road.
SCIP Renewals

In 2014, after more than 20 years of delivering SCIPs, Council commenced a renewal projects program.

The renewal strategy builds upon the successful qualities of the original design and reviews possible elements that are due for renewal; to refresh and update existing SCIPs.

The first major renewal was undertaken at the 20 year old SCIP Mitchelton. It included the replacement of standard and bespoke features. The renewal has reinvigorated this very popular local centre.

Asset Management Plans are prepared annually, together with condition audits and a reassessment of a SCIP’s category.

The audits show that many of the SCIP elements require replacement or restoration as the asset ages. The street trees become well-established with age and generally only require regular pruning. A renewal strategy for vegetation and planting in some older SCIPs reviews the overall vegetation condition and identifies the need for replacement, additional planting opportunities or redesign of the existing garden beds for better growing environment.

Trees are an appreciating asset and continue to deliver against the key SCIP objective of contributing to the distinctive sense of place and Brisbane’s subtropical outdoor lifestyle.

Figure 10: Renewal at the Mitchelton SCIP, as personalised by local users after its recent completion.
USING SATELLITE AND AIRBORNE REMOTE SENSING TOOLS TO QUANTIFY URBAN FOREST COVER AND CONDITION AND ITS RELATIONSHIP TO URBAN HEAT AND HUMAN HEALTH IN AUSTRALIAN CITIES

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Introduction

A wide range of platforms and sensors exist for monitoring vegetation in cities and beyond. These include but are not limited to satellites, fixed-wing planes, helicopters and unmanned aerial vehicles (UAVs or ‘drones’) and thermal infrared (TIR), multispectral (MS), hyperspectral (HS) and standard imagery (RGB). The spatial and spectral resolution is determined by the type of platform used, the height above ground level for acquisition, and the sensor or camera. There are many choices and some of them are freely available and others are costly. The challenge is to select the appropriate platform and sensor to successfully achieve your required objective within the available budget.

The traditional and typical approach to measuring and monitoring urban forest cover and condition involves teams of people, preferably qualified arborists or urban foresters, walking throughout cities and recording numerous attributes including height, crown width and the health on a scale of 0 (dead) to 5 (most healthy). The use of pen and paper has commonly been superseded by field computers with built-in GPS, and more recently by more sophisticated real-time software applications. These tools have ultimately been introduced to improve efficiencies and precision of urban forest monitoring and they have achieved this.

Software packages such as i-tree have enabled managers to utilise field-collected data and input this data into models that produce outputs on many urban forest attributes and services. As with all computer models they have benefits and limitations, and the accuracy of the outputs is dependent upon quality of the inputs and model.

ArborCarbon scientists have been using remote sensing tools for native forest monitoring since 2003 (Evans, Lyons et al. 2012, Evans, Stone et al. 2013) and for urban forest monitoring since 2009. This paper describes how different platforms and sensors have been used for precision urban forest monitoring projects throughout Australian cities and the link to human health.

Methods

Vegetation Cover and Condition

Normalised Difference Vegetation Index (NDVI) data from the Landsat 8 sensor was processed and analysed at a pixel resolution of 30m. NDVI is an algorithm using the visible (VIS) and near infrared (NIR) bands of the electromagnetic spectrum and provides an indication of the presence/absence of vegetation. Spectral radiance data was converted to Top of Atmosphere planetary reflectance using supplied reflectance coefficients, and additional radiometric corrections were applied to enable extraction of NDVI values between -1 and +1 (ArborCarbon 2016).

Four-band multispectral imagery was acquired over areas of interest from a fixed-wing plane. Imagery was acquired at an altitude to provide 40-50cm pixel resolution. The method and timing of acquisition and subsequent radiometric and geometric correction during processing produces a dense 3-D point cloud with resultant Digital Surface Model (DSM) and Digital Terrain Model (DTM). These are analysed to provide a vegetation cover layer stratified into four height-classes (<3m, 3-10m, 10-15m, >15m), enabling the differentiation between canopy and non-canopy. The baseline condition of vegetation was determined based upon an index combining the red and NIR bands, termed the Vegetation Condition Index (VCI). Previous research comparing this index with NDVI showed the VCI to be superior to NDVI for measuring native vegetation. Change in canopy condition was measured by comparing the VCI for each pixel in the baseline image to the subsequent image. Care was taken to ensure that geometric and radiometric variables contributing to unwanted noise in the data were minimised to allow for precise measurement of change in condition.
Surface Heat

Thermal Infrared (TIR) data was processed and analysed from the Landsat 8 sensor selected hottest days over the areas of interest within the satellite orbit cycle. This data is 100m-pixel resolution resampled to 30m. Raw data was converted into surface temperature data using a series of correction equations (ArborCarbon 2016). Mean surface temperatures were calculated for areas of interest such as suburbs and different land-use categories.

In order to identify differences in surface temperature between features of interest (i.e. trees, grass, roads, buildings) higher spatial resolution TIR data was acquired using a FLIR thermal imaging camera from a fixed-wing plane. One project over the City of Perth acquired data at 1m-pixel resolution at nighttime to measure the residual surface temperature within the CBD and surrounds. In a separate project covering the Resilient South region (Cities of Onkaparinga, Holdfast Bay, Marion and Mitcham) in South Australia, 285 square kilometres of data was acquired at 2.0m pixel resolution on one of the hottest days in 2016, exceeding a temperature of 39 degrees Celsius. Concurrent thermal imagery was acquired at ground level at selected locations throughout the region using a handheld FLIR thermal camera.

Children’s Health

Participants (n=300 children) in the Play Spaces and Environments for Children’s Physical Activity (PLAYCE) Study wore accelerometers over 7 days. Time spent outdoors was measured objectively using Radio Frequency Identification (RFID). Personal UVR exposure was objectively measured using polysulphone (PS) film mounted in small cardboard holders attached to a child’s shoulder. A bottom up (sky-view factor (SVF) and top-down (shade coverage from remote sensing imagery) measure of outdoor shade coverage was utilized. The SVF was measured using fisheye photography taken from outdoor play areas. Remote sensing imagery was used to calculate percent vegetation (tree canopy) coverage.

Results

Vegetation Cover and Condition

Satellite-derived NDVI over the City of Mitcham showed highest values in the rural, bushland and peri-urban areas and in pockets of vegetation within the urban area (Fig. 1A). Lowest values for NDVI were mostly confined to major roads and industrial areas located within the urban area. Satellite-derived NDVI is an index affected by both the cover and condition of vegetation and due to the coarse resolution of the data it is difficult to interpret any differences in condition of vegetation between sites. According to the satellite-derived TIR data the lowest surface temperatures are located in the rural forested areas with most of the urban areas high in temperature (Fig. 1B). There is an apparent inverse relationship between NDVI values and surface temperature with a clear urban heat island effect (UHIE) evident.

Using high-resolution multispectral imagery we derived a very precise geospatial dataset of vegetation cover stratified into height classes (Fig. 2) over entire local government areas and sites within. Using this dataset we can very quickly identify where high-density vegetation occurs, and where the largest trees occur. The geospatial nature of the dataset and stratification of height enables us to differentiate between canopy and non-canopy, and to very precisely provide baseline measures (e.g. % cover, m², ha) of the vegetation and canopy cover across entire cities and any smaller region of interest within (e.g. LGA, parks, streets, commercial, residential etc.) (Fig. 3). Subsequent acquisition of imagery in carefully controlled conditions allows for very precise measure of change in condition to be undertaken, providing an ‘early-warning’ system. The parameters used are highly sensitive to changes in vigour and health of the canopy with any increase in condition showing as blue pixels, no or little change showing as white pixels, and loss in condition or complete death of trees showing as red pixels (Fig. 4).
Figure 1. Satellite-derived NDVI (A) and TIR (B) over the City of Mitcham. Values for NDVI are scaled from highest (green) through to lowest (red) and thermal temperatures are scaled from lowest (blue) to highest (red).

Figure 2. Height-stratified canopy cover layer overlaid onto the true-colour base image (A) and with the base layer removed showing only the height-stratified vegetation cover layer (B). All vegetation has been quantified and stratified into height classes as follows: <3m (green), 3-10m (yellow), 10-15m (blue), >15m (red).
Figure 3. Canopy Cover of selected parks throughout the Local Government Area in 2014 and 2015, showing increases, little change and decreases in canopy cover. Names of parks withheld to maintain client confidentiality.

Figure 4. Change Detection Image derived from high-resolution multispectral images acquired in 2012 and 2013 showing increase (blue pixels), no change (white pixels) and decrease (red pixels) in vegetation condition.
Surface Heat

Surface heat can be derived from urban areas using a range of sensing devices. Over recent years we have acquired and analysed surface heat over urban areas in City of Perth and the Resilient South Region in South Australia. The choice of platform and sensor is largely dependent on the required resolution, the objectives of the project and the available budget. Satellite TIR imagery typically produces imagery at 30m pixels enabling the identification of large heat and cool islands in urban areas (Fig. 5A), whereas high-resolution (e.g. 1-2m pixels) airborne TIR can clearly differentiate subtle differences in surface temperature between individual buildings, trees, turf, impervious layers and other materials of interest (Fig. 5B). The higher resolution imagery enables more powerful analysis to be undertaken to determine differences in surface temperatures between lower and higher density developments, and the relationship with vegetation (Fig. 6).

Figure 5. A) Medium resolution (30m pixel) TIR image south of Adelaide city and B) high-resolution (2m pixel) TIR image south of Adelaide city acquired on a day where temperatures exceeded 39 degrees C.

Figure 6. High-resolution TIR image of the suburb of Aldinga Beach in SA showing large differences in surface temperature between lower density development with a high abundance of vegetation, and higher density development lacking vegetation cover.
**Children’s Health**

A subset of the childcare centres where children were monitored for physical activity and exposure to UV were selected. Each of these centres was delineated and these polygons overlaid onto the baseline high-resolution airborne true colour with (A) and without (B) the height-stratified vegetation cover layer. The height-stratified vegetation cover layer was clipped to each of the centre boundaries and a calculation of the area and percentage canopy cover (>3m in height) for each centre was determined. This measure was used as a proxy for shade and protection of children from harmful UV rays.

![Figure 6. High-resolution TIR image of the suburb of Aldinga Beach in SA showing large differences in surface temperature between lower density development with a high abundance of vegetation, and higher density development lacking vegetation cover.](image)

**Discussion and Conclusion**

Our research and work for numerous LGAs over the past seven years has proven that there is a place for remote sensing in precision urban forest management. Remote sensing technologies have traditionally been seen by LGAs as expensive tools that provide information that is difficult to understand and interpret. This can certainly be the case, and the many choices of platform and sensor can be very daunting for people who are unfamiliar with the technology. It is highly important that careful consideration is given to selecting the correct combination of platform and sensor within the available budget. Equally important after this first step is to determine the best way to analyse and report on the data. Traditionally this has required the skills of experienced remote sensing scientists and expensive software. Recent developments in software, processing speeds, bandwidth and server space have helped to overcome many of these hurdles.

Datasets are freely available that will enable the calculation of greenness and surface temperatures across large areas of urban forest and surrounds. Such datasets will allow for the broad interpretation of greenness across the landscape and the relationship between this and surface temperatures. It is important, however, to understand the limitations of this data and realise that one single pixel of 30m in size may be a mixture of many different surfaces including trees, grass, concrete, water and soil. Likewise, the surface temperature data will be an average value for each pixel of each of these different materials. Another limitation of this freely available dataset is the restriction to the satellite orbit cycles (e.g. 16 days) and greater potential for interference from atmospheric conditions (i.e. cloud, moisture, smoke haze) than airborne systems.
Airborne systems will nearly always be more expensive than satellite due to mobilisation costs. It is therefore very important to ensure the objectives of the project are very clearly understood by those providing the data, and that they can and have previously successfully delivered on such projects. Advantages of airborne systems over satellite include the ability to select dates and times for acquisition of data for minimising atmospheric interference, and to modify spatial and spectral characteristics of the data by flying at different altitudes and changing sensors. We have clearly shown that high-resolution multispectral imagery can be used to very precisely map and measure height-stratified vegetation cover and also to monitor and detect subtle changes in the health of trees across the urban forest. This approach has many advantages over traditional ground-based approaches to urban forest measurement and monitoring. For example, ground-based surveys are much more labour intensive and therefore more expensive, are unlikely to be able to measure all vegetation due to access restrictions (e.g. residential property), and are inherently subjective and qualitative in nature. Remote sensing approaches should not been seen, however, as a total replacement for ground-based assessments as these assessments are important for detecting hazards in trees and therefore measuring risk, can more accurately identify species, and can enable the calculation of monetary values for trees. The two approaches should be viewed as complementary rather than one replacing the other.

Remotely sensed data, if used correctly, can be successfully used for the efficient establishment of key performance indicators (KPIs) in urban forest and green infrastructure management. Some examples of our use of such data has included the establishment of KPIs and trigger values for bushland condition based upon our condition index and canopy cover, the setting of targets for increase in canopy cover across entire municipalities and suburbs within, identifying areas suitable for planting and measuring the success of planting strategies, monitoring change in condition of treated and untreated (control) trees suffering from various tree health disorders, detecting the onset of decline in health of trees for early intervention, identifying trees that have been illegally removed, and relating decline/death of trees to causal factors (i.e. construction damage). Ultimately all of these actions result in improved efficiencies, cost-savings, and the conservation of urban forest canopy.

Many local government agencies are striving to develop management plans of varying names (i.e. urban forest, greening, liveable cities). In order to develop robust plans and set realistic and achievable targets it is very important to accurately determine the existing and trend in temporal change in canopy cover. Our assessments of canopy cover across some LGAs have shown a discrepancy of several percent between our data and the data presented from a modelling approach. One must therefore ask the question how reliable targets for increasing canopy cover by a particular percentage can be set and measured against. A great deal of focus has been placed on the planting of trees throughout the landscape to increase canopy cover. Let’s not forget that it is the existing mature canopy that is our most valuable and it is likely to take many years/decades for the planted trees to reach maturity, if at all. Heavy emphasis is also placed upon the measurement of canopy cover area, however, I suggest we should be placing a great deal more emphasis on the change in health of our urban forest and consider how to manage this health in the most sustainable manner.

For many years I have spread the message about the need to conserve our urban forest and manage it much more sustainably. I often feel like I am ‘preaching to the converted.’ I have found the best way to reach out to the ‘unconverted’ is to make this message about money and health and link the trees to these two elements. The premise behind our approach is to help local governments reduce resources for management of the urban forest, allowing more funds to be freed up for projects that will conserve and increase the canopy cover and improve the health of our urban forest. I’m very grateful to have been involved in such exciting projects linking urban heat to green infrastructure, and I’m equally excited about the research into the link between children’s health and urban trees. I do strongly believe that an urban forest full of healthy trees will result in a community of healthy and happy people.
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References


Introduction

One of the main climate change challenges in urban centres is the combined patterns of high density human habitation with increasing urban heat patterns. This is especially true of the urban heat island, where urban areas tend to have higher air and surface temperatures than their rural surroundings because urban form and materials store and trap heat (Oke, 1997). Prolonged urban heat events have also been highlighted as a factor in exacerbating several health problems within cities—including cardiovascular disease and diabetes (Kovats and Hajat, 2008). Additionally, heatwaves have been identified as a major climate change impact in cities and are often associated with increased human morbidity and mortality (Bambrick et al., 2011).

Green infrastructure, which typically refers to an interconnected network of multifunctional green spaces, strategically planned and managed to provide a range of ecological, social, and economic benefits (Wright, 2011), provides many benefits to cities in the context of climate adaptation (Shashua-Bar et al., 2009). Green infrastructure has a key role to play in reducing the amount of solar radiation that is absorbed into building materials such as walls, roofs and pavements during the day and released at night (Rizwan et al., 2008), and modelling studies show that increasing the proportion of tree canopy cover in the urban environment can reduce both surface and air temperatures (Alexandri and Jones, 2008). Empirical evidence highlights that temperatures under trees are lower than areas without trees (Shashua-Bar et al., 2009). Furthermore, strategically located trees adjacent to residential buildings can reduce the energy required for household cooling during hot weather through the provision of shade (McPherson et al., 2011; Pandit and Laband, 2010).

The combined issues of urban densification and urban heat island are particularly pertinent in Sydney, Australia, where the major planning paradigm is for increased residential densities through more compact urban form (Gray et al., 2010). The population of Sydney is projected to grow from 4.3 million to 5.6 million people by 2031 requiring an additional 545,000 homes and associated urban infrastructure (NSW Government, 2013). The majority of this growth is expected to occur within existing urban areas through urban consolidation. This process is transforming Australian suburbs, which typically are low density and characterised by single detached houses.

There are clearly many questions around the compatibility of strategies to increase green infrastructure in urban areas to reduce the urban heat island effect, given the trend for more compact and dense urban form, especially as houses built on smaller blocks of land tend to have smaller yards and less area for tree cover around homes (Hall, 2010). Here, we present a series of analyses undertaken in Sydney, Australia, where decision-makers are grappling with these issues of how to adapt to the likely impacts of climate change, while at the same time planning for a growing population. We report on summary findings of three interrelated investigations examining the relationships between tree and vegetation cover and thermal patterns of land surface temperature at the city, neighbourhood, and residential house scale to identify spatial relationships that affect the distribution of climate regulation benefits and the heat-related health risks to Sydney’s population.
Socio-spatial inequities of tree cover distribution across Sydney

Urban population growth is leading to growing concerns about land use change, green infrastructure provision and the loss of beneficial ecosystem services. Human and environmental health is supported by services such as climate regulation, air filtration and flood mitigation. However, maintaining these services within cities requires the retention and equitable distribution of green infrastructure near where people live. This study investigates the spatial distribution of green infrastructure within Sydney to determine how patterns of green infrastructure vary according to land use, residential density, as well as socio-economic advantage.

Initial investigations used Landsat 5 satellite imagery to investigate the distribution of vegetation and land surface temperature in Sydney. This broadly showed that vegetation cover, derived using the Normalized Difference Vegetation Index (NDVI) was the most important factor explaining variation in land surface temperature (LST), with LST negatively related to NDVI (Figure 1, Barnett et al. 2013). In other words, the hottest areas typically have little vegetation cover.

![Figure 1. LST and NDVI maps for Sydney derived from Landsat 5 satellite imagery captured on 2 February 2011 and clipped to Sydney’s urban boundary. Analyses of urban form and other environmental factors showed that the most important factor driving LST patterns across Sydney was NDVI (Barnett et al. 2013).](image)

Distribution of vegetation cover across land uses

Although high levels of NDVI may indicate areas of lower LST, and potentially where climate regulation benefits are the greatest, relatively little is known about the distribution of vegetation cover in Sydney and if it is benefitting the most sensitive and vulnerable populations. Thus, an environmental stratification was conducted to identify the relationships between land use, residential dwelling density, tree canopy cover and areas of parkland across Sydney, using data sourced from the 2011 Australian Bureau of Statistics Census of Population and Housing and remote sensed data.

More than half of urban Sydney is comprised of residential land use (52%) (Figure 2a). This is more than double the next largest land use, parkland (23%). Not only are residential areas the dominant land use within urban Sydney, they provide a large proportion of Sydney’s green infrastructure with a mean Foliage Projection Cover (FPC) of 43% (Figure 2b).
Foliage Projection Cover, a measure of the percentage of ground area that is covered by the vertical projection of foliage from tall woody vegetation (Walker and Hopkins, 1990), was used to estimate canopy cover in these analyses (NSW Office of Environment and Heritage, 2011). Park and agricultural land each occupy a smaller area, but have a slightly higher proportion of tree cover than residential areas, with a mean FPC of 53% and 45%, respectively. Remaining land uses which include commercial, industrial and education all contribute to Sydney’s green infrastructure, but collectively comprise only one-quarter of the land area taken up by residential land use. Figure 2 highlights the substantial contribution of residential areas and parkland areas to Sydney’s green infrastructure as well as the shared responsibility (public and private) for this green asset.

**Figure 2.** For urban Sydney, (a) the area (km²) and (b) mean Foliage Projection Cover for six major land use types. Residential land use represents the largest contribution to Sydney’s green infrastructure (52%) and parkland second largest (23%). Parkland has a greater mean FPC (53%) than residential land areas (43%).

**Effect of dwelling density on vegetation cover in public and private spaces**

We also wanted to understand how residential density affected both public and private green infrastructure (indicated by parks versus residential tree canopy cover measures). There is a widely held view among urban planners that as urban densities are increased, any subsequent loss of private green infrastructure can be offset by increased access to or provision of public green infrastructure (Maat and de Vries, 2006), but there is little evidence this offset is actually occurring in cities around Australia (Byrne et al., 2010).

Residential dwelling density (number of dwellings per hectare of residential land use) was calculated for each suburb in Sydney from population and dwelling counts derived from the 2011 Census of Population and Housing (ABS, 2011) in order to see whether tree cover across Sydney suburbs, expressed by mean FPC, varies with changes in residential dwelling density. The amount of designated parkland in each suburb was also identified to test if there was a higher availability of public green space in areas where private (residential) tree cover was at a lower level. A regression model between the dwelling density (log transformed) and the amount of tree cover (log transformed), expressed as mean Foliage Projection Cover, of residential areas in Sydney suburbs (Figure 3), shows that with greater dwelling density, there is a decrease in the amount of residential tree cover (p<0.0001, t=-9.06 R²=0.269). Results also indicated a small decrease in the area of parkland within a suburb with an increase in dwelling density (p<0.01, t=-2.69, R²=0.034). As such, we found that there is not a greater amount of public parkland in high density residential areas to offset lower amounts of private green cover.
Figure 3. For each suburb in the Sydney UCL (n = 221), the log of residential dwelling density (dwellings/ha of residential land) was compared to (a) the mean Foliage Projection Cover (FPC) of the residential areas (log transformed) and (b) the percentage of land in each suburb that is designated as parkland (ABS 2012).

Distribution of tree cover can lead to inequities in green space access

Availability of private versus public green infrastructure, however, differs according to socio-economic advantage. Areas of high socio-economic advantage have significantly more private green cover, but slightly less public green cover than suburbs of greater disadvantage. In fact, tree cover in public parkland remains relatively high for all decile categories compared to private residential tree cover. In those areas where communities were more disadvantaged, the parkland tree cover provided a larger proportion of overall tree cover in these communities, largely due to the lack of tree cover in private residential areas.

Figure 4. Patterns of socio-economic advantage and disadvantage using the IRSAD Decile Categories defined in the ABS Census of Population and Housing (2011) and presented at SA1 scale in relation to private green cover (FPC of residential land) and public green cover (FPC of parkland). Patterns show an increase in private green cover (p<0.0001) and a slight declining trend in public green cover (p=0.0274) with increasing socio-economic advantage (Lin et al., 2015).
These findings highlight that urban densification can lead to a general loss of two important reservoirs of urban green infrastructure (public parkland and residential tree cover), but disadvantaged communities may have a greater reliance on public green infrastructure in the form of parkland due to a lack of private residential tree cover. This may have important ramifications during extreme heat events, as disadvantaged populations also tend to have a higher prevalence of heat-related health risk factors including the elderly, people living alone, and so on. Resources directed towards future urban greening must consider both public and private land and the equitable distribution of the climate regulation benefits from urban green spaces.

**Understanding patterns of tree cover mediated climate regulation at the neighbourhood scale**

Although vegetation cover has been associated with lower land surface temperatures, it is important to understand how these patterns play out at the neighbourhood scale, where people live and interact with their environment. Using fine resolution (2x2m scale) hyperspectral and thermal airborne remote sensing imagery, we examined a case study transect (Figure 5) in the northern suburbs of Sydney to sample climate and vegetation gradients and to evaluate how tree cover affects the climate regulation benefit of reduced land surface temperatures at the neighbourhood scale — that is houses, streetscapes, and parklands (Figure 6).

![Figure 5](image)
Figure 6. Examining relationships between vegetation cover and land surface temperature at the neighbourhood scale – that is house rooftops, roads and streetscapes, as well as nearby parklands.

Residential homes

Thirty houses were selected for the analysis of roof surface temperatures. To control for variation in the size of residential land parcels, properties were selected from within a range of 650–750 m², approximately the median parcel size within the transect. Google Earth was then used to perform a visual assessment, identifying houses with similar roof colour (grey-brown) and roof construction material (tile). By choosing similarly sized houses with similar roof types, in general, the houses have a similar development style. Only houses with tree canopy cover located on the north and north-western sides of the house were selected for inclusion in the analysis, ensuring maximum and consistent tree shadow given the direction of the sun during the time of the data collection flight (from true north the sun was 358° at noon and 317.5° at 2 PM).

Based on the analysis of the thirty houses sampled, a proxy measure of percentage tree canopy cover (defined by NDVI > 0.3) within a 15 m buffer centred on the north-western corner was used to assess the influence of tree canopy cover in the vicinity of the house (Figure 7). Mean roof temperature was reduced with an increase in tree cover to the north and west of the roofline. The model shows that a 10 percent increase in vegetation cover (NDVI > 0.3) decreases mean roof surface temperature by 0.74 °C ± 0.2 °C. The NDVI measure is considered to be a better measure than direct canopy cover as it includes tree canopy cover that is located beyond the immediate roofline of the house, but able to cast shadows across the roof throughout the day.
Figure 7. Direct canopy cover footprints digitized in Google Earth to capture canopy over roofs. This was used to distinguish roof cover from tree cover in the temperature measurement. Building footprints were overlaid on land surface temperature thermal data in ArcGIS and green canopy areas were excluded from the thermal sampling on rooftops as they would represent cool areas not indicative of roof temperature.

Roads and streetscape

Road corridors were another dominant feature examined at neighbourhood scale. Road corridors not only comprise roads, but also a significant amount of road verge utilised for footpaths and street tree plantings.

Figure 8. Road side vegetation can provide benefits for both private space (additional shade canopy for cooling residential houses) as well as public space (cooling of streets for walking and parking of vehicles).
When looking at the road corridor analyses \((n = 1353)\), the proxy measure for tree canopy cover \((\text{NDVI} > 0.3)\) had a highly significant negative relationship with the mean and maximum surface temperature of the non-vegetated ground surface \((\text{NDVI} < 0.1 \text{ was considered pavement})\). The greater the percentage of vegetation within the road corridor, the cooler the surface temperature of the roads and footpaths with lower maximum and mean temperatures \((p < 0.0001)\) (Figure 8). Based on the regression models that were developed, it was estimated that a 10 percent increase in vegetation cover \((\text{NDVI} > 0.3)\) would result in a decrease in the mean road surface temperature by \(0.37 \degree C \pm 0.02 \degree C\) and maximum road surface temperature by \(0.45 \degree C \pm 0.02 \degree C\).

**Parkland areas**

The objective of the park analysis was to determine the influence of vegetation, as expressed by FPC, on land surface temperature \((LST)\). To perform this analysis, 1518 random points were selected within parklands along the transect. Examination of the relationship between vegetation \((\text{measured using percent FPC})\) and surface temperature within parks revealed higher FPC was associated with lower surface temperatures in parks \((p < 0.001, R^2 = 0.324)\). In parks, the higher the density of tree cover, the lower the surface temperature.

Overall, these analyses at neighbourhood scale have shown that increased tree cover around homes, and in streets and parklands can significantly reduce LST, potentially leading to greater use of outdoor spaces (Takano et al. 2002) and reducing heat-health impacts (Kilbourne et al., 1982; Vandentorren et al., 2006).

**Understanding the potential for tree shade to provide climate regulation services at the household scale**

While numerous studies have investigated the effects of tree shade on the energy requirement for heating and cooling of residential buildings (McPherson et al., 1988; Pandit and Laband, 2010), there has been little consideration of how this influence might vary with climate change. Although all new homes in Australia are required to meet minimum energy and water efficiency standards (Ambrose 2008), much of Australia’s existing housing is 20 years of age or older and built with little thought for climate change or sustainability.

Disadvantaged populations are more likely to reside in older, poorer quality housing, often in locations of high climate change risk, with few resources to invest in climate adaptation. Although air-conditioning is considered a protective solution against heat-related illness (Vandentorren et al., 2003), in low-income households, this solution may often not be utilised due to concerns over the cost (Farbotko et al., 2011).

Passive shading options, including the use of vegetation, can also modify the thermal performance of buildings (McGee and Reardon 2013). The effectiveness of trees for providing shade is determined by a number of factors, including tree size, shape, canopy porosity, and the direction and distance of the tree relative to the building (Simpson and McPherson 1996). As trees block incoming solar radiation, they have the potential to ameliorate the effects of climate change by reducing the energy requirement for artificial cooling of residential buildings as well as the associated heat-related health risk that is posed to occupants.

Little is known about the impacts of tree shade on the thermal performance of housing under projected climate change. Here we explore how differing tree size, differing leaf-fall habits (deciduous and evergreen), and differing planting strategies (distance from and orientation to the house) may affect building thermal performance. We present results of computer simulations for one house (referred to as House 1), which represents a three bedroom, fibrous cement sheet house with a gross floor area of 101.5 \(m^2\) (Figure 9). It is assumed no ceiling insulation is installed and windows are single-glazed with aluminium frames. House 1 has a thermal performance of 0.8 stars assessed using the Australian Nationwide House Energy Rating Scheme (NatHERS). It represents one of several common low-income house types (Barnett et al. 2013).
Building thermal performance was simulated for House 1 using AccuRate, a benchmark house energy rating tool commonly used in Australia (Delsante 2005). The software calculates the energy requirements and thermal comfort of residential buildings for every hour in a year \( (n = 8760) \). Simulations were repeated for climates centred on the years 2000, 2030 and 2070. Changes in the annual heating and cooling \( (H/C) \) energy requirement were estimated using common assumptions about thermostat settings for mechanical heating and cooling (ABCB 2006). Heat-related health risk was estimated using the Discomfort Index (DI) developed by Epstein and Moran (2006), with values above 28 representing a severe level of health risk. AccuRate uses information on tree size and height, canopy porosity, distance to house, sun angle, and various wall surface information (including windows and doors) to simulate the influence of tree shade on buildings (Figure 10).

Twenty individual tree shade simulations were run in AccuRate for House 1, with variations of trees that were either large evergreen or large deciduous and positioned 15 m from the house, or small evergreen or small deciduous located 5 m from the house. Results from individual tree scenarios were used to develop mixed tree scenarios to determine the influence of multiple trees on building thermal performance. The mixed scenarios were based on the individual scenarios that were most effective at reducing H/C energy requirement (Figure 11).
Figure 11. A schematic of the tree scenarios modelled in AccuRate with a) showing locations, orientations and distance from the house representing 20 single tree scenarios, b) mixed trees to the east and west of the house (M1), and c) based on M1 with additional mixed trees located to the north and northwest (M2).

Results from the mixed tree scenarios were compared to baseline ‘no trees’ scenarios to identify how tree shade alters building thermal performance. The results of the ‘no trees’ scenarios are presented in Figure 12. What these results show is that for the climate baseline in the year 2000, H/C energy demand for House 1 was substantially heating dominated, by 2030 was almost balanced in heating and cooling requirements, and by 2070 was primarily cooling dominated. This means that irrespective of tree shade, the performance of House 1 will change with climate change. This is also the case in terms of the Discomfort Index, with the annual hours DI exceeds the threshold value of 28 increasing substantially in 2030 and again in 2070.

Figure 12. Baseline data on building performance without trees, with a) showing changes in H/C energy demand over time, and b) changes in the Discomfort Index (DI) as measured by annual hours DI ≥ 28.

Results for the mixed tree scenarios are presented in Figure 13. In the year 2000, House 1 has savings of less than 2% of H/C energy when trees are planted to the east and west (M1), but requires more energy if trees are also planted to the north (M2) as shown in Figure 11. The additional heating that is required in winter negates any savings due to the reduced need for cooling in summer. By 2030, House 1 achieves savings of 3.3% with the addition of trees to the north (M2). In 2070, the scenario with the most amount of shade (M2) delivers H/C energy savings of 5.8%. What this reveals is that there is an optimal pattern to staging the planting of multiple trees around a house to avoid increased costs and to maximise savings on heating and cooling, but this staging varies with climate change as the heating to cooling ratios change (Figure 11).
In the current Sydney climate, tree planting for the provision of shade to buildings should be staged over time. Initially, trees are best located to the east and west of the house, allowing solar access in winter while blocking solar heat gain in summer. As the climate warms, trees to the north will provide increasing benefit. To reduce the heat-related health risk to occupants, the more trees that are located around houses with poor thermal performance the better, but air-conditioning may still be required to attain safe levels of comfort. Tree shade can reduce heat-related health risk, but will not fully compensate for climate change.

Conclusions

Such research highlights the extent to which vegetation can contribute to climate regulation benefits across a city, within public and private neighbourhood areas, as well as within homes. Although the overall pattern of vegetation cover has a significant effect on urban microclimates, vegetation cover across Sydney is not evenly distributed. Because vegetation cover is skewed towards residential land use and areas of greater socio-economic advantage, it is important to consider the future distribution of green infrastructure planning in public areas as well as more disadvantaged areas. Within neighbourhood areas, we show that tree cover can have a significant impact on rooftops, streetscapes, as well as parklands. Strategic planning of tree cover throughout a neighbourhood could have significant benefits in providing cool pathways for walking and social interaction where people live and recreate. Additionally, tree shade around homes, to the east and west, and increasingly to the north, will be important in Sydney under a warming climate.

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References


Introduction

There is no doubt that urban trees provide valuable services. Many individuals spend significant time and resources planting and maintaining trees (Figure 1), and as Mansfield et al (2002) note “...everyone has observed that the first thing people do in new, clear-cut subdivisions is plant trees.”

**Figure 1**: View from Mt Ainslie at northern extent of Canberra (as denoted by the row plantings in Haig Park, 1927) and expanded city (1990), showing the substantial number of trees planted.

The services provided vary by the species (or species group chosen) and their location (e.g. in parks or open places and along streets). The services can range from mitigation / amelioration of unpleasant and harmful environments to direct provision of positive and valuable environments (Table 1).

Numerous studies have attempted to quantify the benefits of these services. For example, Wee (1999) predicted that a single urban tree in Canberra, planted appropriately, could provide an estimated $16,000 of benefit during its safe lifetime by means of energy savings, air pollution uptake, water quality improvement and property value increases. Brack (2002) estimated that the planted trees on public land in Canberra had a combined energy reduction, pollution mitigation and carbon sequestration value of US$20–67 million during the period 2008–2012 (the Kyoto commitment period relevant to carbon sequestration). Other urban forest studies, particularly in the US have similarly estimated the ecosystem services or pollution mitigation values in the tens to hundreds of millions of dollars. Brack and Merritt (2005) used the DISMUT model (Brack, 2006) to calculate the amenity value of trees in Canberra and concluded they these may be up to $1,100 million or $3,100 / tree (using the Thyer Method).

However, there is also no doubt that urban environments can be very harsh on trees, and consequently trees may display significant stress in their crowns and their life span may be substantially less than the maximum biological ages observed in nature. When the tree crown breaks up or otherwise loose substantial branches and leaf area, many of the services they provide are also lost. Even though some services remain, especially those related to habit, many trees may be classified as having reached the end of its “Useful Life” (UL) at this stage. In the interests of safety and aesthetics, trees may be removed after only a few to several decades rather than after centuries. It is not uncommon for urban forest inventories to include Useful Life Estimates (ULE), with individual trees being classified into classes of remaining life of, say 0-5; 5-10; 10-20; 20-40; 40+ years.
Table 1: (Derived from Brack, 2002) Services of an urban forest

<table>
<thead>
<tr>
<th>Benefits relating to pollution mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amelioration of urban climate extremes</td>
</tr>
<tr>
<td>Mitigation of urban heat islands</td>
</tr>
<tr>
<td>Store and sequester carbon</td>
</tr>
<tr>
<td>Reduce noise pollution</td>
</tr>
<tr>
<td>Improve air quality</td>
</tr>
<tr>
<td>Improve water quality</td>
</tr>
<tr>
<td>Lower temperatures of parked cars</td>
</tr>
<tr>
<td>Reduce volatilisation of bitumen</td>
</tr>
<tr>
<td>Reduce consumption of electricity for heating and cooling</td>
</tr>
<tr>
<td>Reduce need to invest in new power utilities</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetic contribution, scenic beauty, visual amenity</td>
</tr>
<tr>
<td>Architectural enhancement of buildings</td>
</tr>
<tr>
<td>Improve property values</td>
</tr>
<tr>
<td>Increase privacy, barrier against unpleasant/stressful scenes</td>
</tr>
<tr>
<td>Control urban glare and reflection</td>
</tr>
<tr>
<td>Improve general liveability and quality of urban life</td>
</tr>
<tr>
<td>Increase tourism</td>
</tr>
<tr>
<td>Provide opportunities for outdoor recreation and enjoyment</td>
</tr>
<tr>
<td>Contribute to human health and relaxation, reduce stress and anxiety levels</td>
</tr>
<tr>
<td>Attract birds and other wildlife</td>
</tr>
</tbody>
</table>

Removing trees at the end of their Useful Life is expensive. As well as requiring substantial community involvement to explain the removal and replacement options, the removals also often includes disruption to traffic and power services for larger trees. Disposal of the material is an additional and not insubstantial cost – a few small portions of trees may be sold to local wood turners and hobbyists, but the majority of the tree is often chipped or dumped. Woodchip is a very low value product and, where the tree was diseased, may not be usable for landscaping due to fear of spreading pathogens. In the ACT, the removed material may not be dumped in Territory facilities, nor may it be used as firewood (even if dried and split) due to a policy of discouraging wood stoves and heaters to potentially improve air quality.

Tree removals often occur on an ad hoc basis in response to requests from the public, but given the nature of the original tree plantings (whole suburbs and thousands of tree may be planted in one period) and the fact that climate cycles tend to stress or kill a wide range of trees at the one time, such ad hoc requests are rarely evenly spread across the years. Management of this waste material can be quite a significant issue for the Government or private companies contracted for removal.

**Unexpected forest products**

Clark et al (1997) conclude that “A sustainable urban forest is one that recycles its products by composting, reusing chips as mulch and/or fuel and using wood products as firewood and lumber.” However, as noted above, chipping and composting produce relatively low value products and may be associated with disease spread while fuelwood/firewood sales may be banned due to agendas that discourage wood-based heating or cooking. Lumber production, both for general or specialty timbers, are usually restricted to larger, more “conventional” forested areas that exist on the boundaries of urban areas. Street tree plantings or small treed reserves and parks within urban boundaries very rarely provide lumber on a commercial or regular scale.

However, over recent decades, the range of products available from trees has been expanding and the efficiency of small scale production has improved. These trends may allow improved sustainability of urban forests by improving the potential to recycle material and/or support profitable micro and “cottage” industries.
Edible Urban Forests

Fruit and berries are obvious products produced by urban forests. Breeding and other modern developments have expanded the ranges of these products to allow them to be grown in harsher urban environments. However other parts of trees can also be eaten, including a few dozen species of trees whose leaves are regularly eaten by humans (e.g. *Toonia sinesis* - Fragrant Spring Tree - with a garlicky flavour). Of course, the spice cinnamon is simply the dried bark of the *Cinnamomum* sp. Small cottage industries could develop to produce and market these foods, similar to the “local honey” movement which is gaining popularity. Unfortunately, many modern urban dwellers distrust foods harvested in the city, fearing that urban pollution or even human interference may make consumption unhealthy. It is not uncommon to see fruit on public trees left to fall and rot, adding further to the safety issue of pedestrians and cyclists with slip hazards. Recent trends of public food gardens and food forests returning to urban environments however may indicate a change in these fears and urban forests may once again become a source of human consumable food.

However, these traditional forest foods will usually only be produced by healthy trees which are also producing the other beneficial services to the city – that is, the production of these food goods happens at the same time as the production of the other services before the trees have reached the end of their Useful Life. Some wood however, laid down when the tree was healthy and actively growing, may be fit and attractive for human consumption. Yacaratia wood (*Jacaratia spinosa*) for example is soft and fibrous and has been made into a commercially successful lemon soup, a cream cheese, and even a cinnamon ice cream. Some wood pulp can now be made into an edible noodle that’s rich in fibre, low in calories and carbohydrates, and free of gluten and fat. Mixing this pulp with a plant called konjac produces a new type of flour that can be used to make ramen, pasta and dumplings – with only 27 calories per pound as compared to 1,669 calories per pound for wheat. The manager at Omikenshi where the flour has been developed – Takashi Asami – suggested that such a low calorie food option may be promising because the “demand for diet food is strong”. A risk-taking city enterprise might be able to develop a niche health market where clients take a healthy stroll through its urban forest before consuming the low calorie and environmentally sound trees felled to keep the forest balanced and healthy.

But if you think that consuming wood is going too far, you might be surprised to read that powdered cellulose derived from wood pulp already can be found in several shredded or grated cheese products to help keep them looking attractive and edible. Xylan, extracted from Birch Trees, is also added to some yoghurts to provide a smooth and creamy taste and reduce flatulence!

Urban Forest Warmth and Energy

Standing, healthy urban trees can warm cities by blocking cold harsh winds. Haig Park in Canberra (Figure 1) was planted at the birth of the city to mark the formal entrance to the city but also to mitigate the strong and bitterly cold winds for which the area was renowned. Trees past their Useful Live can also warm the city as environmentally produced firewood - as recommended for a sustainable urban forest by Clark et al (1997). Firewood is relatively low value and the demand for dry, split logs may decrease as open, restricted or even slow combustion stoves are being discouraged in many urban areas. However, there are an increasing number of options being developed where wood can efficiently produce heat without the coproduction of unhealthy or unsightly smoke.

Pellet fires, using wood chips or even other organic matter that is compressed and dried into uniform pieces, are very efficient sources of home heating with efficiency ratings up to more than 80%. Pelletisers can be as small as bench-mounted units for occasional personal consumption up to commercial engines to supply the mass and export market.

Gasifiers and ethanol digesters are also making a come-back as technological advances improve the efficiency and cost effectiveness of turning wood into fuel.

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14 Gizmodo 18 Nov, 2014
The gas or ethanol can be used for heating or as a non-stationary fuel. Transport running on gasification was commonplace in the mid-20th Century, when almost every motorised vehicle in continental Europe was converted to use firewood during World War 2. Since that period, there has been relatively little change in the underlying theory or processes of production, but improved tools and materials have resulted in lighter and more reliable units. Energy efficiency is better than the best solid fuel fireplaces and when the fuel is sourced from sustainably managed forest it has a much better environmental footprint than petrol or diesel. As wood is more freely available that battery charge stations, wood-fired vehicles are also free of the current limitation of electric vehicles over long distances.

Both gasification and ethanol digestion are scalable, with gasifiers being fitted to power cars and trucks or to supply energy to large apartment buildings.

Growing your physical structures

Lumber, both from general or specialty species, may be produced from urban trees at the end of their Useful Life. Urban trees growing along street or in open parks may have very large diameters due to the lack of competition, while pruning to maintain pedestrian and vehicle clearance may also result in these large pieces remaining free from knots. In the right circumstances, large knot-free wood can command substantial price premiums. Unfortunately, without the right conditions, large dimensional lumber is difficult to handle and often requires separate processing to “break it down” into more manageable sizes. The open growth may also result in rapid rates of taper and a nieloid form which hampers the traditional recovery of useful timber. Urban trees, especially near the end of their Useful Life, may also contain internal rot and other defects as well as foreign (and potentially dangerous) items due to wounds inflicted by cars, children and other agencies. While the non-standard size and pockets of decay may render much of an urban tree unfit for routine or large-scale timber milling, niche market and hobby makers may enjoy and profit from “interesting” resources that engage their imagination and artistic talent. A major barrier to enabling such a market would be “finding” the appropriately shaped or coloured piece of raw material of the right species from the thousands of pieces of trunk and branches that result from removing trees. Scanning lasers and cheap Radio Frequency Identification tags (RFID) now allow three-dimensional images to be captured and identified for each piece in an inventory which could allow makers to specify then find the shapes of pieces they need to almost literally put together jigsaw-style an artistic or functional wood-based structure.

An alternative to the above approach where the unique shape and size of each piece of the recovered urban tree is used would be to break everything back down to the smallest common size and shape – pulp. While wood pulp has a reputation for being of low value and only good for low value and transient products, modern technology has again made such a reputation outdated. Giant 3D printers can literally print large scale structures overnight! Other developments, not quite as futuristic-looking as a building-scale 3D printer, allow waste or “scrap” wood to be formed into self-supporting panels of custom dimensions with superior thermal and soundproofing capabilities. These processes can reconstitute wood from an extremely wide range of sizes and qualities, to produce products which are flexible, beautiful and potentially very long lasting.

Growing the future right outside your door

The real future of wood products though might be considerably smaller that the woodchip – nanocrystalline cellulose (NCC). NCC starts as “purified wood” with all the impurities removed. The purified pulp can be formed into a “thin” paste of crystals which moulded to form a laminate or strands of amazing toughness despite being incredibly lightweight. This new material, as well as related off-shoots are being used in an incredible range of new products that range from very strong yet fully biodegradable drink bottles; flexible computer chips to clothing that generates electricity and the wearer moves. And, if the geneticists succeed, there might even be a return to wooden street lights, or more specifically lights from genetically modified trees glowing in the dark - acting as a sustainable source of lighting in your sustainable urban forest.

17 https://www.theguardian.com/science/2016/jul/03/fungi-glow-dark-luminescent-mushrooms-conservation-enviroment-bioscience
A “normal” forest; a certifiably sustainable forest

In addition to concluding that a sustainable urban forest should use or recycle its products, Clark et al (1997) also state that a mix of age classes and a mix of species is critical. They conclude that no more than 10% of trees should be of any one species, and that the age class distribution should be appropriate for a mixed age forest where the net forest canopy remains relatively stable.

Unfortunately very few urban forest estates meet the idea diversity of species and age classes, with an irregular pattern of species and age classes reflecting various periods of establishment and public or government enthusiasm. The urban forests of Canberra, for example, despite Canberra having a reputation as a “planned city” where trees were considered right from the establishment of the city, has a very unbalanced distribution of ages and species. The city is dominated by one Genus with Eucalyptus representing over half the street plantings. The forest is also dominated by trees planted in the 1970’s (40 – 50 years old now) with uneven numbers spreading up to more than 100 years old and a relatively small number still being established in new suburbs.

In traditional forestry terms, forest with a balanced age class and species structure is termed a “normal” forest – not in the sense of an “average” but rather in the Greek sense of a “model” or “ideal”. A normal forest means that silvicultural (arboricultural), establishment and removal operations are evenly balanced across the entire estate, which minimises cost and extreme resource requirements. Further, a sustained yield of goods and services is more easily regulated from a normal forest. Any unbalanced structure in an urban forest can be progressively transformed into a normal forest by the removal of over represented classes even before they reached their Useful Life. For example, if there were no further expansion in the urban forests of Canberra, and if management desired a 50 to 75-year rotation with a normal forest structure, then 1/50 to 1/75 of the total trees would need to be replaced (felled and processed, then replanted) annually. If the desired estate was proposed to be larger, then more trees may initially be planted than are felled, but some of the heavily overrepresented classes should nevertheless be replaced to avoid an ongoing imbalance in the overall structure. This annual program would gradually change the irregular age class distribution to a regular pattern, although in the case of Canberra, such a transformation would take more than three decades to complete.

An urban forest which is “normal” could easily gain certification as a sustainable forest and also have the best structure to withstand unexpected future stresses from climate change, population increase, etc. However, it would be expensive to convert to such a normal forest. Banks et al (2002) concluded that to bring the urban forest of Canberra into a normal state would require many years of systematic effort, including the replacement of about 6000 trees / year. Many of those replaced trees after the first few years of removing those with some obvious stress or other obvious signs of stress of incipient mortality, would appear to be healthy and valuable to the community. Thus, effort would also need to be directed towards the education of the community into the health and safety benefits of keeping the life cycle of the trees well below their biological maximum, and possibly even below their Useful Life during the transition to a robust and healthy normal forest.

It is possible that the new products described above and their resulting urban forest-based niche industries that allow local Canberra residents to engage their creativity, independence from big industry and even engage in a healthier and wealthier lifestyle would greatly enhance community engagement and support for active urban forest management.
References


TREES AND HEALTHY DESIGN: GETTING PEOPLE TO WALK MORE

Tuesday Udell
Heart Foundation


INTRODUCTION

Though the benefits of urbanization for human society are unequivocal, it is now considered one of the most critical global health issues of the 21\textsuperscript{st} century [1, 2], with high rates of chronic, non-communicable physical and mental health conditions in cities [3, 4]. There is growing recognition of the role green spaces could play in addressing this challenge [5, 6], with research demonstrating that experiences of nature are linked to improved physical health [7] [8] [9], mental wellbeing [10] [11, 12], greater social wellbeing [13], and positive health behaviours such as physical activity [14, 15]. Consequently, many municipalities are investing heavily in the provision, management and enhancement of urban green spaces to promote the health and wellbeing of city populations [16].

Despite the positive shifts towards improved green spaces in cities, advice about how to ensure health outcomes are realised from these efforts currently remains very general [17, 18]. Furthermore, the biodiversity in urban landscapes is heterogeneous [19] and land access arrangements are highly variable. As such, some people have greater access to urban green spaces than others [20]. Compounding this inequality is the possibility that some benefits of experiences with nature may be greater in more biodiverse areas [12]. These issues raise a number of questions that I will address in this talk. First, who in cities has access to green spaces, and is its presence alone enough to encourage its use by the community [21-23]? In the second part of this talk I will examine the implications of green space use for health and wellbeing. Specifically, I will assess how the different components of nature experiences influence physical and mental health; this includes the intensity of nature experiences (i.e. the quality or quantity of nature itself), as well as the duration and frequency [24]. Deconstructing exposure to nature down in this way provides a means to explore exactly how peoples behaviours, or green spaces themselves might be modified to improve the health and wellbeing benefits received. Furthermore, we show how it allows a dose-response analysis to assess exactly what dose of nature is needed to gain the best benefits.

METHODS

We delivered an online urban lifestyle survey to 1358 Brisbane residents in November 2012, prior to the onset of high summer temperatures. The respondent group closely reflects that of the actual population across several demographic criteria, and is relatively evenly spread spatially across the city. This was achieved through stratification of respondents to ensure that (i) participants were 18 - 70 years of age, (ii) equal numbers of participants above and below 40 years, (iii) equal numbers of females and males, (iv) the income quartiles of the participant group reflected those of the total Brisbane population, and (v) participants' addresses were spread evenly among four spatial zones reflecting the four quartiles of tree cover across the city.

Respondents provided their address or an approximate address, their age (selected from 11 brackets), sex, personal income (selected from 11 brackets) and their highest qualification (selected from 11 categories). Participants also provided an indication of their orientation towards nature by completing the nature relatedness scale [25], where 21 statements about nature were rated using a five-point Likert scale. A higher average nature relatedness score indicates a stronger connection with nature.
Survey respondents also provided information on their exposure to nature through a range of locations; here I focus on public parks as they are readily able to be manipulated by local management authorities. We measured experiences of nature across three components, including the usual frequency of park visits across a year and the average duration of visits across a week. The ‘nature intensity’ (in this case, the level of vegetation complexity within visited parks) was also determined by first spatially locating the visited place (a description or place name was provided by respondents, and these were manually geolocated), and then measuring complexity with LiDAR-derived maps of vegetation cover at a 5x5m resolution across five separate vegetation strata. The use of vegetation complexity here follows a hypothesis that higher levels of vegetation lead to greater health outcomes.

Analysis

Full details of all analyses can be found in the references cited here-in. In brief, we analysed the data to address a series of questions. First we explored what proportion of the population engages with public parks, and what physical, social or personal factors were associated with their use [21-23]. These factors included vegetation cover within the parks or backyards themselves, socio-demographic factors such as age or sex, and also the extent to which a person feels oriented towards nature.

We also explored whether either nature intensity, duration or frequency of exposure to nature in parks had a greater influence on health and wellbeing outcomes, after accounting for other socio-demographic correlates of poor health (age, gender, Body Mass Index, and socio-economic indicators including the income, education, and neighborhood socio-economic disadvantage) [26]. The main health outcomes of interest were high blood pressure and depression. We then examined the dose-response relationship between the odds of a respondent being recorded as having high blood pressure or depression and incremental increases in the duration of nature experiences, while accounting for covariates. Finally, we assessed the fraction of cases of depression or high blood pressure in the population that could be attributable to not spending enough time in nature (population attributable fraction analysis; i.e. the proportion of the population would benefit from greater exposure to nature).

RESULTS

We found that around 40% of Brisbane residents did not visit public parks in the week they were surveyed. Furthermore, we found that orientation towards nature was more closely associated with use than availability of parks, and that people tended to prefer visiting places with moderate vegetation complexity [21, 22]. There were a range of other socio-demographic correlates with green space use, including age, sex and highest qualification [21, 22].
Figure 1: The level of a) nature relatedness (orientation towards nature), b) % park cover around the home (opportunity for nature experiences), and c) time spent in yards for survey respondents clustered into low, medium or high users. Adapted from [21].

Figure 2: Graphs showing a) frequency of visitation to parks with different levels of tree cover, and b) nature relatedness of visitors to parks with different levels of tree cover. Adapted from [22].
We also found that nature experiences affected people across multiple health and wellbeing outcomes, including depression, high blood pressure [26]. When considering the three different components of nature dose, duration had the greatest association with the prevalence of depression and high blood pressure over both frequency of visits and intensity (vegetation complexity) of visited locations. We found that the odds of having either depression or high blood pressure were significantly lower than the null model when reported green space visits were an average of 30 minutes or more (i.e. the confidence interval did not overlap with an odds ratio of one; Figure 3a), with a slight increase in mean gains after that.

![Figure 3: Dose-response graphs showing the adjusted odds ratio from logistic regression for incrementally increasing average duration of visits to parks. 95% confidence intervals are shown. An odds ratio above one indicates an individual is more likely to have the disease where the threshold of green space visitation is not met. From [26].](image)

The proportion of cases of depression and high blood pressure in the population that could be attributed to city residents failing to spend an average of 30 minutes or more during a green space visit across the course of their week (the ‘population attributable fraction’) was 0.07 for depression, and 0.09 for high blood pressure; that is, up to 7% of depression cases and 9% of high blood pressure cases recorded in the study could potentially be reduced if the green space visitation duration was 30 minutes or more [26].

**DISCUSSION**

A surprisingly high proportion of people (40%) rarely engage with the outdoors, with a range of important mediating factors influencing this including socio-demographic and personal correlates such as age, sex and income. We also found that orientation towards nature (measured here as nature relatedness) had a critically important role in influencing whether people actually venture out and use public greenspaces, even more so than the availability of green space.

Characteristics of parks themselves also have an important association with park usage, with those with 30-40% of tree cover receiving the highest frequency of visits. However, an interesting pattern revealed in this study was that there was an almost linear relationship between vegetation cover within parks and the average nature relatedness of visitors. This suggest that orientation towards nature is not only important in determining whether people use green spaces, but also what types of spaces they visit [21-23]. This has potential implications for health and wellbeing, but also how parks are designed to fit the needs of different communities.
We have developed here the first ever recommendation for a minimum dose of nature, which in this case is a 30 minute visit to a green space during the week to lower levels of high blood pressure and depression in the population [26]. Furthermore, the dose response relationship shown here contributes to the evidence for causality between nature and health at the population level [27]. This analysis further revealed that the proportion of the population that could benefit from additional visits to green spaces is high, with 7% for depression and 9% for high blood pressure. These could amount to considerable savings for the public health purse, with depression costing Australian society AUD$12.6 billion per annum.

What does all this mean for urban green space management? Interventions in cities need to go beyond provision alone to encourage use through either mechanisms, such as park programming, or through fostering a greater connection between people and nature in the general population. This approach is critical to ensure the entire community can access and gain the health benefits of spending time in nature.

REFERENCES


POLLUTANTS AND STREET TREE HEALTH
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Abstract
Trees vary in their responses to air and soil borne pollutants; some are sensitive while others are tolerant of some or many pollutants. The age and physiological state of the plant, as well as the prevailing environmental conditions, can influence the tree’s responses to pollution.

Although Australia does not suffer from the widespread pollution damage to trees that is common in other countries, pollution damage to trees at a local level is not uncommon, especially in larger cities where population densities are high. Particulate matter, chlorides, natural gas, petroleum products and horticultural chemicals can be problematic urban pollutants that effect street trees. Microclimatic effects can influence the effects that pollutants might have on urban trees.

Identification of pollution damage is often difficult because the symptoms can be confused with other causes of plant injury. However, the identification of the pollutant is often the first step to returning damaged plants to normal health and vigour.

Introduction
Inadvertent damage to trees as a result of unwanted chemicals in the soil, air or water has been known for centuries and in 1969 pollution was formally recognised as a cause of tree injury and death on a global scale (Andrews 1972; Ormrod 1978; Nowak et al 2006). Definitions of pollution vary (Moore 1983), but one which is both comprehensive and indicative of human involvement is: Pollution is the unfavourable alteration of our surroundings wholly or largely as a by-product of human actions, through direct or indirect effects of changes in energy patterns, radiation levels, chemical and physical constitution and abundances of organisms (Presidents Science Advisory Committee, 1965). It is also difficult to adequately define a pollutant, but in this paper it is defined as any substance that adversely affects something that human’s value, provided it is in concentrations high enough to do so.

Trees vary in their responses to and tolerances of pollution and certain species or cultivars have been developed for their pollution resistance. Such plants often come from those environments where potential pollutants are at naturally high levels (Nowak et al. 2006). The list of potential pollutants is almost limitless, but there are relatively few substances which represent a major and common threat to urban trees. This paper reports a number of cases studies involving pollution to urban street trees in Melbourne over the last twenty years.

The effects of any pollutant on a tree depends on its concentration, the duration of exposure and the number of times exposure occurs as well as the species of tree and environmental conditions (Moore 1983). Pollutants may also affect tree health and vigour indirectly by altering the physical properties of the soil such as aeration, or the biological components of the soil, like mycorrhizal fungi. Pollutants may be present in air or water, where they can come into direct contact with trees, but for many of the pollutants that affect street trees, their final destination is in soils.

Globally the major pollutants that impact upon street trees are sulphur dioxide (SO2), oxides of nitrogen (nitric oxide NO and nitrogen dioxide NO2), carbon monoxide (CO), ozone (O3), particulate matter and in developing nations, heavy metals (lead, cadmium, zinc, copper, iron and nickel). Several of these combine to form peroxacetyl nitrate (PAN), which is often called photochemical smog (Table 1) (Ormrod 1978; Moore 1983). Within Australia, there are relatively few pollution issues related to street trees, apart from localised occurrences within inner city regions, and pollution damage to trees is occasionally acute but may be subtle or chronic. The coastal positions of major cities, their relatively small population densities and prevailing winds combine to minimize wide-scale air-borne pollution damage, while pollution spills into waterways are rare and pollution of soils is generally localised. When damage does occur, however, the causes are often difficult to identify due to the length of time taken to diagnose the cause and remedies can be difficult to prescribe.
Table 1: Major pollutants causing damage to street trees. The highlighted pollutants are those that occur more commonly in urban Australia (after Moore 1983).

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Medium affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Air</td>
</tr>
<tr>
<td>Sulphur Dioxide (SO₂)</td>
<td>✓</td>
</tr>
<tr>
<td>Ozone (O₃)</td>
<td>✓</td>
</tr>
<tr>
<td>Peroxyacetyl nitrate (PAN)</td>
<td>✓</td>
</tr>
<tr>
<td>Nitrogen dioxide (NO₂)</td>
<td>✓</td>
</tr>
<tr>
<td>Fluorides</td>
<td>✓</td>
</tr>
<tr>
<td>Chlorines</td>
<td>✓</td>
</tr>
<tr>
<td>Ammonia</td>
<td>✓</td>
</tr>
<tr>
<td>Ethylene</td>
<td>✓</td>
</tr>
<tr>
<td>Particulates</td>
<td>✓</td>
</tr>
<tr>
<td>Heavy metals (Cd, Mg, Pb, Zn, Cu, Fe, Ni)</td>
<td>✓</td>
</tr>
</tbody>
</table>

Agrochemicals:
- Fertiliser
- Herbicides
- Pesticides

Detergents:
- Natural Gas
- Petroleum
- Salt (usually, but not always NaCl)

Because pollution damage to street trees is considered rare in Australian cities, it is often not considered at all when trees exhibit symptoms of poor health and vigour. However, it does occur and fortunately there is a relatively small list of likely causal agents in Australia as many of the more significant pollutants have been controlled by environmental pollution controls over the last thirty years. Australian legislation, for example, that banned lead from petrol has meant the heavy metal pollution from lead has all but been eliminated and the uses of ozone and fluorides have also been restricted. This leaves a relatively short list of suspects as sources of pollution damage to urban trees with the most commonly encountered source of pollution being particulate matter from vehicular traffic. This is followed by spills of petroleum products, especially diesel fuel, natural gas from leaking pipes, accidental spraying with horticultural or agricultural chemicals and chlorines.

The sensitivity of trees to pollutants varies. Some trees are sensitive to most pollutants while others are quite tolerant (Nowak et al. 2006; Alkalaj and Thorsteinsson 2014). However, many trees show seasonal variation in their pollution sensitivities and many species are more sensitive to pollutants when they are young or when they are actively growing (Harris 1983). Evergreen species are generally regarded as being better at removing pollutants from the air than deciduous species, probably because they do so all year round, but deciduous trees may have higher tolerances as they dump pollutant loads with each leaf fall (Nowak et al 2006; Alkalaj and Thorsteinsson 2014). The sensitivities and tolerances of many Australian native trees to pollutants are still unknown.
Pollution Damage to Street Trees
Particulate Matter

Trees may be damaged by particulate matter such as dust, soot, smoke, grease, oil or soil present in the air. This is a major problem in developing countries such as China and India (Andrews 1972, Pirone 1978). Many of the particulates are not toxic, but they impair plant function by coating leaf surfaces which may reduce light penetration to the mesophyll and so reduce photosynthesis. They may also clog stomata which interferes with gaseous exchange reducing photosynthesis, respiration and impairing transpiration which may result in higher leaf temperatures.

Under Australian conditions, particulate matter influence on street trees is likely to occur in two contrasting environments. Particulate matter levels in the air are often highest at major controlled traffic intersections where vehicles are stopped for increased periods of time. Trees growing close to these intersections are likely to experience much higher levels of pollution than trees growing further from the intersections (Chen et al. 2015). This often results in trees that are showing chronic or subtle symptoms of pollution damage such as slower and/or stunted growth, early leaf shed or delayed bud burst. Such trees often have shorter life spans than other trees of the same species growing in the same street.

Another common occurrence is that trees exposed to fine dust particles that are churned up by vehicles moving on unsealed roads grow more poorly than trees of the same species and age growing in paddocks. This phenomenon is also common in cities where roads to industrial sites are unpaved or in poor condition and where the traffic consists primarily of trucks.

Trees with smaller compound leaves are more efficient in removing particulate matter than trees with larger leaves (Kumar et al. 2013) and particulate matter concentrates on the leaf tip and margins (Kumar et al. 2013) and leaves of complex shapes with large circumference tend to be more efficient in removing particulates (Ingold 1971). Trees with stickier, rougher and hairier accumulate more particulate matter on their leaf surfaces (Beckett et al. 2000; Kumar et al. 2013).

In a recent study by Guo of particulate matter on the leaves of trees growing on the intersection of Grattan Street and Royal Parade, Melbourne, particulates were measured using a simple wipe technique. Leaves on trees at various distances from the intersection were wiped with dry filter paper, then water-moistened paper and finally alcohol soaked papers. Using the three wipes removes most of the particulate matter from the leaf surfaces. The collected filter papers, as well as the leaves, were scanned into a computer (as shown in Fig.8) and processed in Photoshop. Using Photoshop, the images were converted into binary colour (white and black) where the particulate matter appears as black spots and recorded as the number of pixels of black. However, because leaf surface areas differed they were also calculated as a number of pixels. With the area of filter paper constant, the particulate matter present was expressed as the ratio of black pixels on filter paper to pixels of leaf surface area:

$$\frac{\text{Relative PM concentration}}{\text{the number of pixel of black spots}} = \frac{\text{the number of pixel of leaf surface area}}{\text{black pixels on filter paper}}$$

The relative PM concentration presented in this research is expressed as a percentage based on the leaf area. It was found that particulate matter on the leaves was higher in the trees closest to the intersection, but was negligible on trees 100m from the corner (Figure 1). Particulate matter on trees growing in nearby parks but away from roads was also negligible.
It is also of interest that street trees can have a role in the removal of particulate matter and dust from roads (Beckett et al. 2000; Mori et al. 2015), which is one of the reasons behind the massive tree planting that is taking place along highways and urban roads in China – mitigating the urban heat island (UHI) effect is another. Different species of trees have different capacities both for the uptake of pollutants into leaf tissues and for the adsorption of particulate matter onto the leaf surfaces (Blanusa et al. 2015). In the Melbourne study, it was found that the hairy surface of plane tree leaves was more effective in accumulating particulate matter of the leaf surface than either elm or eucalypt leaves (Figure 2).

Particulate pollutants can be removed from the surfaces of the plant, but it is a tedious and expensive operation, using compressed air or high pressure water jets. Not all particulates do damage through physical changes alone, some are absorbed by the plant causing chemical and toxicological changes to structure and metabolism.
Chlorine

Chlorine is quite a quite common pollutant that affects urban trees as it is a common constituent in chemicals that are used for household swimming pools and cleaning products or for industries where chlorine is used as a disinfectant. The symptoms of chlorine damage, which include a yellow mottling of the leaves or rapidly induced chlorosis are variable making it difficult to establish chlorine as the cause of damage (Ormrod 1978), but the source of the chlorine is often close to the injured trees. Confusion with insect damage can usually be avoided as the agents are not present (Ormrod 1978, Davis 1979).

Generally, chlorine damage to trees is restricted as spills are small and damage only occurs to trees in the immediate vicinity of the spill or leak. However, an incident occurred in Melbourne in December 2007 in which a fire caused the decomposition of chlorine swimming pool chemicals that had been poorly stored. Significant chlorine was released into the atmosphere which affected trees growing along four streets close to the storage site. In trying to assess whether and the extent to which any trees had been affected, the following symptoms were sought (Table 2):

- mottling, chlorosis and/or necrosis of leaves typical of chlorine damage (Figures 3 and 4)
- evidence of an uneven mottling, chlorosis or necrosis across the canopy. Depending on the canopy density, gaseous pollutants usually have a greater impact on the windward side of the tree while damage to the leeward side may be less extensive or absent.
- evidence of a rapidly induced chlorosis – specifically where older and new leaves were healthy but other leaves showed mottling, chlorosis or necrosis consistent with chlorine
- where symptoms consistent with chlorine damage to plants were established, attempt to eliminate other causes of similar symptoms. These are usually due to insect pests or diseases, which can be detected by a leaf inspection using a hand lens (x10).
- under some circumstances soil nutritional deficiencies can cause symptoms similar to chlorine damage. If plants were generally chlorotic or showed a longer history of chlorosis indicating a long term problem no attribution to chlorine damage can be made.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>SYMPTOMS</th>
<th>PROGNOSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peppercorn</td>
<td>General loss of foliage and any older foliage remaining on the tree necrotic. New shoots green and should persist. Symptoms consistent with chlorine exposure (Figure 6).</td>
<td>Severe, sub-lethal exposure to chlorine from which the tree should recover</td>
</tr>
<tr>
<td>Poplar</td>
<td>Several specimens showing significant necrosis of all leaves on some trees. Other specimens showed necrosis and chlorosis of most leaves. For specimens further way most severe damage is on the side closest the source. Some specimens showed minor mottling, chlorosis and necrosis of some leaves. Most severe damage on the side of the tree closest to the source, but new shoots were green and should persist (Figure 5). All being consistent with chlorine exposure</td>
<td>A severe but sub-lethal exposure to chlorine from which the trees should recover or a relatively minor exposure to chlorine from which the tree should recover</td>
</tr>
<tr>
<td>English Oak</td>
<td>Moderate mottling, chlorosis and necrosis of leaves. Most severe damage on the side of the tree closest to the source with little or no damage on the leeward side of the tree. All consistent with chlorine exposure. New shoots green and should persist (Figures 3).</td>
<td>A relatively minor exposure to chlorine</td>
</tr>
</tbody>
</table>
The pattern of affected plants was consistent with a point source of chlorine from the storage site, with the chlorine spread by a wind blowing from a westerly direction. Once a point is reached at a distance from the source, the concentration of chlorine is insufficient to cause symptoms. The health and growth of plants growing outside the boundaries of the drifting chlorine is normal, which is consistent with the symptoms observed not being caused by soil conditions or the presence of pest or diseases.
Chlorine is also a vital ingredient in the creation of hydrochloric acid, which is the destructive element of acid rain. However, this rarely has impact in Australia and when it does it is almost always a local event centred upon a major chemical spill or manufacturing plant malfunction.

Natural Gas

Both natural and manufactured gas (coal gas) can cause damage to trees. Manufactured gas can cause direct damage as it may contain hydrogen cyanide, carbon monoxide and other contaminants (Grey and Deneke 1978) that are toxic to the plant. However, it use in Australia has largely, if not wholly ceased, as natural gas dominated the market (Moore 1983). Natural gas is not toxic to plants (Pirone 1978), but can cause injury by indirect means usually by the displacement of oxygen in soils that makes them anoxic. It is the methane present in the gas that contributes to many of these effects. Gas may also compete with other chemicals for enzyme binding sites and so interfere with plant cellular metabolism. Natural gas may also impact plants by drying soils (Grey and Deneke 1978, Pirone 1978, Davis 1979) and upsetting the balance of the soil micro-flora and faunas and reducing the growth and efficacy of mycorrhizal fungi.

Natural gas leaks can be a major source of pollution, as they often go undetected for some time and so their effects can be widespread. The symptoms of gas injury are varied. Growth may decline, leaves and young branches may die-back and in some cases the bark may crack and lift and rupture (Figure 7) (Davis 1979). Often when the bark lifts, a pulpy material develops under the bark which is indicative of natural gas as the causal agent. The lifting of the bark often allows subsequent insect or fungal attack upon the tree. When gas leaks occur several trees will usually show symptoms not just a single plant.

Methane can be produced by organic materials deposited in landfill sites (Davis 1979). The organic materials decompose over many years, releasing methane. High levels of methane have prevented filled sites from being vegetated in Melbourne for up to three decades after capping. The natural gas produced from such decomposition can travel for considerable distances under capped sites and injure plants up to 1km away. With old landfill sites on the edges of waterways, the methane may be trapped under the capping and flow under it to emerge on the banks of a river or creek and cause damage to riverine vegetation. Because the river is at a distance from the landfill and has never been disturbed, the cause of the damage may remain a mystery.

Figure 5: Chlorine damage to poplars.  Figure 6: Chlorine damage to peppercorn.
Both methane and natural gas can leak through cracks in the cap which can result in severe but localized damage. It is not uncommon that when old landfill sites are to be revegetated, planting pits penetrate the cap and act as vents through which the gas emerges killing planted advanced specimens. Often horticulturists are blamed for these planting failures until the site history is revealed.

Petroleum Products

Spills of petrol or oil based products often cause damage to trees. Street trees are more likely to be impacted from petrol tanker accidents and rollovers. Their effects are usually localized (Grey and Deneke 1978), and attract media attention and so the cause of damage is easily found. However, seepage from small spills can cause damage over wide areas and the cause of the damage is not detected due to the volatile nature of the fuel (Davis 1979). Spills usually give localized plant mortality, but the more volatile materials may cause leaf chlorosis and necrosis.

Diesel fuel is a powerful phytotoxin and even small spills can prove deadly (Moore 1983). A common arboricultural situation involving trees and fuel is the accidental or deliberate spill of diesel on construction sites. The diesel rapidly kills tree roots and trees can wilt and die with 48 hours (Figure 8). Soil analysis will often reveal the presence of diesel fuel if the tests are done within a week or two of the tree decline. Fuel, but particularly diesel should not be stored on development sites in the vicinity of trees or their root systems and the application of Australian Standard, AS4970 Protection of Trees on Development Sites should be applied to such situations.

Some other petroleum based products can also be problematic. Kerosene is very toxic to plant tissues and root tissues in particular. It is occasionally encountered on domestic properties, especially in rural parts of Australia where kerosene was used as a source of fuel for lighting, refrigeration and for other household appliances. When these were replaced, tanks with kerosene were often just left standing and when they rust, the fuel leaks into the soil. Such leaks will kill trees and the kerosene can persist in the soil at high levels for at least three decades, if not longer, making planting in the sites impossible. The soil has to be removed and replaced if planting is to occur earlier.
Horticultural Chemicals

The use of chemicals in horticulture and agriculture as fertilisers, herbicides and pesticides has meant that their abuse, accidental spraying and spilling is inevitable. The most damaging of these chemicals that injure plants are non-selective herbicides (Grey and Deneke 1978, Davis 1979) and the extent of injury may range from a few chlorotic spots on a leaf to the death of the whole plant.

A common group of chemicals causing damage to plants belong to the group of auxin mimics, which includes 2,4-D and MCPA (Pirone 1978, Davis 1979). Fortunately, their mode of action leads to quite distinctive symptoms of damage (Figure 9), which include the recurving of leaf petioles, twisting of shoot tips and leaves losing colour and becoming chlorotic. Such distinct symptoms often means that the causal agent can be easily and quickly identified. If an auxin mimic herbicide affects plants via drift or is diluted in a mist or rainfall event, the symptoms may be more subtle and hormone-like and include the development of root growth at stem nodes, development of epicormic buds and changes in leaf morphology.

Accidental spraying by of glyphosate and the effect of drift is also common. Because it is so widely used, careless use of glyphosate (often as Roundup or Zero in domestic contexts) has caused considerable damage to non-targeted trees. Depending on the species affected and concentration of the dose of chemical applied, symptoms range from the death of whole specimens to the killing of branches and leaf necrosis (Figure 10).
Conclusion

While pollution damage to trees in Australian cities is not common, pollutants can cause significant injury to street trees. Often the damage is subtle or chronic and so may not become evident for many years by which time the damage has been done (Moore 1983). The damage done to street trees by particulate matter, petroleum product spills, accidental spraying with pesticides and natural gas leaks should not be underestimated and the possibility of pollution damage should not be discounted when street trees perform badly without other apparent causes such as poor soils or insect or fungal attack.

As is often the case with plant responses to stress, the alleviation of other environmental stresses may reduce the effects of pollution damage (Harris 1983). Trees that are otherwise healthy and that are growing in good environments often show higher tolerance of pollutants – prevention is always better than cure. Knowledge of pollutants and their symptoms when affecting trees is important to those managing street trees. Pollution can reduce the amenity value and life spans of street trees, and the competent urban forest manager needs to be aware of pollution as a real and potential risk.

Acknowledgements

The assistance of Dr E Moore, linguist, for her helpful comments on the manuscript is greatly appreciated, as is the permission of Ms Jingyi Guo to use two figures on particulate matter pollution in Melbourne from her Master in Environmental Science at the Office of Environmental Programs at the University of Melbourne.
References


President’s Advisory Committee (1965), Environmental Pollution, Environmental Pollution Panel, Washington.
Introduction
Trees have long been recognised in the scientific field for the benefits they provide both to the environment and people, such as: climate change adaptation and mitigation, providing flora and fauna habitat and resources, improving human health and well-being, and increasing local economic prosperity and real estate values. Though the benefits of trees and associated green infrastructure elements is not new, only recently has their importance been actively recognised and pursued by urban planners and decision-makers. As a result, there is now a rapidly growing impetus at the local government level to increase urban green infrastructure as an adaptation strategy. However, justifying and advocating for more trees has proven difficult in urban areas where competition for land area is high.

Being able to value trees as an urban asset allows us to justify the business-case for trees and so advocate for increased tree plantings on public land. However, effectively and efficiently increasing tree cover in urban areas also requires trees to be retained and planted on private property, which will need a cultural and behavioural shift by the people living and working in urban areas. Local councils play a key role in leading and nurturing such cultural and behavioural change.

This paper provides an overview of a case study project conducted by the City of Unley aimed at valuing their urban trees and then engaging the local community as a means of initiating positive cultural and behavioural changes towards trees.

Tree Ecosystem Services Assessment
An inventory assessment of the structure, function, and value of Ridge Park’s trees was conducted between November and December, 2015. A total of 683 trees were measured and analysed using the i-Tree Eco model developed by the U.S. Forest Service. Based on this assessment the Park’s trees were shown to be diverse in composition and structure offer a substantial amount of ecosystem services, such as carbon storage and sequestration. Together the structural and functional values of the Park’s trees were calculated to have a market value of just over $3.1M. Additional key findings from the assessment are shown in the Table 1.

The Park’s trees were also noted to contribute significant biodiversity and landscape values. The full methods, results and discussion of this assessment are available in the following report: Seed Consulting Services (2016) Tree Ecosystem Services Assessment, Ridge Park. A report prepared for the City of Unley, South Australia. Available for download from: http://www.itreetools.org/resources/reports.php
Table 1. Summary of key findings from the Ridge Park i-Tree Eco complete inventory assessment.

<table>
<thead>
<tr>
<th>ELEMENT ASSESSED</th>
<th>KEY FINDINGS</th>
</tr>
</thead>
</table>
| Ridge Park’s forest structure and value (i-tree Eco assessment) | • Number of trees: 683 (58 species, including 16 exotic species)  
• Total canopy area: 40,226m² (equivalent to ~77% of total park area)  
• Most abundant and diverse genus: *Eucalyptus* (274 trees; 12 species)  
• Most abundant species: river red gum, European olive, grey box  
• Proportion of small trees (<20cm diameter breast height, DBH): 53%  
• Proportion of very large trees (>100 DBH): 4.25%  
• Structural value: $3,093,814 |
| Ridge Park’s forest function and value (i-Tree Eco assessment)   | • Pollution removed: 203.56 kg/yr ($99.22/yr)  
• Carbon stored: 342 tonnes ($7,871)  
• Carbon sequestered: 10.08 tonnes/year ($232/yr)  
• Avoided run-off: 254.5 m³/yr ($578/yr) |
| Tree removal impact (derived from i-Tree Eco assessment)          | • Number of trees recommended for removal: 135 (109 exotic trees; 37 immature or young trees);  
• Dominant species: European olive (96 trees)  
• Decline in current canopy cover: 10%  
• Decline in structural value: $275,510  
• Decline in functional value: $577 |
| City of Unley street tree structure and functional value (extrapolated from i-Tree Eco assessment) | • Number of street trees considered: 15,660 (70% of known street tree population)  
• Structural value: $35,581,881  
• Pollution removed: 2,479 kg/yr ($1,047/yr)  
• Carbon stored: 3,001 tonnes ($69,013)  
• Carbon sequestered: 166 tonnes/yr ($3,823/yr)  
• Avoided run-off: 4,057 m³/yr ($9,214/yr) |
| Biodiversity and landscape values (drawn from direct observations and expert knowledge) | • Fauna species identified: 18 vertebrates (1 frog, 15 birds, 2 mammals, 1 reptile) – all native  
• Observed tree uses by fauna: foraging, shelter, habitat/breeding, roosting, shading/cooling  
• Key landscape values of Ridge Park: structure and connectivity |

Community Engagement Event – Valuing Trees
Data from the Tree Ecosystem Services Assessment is being used by City of Unley’s Asset Management team to underpin green infrastructure decisions and activities. One of the first applications of this data was in the creation of novelty “tree tags” which were trialled as a community awareness and education tool during “Mud central”, a community fun day held at Ridge Park in early 2016. Below is a copy of a report generated by Seed Consulting Services about the findings from community surveys conducted during the event relating to how participants value trees.
Key Learnings

- People believe trees are important and there should be more trees planted in urban areas;
- There is a strong recognition of the observable benefits provided by trees (e.g. shade) but less recognition of other less tangible benefits (e.g. carbon dioxide storage/sequestration); and
- Tree tags, as trialled in Ridge Park, are a valuable and desirable addition to the urban environment, providing educational, awareness, and interactive benefits for adults and children.

Understanding how attendees at Mud Central 2016 value urban trees

On April 21, 2016, the City of Unley hosted “Mud Central”, a community fun day celebrating nature and raising awareness of the importance of interacting and connecting with nature and the outdoors. As part of the Mud Central event, the City of Unley sought to better understand current community awareness and values regarding green infrastructure and, especially, trees.

Understanding community awareness and values complements recent project works completed within the City of Unley regarding their urban forest, and understanding the values of trees as a means of justifying the need to increase tree cover in the City (Seed Consulting Services, 2016). By combining environmental data with community values, the City of Unley will be able to more effectively and efficiently target ongoing activities which support a positive cultural and behavioural change towards managing and increasing trees and green infrastructure.

Method

The Mud Central event attracted an estimated 4,000 people, of which approximately one-third were adults and two-thirds young children. During the event Seed Consulting conducted three surveys primarily targeting adults: vox pop style videos; tree survey; and tree tag survey.

Vox pop style videos

This survey format used an approach of recording people’s impromptu answers to the question: what do you like about trees?

The videos collected during the event were edited and cut together with photos and quotes also taken during the event. Express verbal consent was given at the time of recording by parents of any children under the age of 18 featuring in the videos.

Tree survey

This survey was completed by attendees and incorporated seven Likert scale questions, as well as two open answer questions, and a question about the person’s demographics (Attachment A). The questions were designed to understand how people feel about (i.e. value) trees in urban areas, and their current awareness of benefits provided by trees (e.g. ecosystem services).

Likert scale questions were analysed by calculating the median and interquartile range (IQR) of responses. The median indicates what most respondents seem to believe, whereas the IQR indicates the level of consensus. A relatively small IQR indicates more consensus and a relatively large IQR indicates opinions may be polarised for or against the topic. An IQR of zero indicates complete consensus among respondents.

The list of benefits provided by people were collated into 13 main categories and arranged in order of the number of people who identified the benefit. Other comments provided by people are listed.
Tree tags survey
Six questions were asked by Seed Consulting to randomly selected attendees of Mud Central (primarily adults). The questions were designed to open a conversation with people to understand their opinions and responses to the tree tags attached to a number of trees around the park (Attachment B).

The responses were collated as an information base for the City of Unley when considering the potential future use of tree tags to raise awareness and disseminate information to the public.

Results and Interpretation
Vox pop style videos
Two videos were generated, each just over 3mins in length. These are publicly available at:

Tree survey
Surveys were completed by 50 people ranging in age from late teens to over 70 (Figure 1). At least 78% of respondents were women, of which 69% were aged 32-51. This reflects the predominance of mothers with young children drawn to the free community event during school holidays.

The majority of respondents either agreed or strongly agreed with the Likert scale questions (Figure 2), and there was generally good consensus (Table 1). This indicates overall that people believe trees are important and there should be more trees planted in urban areas. Planting trees on public land received slightly stronger agreement than planting on private land, and there was agreement that non-sporting grassy areas and some on-street parking should be used for plantings, though there was slightly more consensus for replacing grassy areas than on-street parking (Table 1). People also tended to agree that more trees should be planted in Unley specifically and that they would plant more trees on their property if incentives were provided, though there was slightly lower consensus than some other responses. Based on additional comments provided, the lower consensus related to people not having room to plant more trees on their property, irrespective of incentives.

A wide range of responses were received when asked to list some benefits of trees. The benefits provided were distilled into 13 main categories, of which shade, wildlife habitat/food, and aesthetics/beauty/appeal were the most commonly noted (Table 2). This indicates that there is a strong recognition of the observable benefits provided by trees but less recognition of other less tangible benefits such as carbon storage and sequestration, erosion control, and rainfall interception. Certain benefits were not mentioned at all, such as the positive impacts on real estate values and economic prosperity, the ability to reduce energy use and costs in buildings, the contribution to climate change adaptation, and the potential to extend built infrastructure lifetimes (e.g. road surfaces) and so minimise maintenance costs.

In response to the question “do you have any other comments about trees in urban areas, the following comments were provided:

“More trees on verges and maybe shopping car parks (implement in legislation)”

“The tags are really amazing pieces of information for the common public to understand the importance of trees for our lives”

“This park is a great spot and good example”

“They really add to atmosphere and are relaxing”

“Because I love trees!”

“They are beautiful…I love them”

“Could grow more local indigenous trees on foot paths (street trees); cut down the weed trees there at the moment; Would plant more trees on my property but can’t fit any more in”

“I couldn’t live in a suburb without greenery/trees”

“Need to be prioritised more esp. with regard to developments”
Figure 1. Age range of tree survey respondents
Figure 2. Cumulative responses to each Likert scale question from 50 tree survey respondents. Numbers in circles indicate the number of respondents.
Table 1. Analysis of Likert scale questions showing the median score (i.e. what most respondents believe) and the interquartile range (IQR) (i.e. the level of consensus in the responses).

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>MEDIAN SCORE</th>
<th>IQR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees are important in urban areas</td>
<td>5 (strongly agree)</td>
<td>0</td>
</tr>
<tr>
<td>We need more trees in the City of Unley</td>
<td>4 (agree)</td>
<td>1.75</td>
</tr>
<tr>
<td>We should plant more trees on public land</td>
<td>5 (strongly agree)</td>
<td>1</td>
</tr>
<tr>
<td>We should plant more trees on private land</td>
<td>4.5 (agree to strongly agree)</td>
<td>1</td>
</tr>
<tr>
<td>I would plant trees on my property if incentives were provided</td>
<td>4 (agree)</td>
<td>2</td>
</tr>
<tr>
<td>I think some on-street parking space should be used to plant more trees</td>
<td>4 (agree)</td>
<td>2</td>
</tr>
<tr>
<td>I think some public grassed areas (not sporting fields) should have more trees</td>
<td>4 (agree)</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2. Number of respondents who identified tree benefits falling in to the 13 collated tree benefit categories.

<table>
<thead>
<tr>
<th>TREE BENEFIT CATEGORY</th>
<th>NUMBER OF PEOPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shade</td>
<td>33</td>
</tr>
<tr>
<td>Wildlife habitat/food</td>
<td>25</td>
</tr>
<tr>
<td>Aesthetics/beauty/street appeal</td>
<td>20</td>
</tr>
<tr>
<td>Pollutant removal/clean air</td>
<td>14</td>
</tr>
<tr>
<td>Produce oxygen</td>
<td>11</td>
</tr>
<tr>
<td>Mental wellbeing/relaxing</td>
<td>11</td>
</tr>
<tr>
<td>Physical wellbeing/play opportunities</td>
<td>8</td>
</tr>
<tr>
<td>Good for environment</td>
<td>6</td>
</tr>
<tr>
<td>Reduce/store/sequester CO2</td>
<td>4</td>
</tr>
<tr>
<td>Cooling/UHI mitigation</td>
<td>4</td>
</tr>
<tr>
<td>Erosion control/mitigation</td>
<td>4</td>
</tr>
<tr>
<td>Rainfall interception</td>
<td>2</td>
</tr>
<tr>
<td>Storm protection</td>
<td>1</td>
</tr>
</tbody>
</table>
Tree tags survey

A conversation about the tree tags was had with 26 people, the majority of whom had noticed the tree tags, though had not necessarily read them in detail until the conversation began. This is likely due to the large crowds and numerous child-based activities being run at the Mud Central event and the need for parents to be watchful of their children, rather than focussing on the tree tags. Seventeen people surveyed were females, three of which were children aged 7-12; one boy aged 8 was also surveyed.

Overall, people considered the **tags to be a valuable and desirable addition to the urban environment, providing educational, awareness, and interactive benefits**. The key messages from the survey are:

- Everyone surveyed responded positively to the tree tags, with enthusiastic feedback being that they were a: “wonderful”, “great”, “good”, and “fantastic” idea.
- Everyone also agreed that there should be more implemented on trees in urban areas, especially focussing on trees where children often congregate (e.g. schools, libraries and parks) as it was considered an excellent educational tool for children. Trees of a particular age or conservation concern were other target suggestions.
- The design of the tags was well received, with the font type and size and colour all being positively critiqued, though a few people commented that the colour could be brighter and perhaps the tags could be bigger (to fit more information).
- Most people agreed the information provided, including slogans on the back of the tags, were of interest and the right level of detail. A few people commented that it was good to “find out information without being an expert or needing to go to a Botanic Gardens”.
- People commonly commented that they would have liked to see other benefits/services included on the tags (e.g. good climbing tree, habitat/food for animals). One person also suggested a rearrangement of information so that the species name and age were most prominent, followed by the shade and oxygen information, plus any other benefits information, and the tree ID number being less prominent.
- The most liked element of the tree tags was the conversion of shade and oxygen amounts to the number of beach umbrellas and number of people per year, respectively. This seemed to make the information more readily understood by the general public with one lady commenting, “I get that!”
- Many people also liked knowing the tree name, with one lady commenting that people may see trees they want to “plant in [their] own garden but don’t know what it is; the tags help with this”.
- There were mixed opinions about the attachment method, with people either really liking the spinning element of the tags when hung from branches as it is “eye-catching” whilst others found this “distracting” and thought it made the information “difficult to read”.
- There was concern about the material used for the tags. Although the environmentally friendly element of the tags being made from recycled material was good, a number of people mentioned their concern about the tags being vandalised. More permanent material, fixture methods, and display locations were discussed as possible solutions to help avoid vandalism.
- There were also comments that better marketing around what the tree tags are would be good, as this would help draw people’s attention to them and make them seek them out and go and read them. This seemed largely to be targeted towards adults who would otherwise potentially notice the tags but not bother to go out of their way to read them; compared to the children surveyed who were naturally drawn to the tags as something unusual in the environment to explore, with one child commenting that, “when you see them you know they’re something special so you go and have a look”.

If generating additional tags for urban trees, the City of Unley may wish to consider the specific suggestions provided in response to the question “is there anything you would change about [the tags]”. Note these suggestions have been ordered in to similar response categories.
**Design**

- Not bright enough
- Perhaps brighter colour
- Colour - white rather than yellow
- Making them more bright would make them more visible
- Make the tags bigger
- Colour-code tags by significant tree or tree species
- A bit busy in oxygen and shade boxes
- Perhaps reorder so tree name and age more prominent, then shade and oxygen amounts, other services (e.g. hollows), and ID # less prominent
- Make titles smaller so can fit more information
- Better marketing of tree tags
- Needs to draw in more people

**Attachment method**

- Attached differently - higher away from vandals
- Could be potentially vandalised - consider another method of attachment/material
- Attachment method - spinning is annoying
- Spinning makes it difficult to read

**Information**

- Information about caring for trees rather than them being a nuisance
- Is it native or not?
- Other uses e.g. climbing, hollows
- Both sides with information about the tree

Other general quotes about the tree tags provided by people surveyed are as follows:

- "Would like to see more especially where there are children and in parks"
- "Get young ones involved from an early stage"
- "Good for kids"
- "Good for educating kids easily"
- "Not enough taught in schools"
- "Great educational tool for kids"
- "Be great to involve kids if around schools - perhaps include more pictures for younger kids"
- "Definitely need more tags around schools/libraries"
- "Target certain areas and bigger trees for other tags"
- "Good to have a figure...people can relate to easily"
- "Fun for people to see/recogise"
- "Year 4's [at Burnside Primary] are learning about animal habitats...including trees...these would be really good"
- "Make a map of trees publicly available to help increase awareness when development occurs"
- "Perhaps let kids name them, like 'Big Borris'"
- "I think all councils should do something like this"
- "Helps the community value them more"
- "Makes people appreciate trees"
- "Need signs to explain what the tags are"
- "Before I thought [that tree] was old and ugly but after reading the information on the tag I don’t think that anymore...yes, I will view other trees differently now"
## TREE SURVEY

Please circle the response that best characterises how you feel.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees are important in urban areas</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>We need more trees in the City of Unley</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>We should plant more trees on public land</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>We should plant more trees on private land</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I would plant trees on my property if incentives were provided</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I think some on-street parking space should be used to plant more trees</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I think some public grassed areas (not sporting fields) should have more trees.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Can you list some benefits provided by trees?

- 
- 
- 

Do you have any other comments about trees in urban areas?

- 
- 

### About you

- **Are you (please circle):**
  - Male
  - Female

- **Your age is (please circle):**
  - <20
  - 20-31
  - 32-51
  - 52-70
  - >70

- **What suburb do you live in?**

- **Have you noticed the tree tags today?**
  - Yes
  - No

**THANK YOU**
Attachment B. Tree tag survey questions and images of tree tags

<table>
<thead>
<tr>
<th>M</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did you notice the tree tags?</td>
<td>Did they make sense to you?</td>
</tr>
<tr>
<td>Did you learn anything new/interesting?</td>
<td></td>
</tr>
<tr>
<td>What did you like most about them?</td>
<td></td>
</tr>
<tr>
<td>Is there anything you would change about them?</td>
<td></td>
</tr>
<tr>
<td>Would you like to see more on urban trees?</td>
<td></td>
</tr>
<tr>
<td>Other comments</td>
<td></td>
</tr>
</tbody>
</table>

Example of tree information provided on tree tags (photo credit: J. Garden)
The four slogans provided on the back of tree tags (photo credit: J. Garden)