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ENHANCING THE BENEFITS OF THE TREES ON CAMPUS

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Acknowledgements
This project was funded by United Bank of Carbon, the University of Leeds Sustainability Service, the University of Leeds Living Lab programme, and the Woodland Trust.

Our thanks go to Thom Cooper (Sustainability Service), Glenn Gorner (Leeds City Council), and Joe Coles (Woodland Trust). In addition, thank you to Kenton Rogers and Keith Sacre of Treeconomics, for training the core team in tree surveying techniques and in the use of the i-Tree Eco software and to all volunteer tree surveyors who measured every tree on campus over two summers (see page 53).

Document: i-Tree Report 2019 v1.42
Date: 26th July 2019

This report should be cited as: Gugan et al., 2019, 'University of Leeds: Enhancing the Benefits of Trees on Campus', by United Bank of Carbon & Leeds Ecosystem, Atmosphere and Forest Centre, University of Leeds.

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The main university campus and study area
High Resolution (25cm) Vertical Aerial Imagery [JPG geospatial data] Scale 1:500, Tile [se2934] Updated 5 November 2017, Getmapping Using: EDINA Aerial Digimap Services, <http://digimap.edina.ac.uk> Download:2019-02-19
0
50
100
150
200
250
300
350
400
450
500 m
Projection: British National Grid

1 FOREWORD

Piers Forster

Director of the Priestley International Centre for Climate
Professor of Physical Climate Change, University of Leeds
Trustee of the United Bank of Carbon

The world is waking up to the challenge of climate change but remains on course for 3˚C or more of global warming by the end of the century. If we are able to get the world on a path to 1.5˚C, we will save billions of people from extremes of heat and save thousands of plant and animal species from extinction.

Trees are the best technology we know for removing carbon from the atmosphere; preserving existing trees and growing more of them is a vital part of the solution. They also remove air pollution, help alleviate flooding and improve our mental health. Putting the world on the right path begins at home with evidence-based practical action. While growing any trees help, the right tree in the right place is better. The work done by the United Bank of Carbon team shows how important our campus trees are. Covering 17.2% of campus, they store an estimated 540 tonnes of carbon and absorb pollution emitted from around 1 million cars passing the University. Campus trees are working to protect us from ourselves. By saving the bigger ones and planting new ones they could be doing even more.

The Parkinson Building

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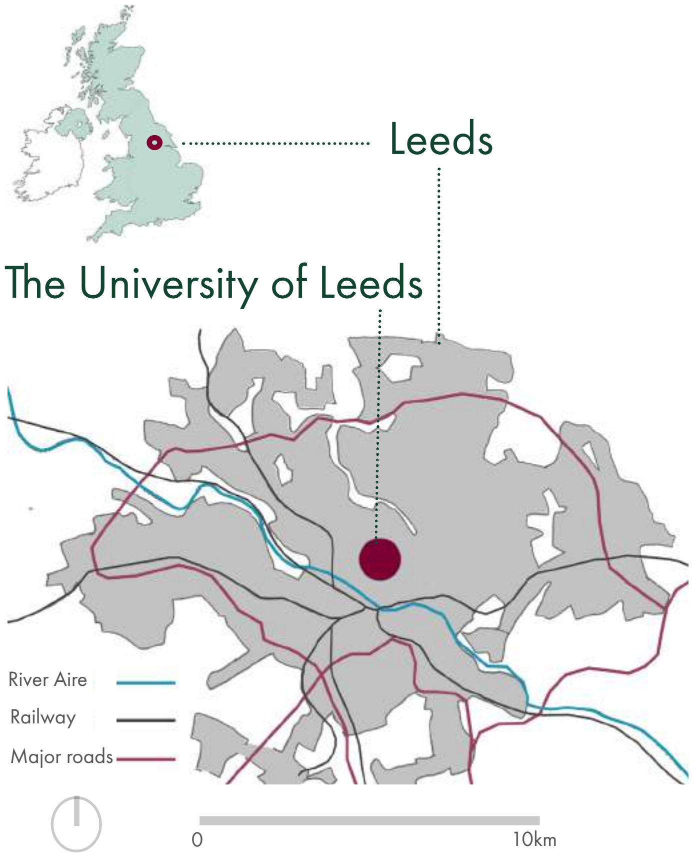
2 EXECUTIVE SUMMARY

The University of Leeds provides a place of study and work for over 46,000 people.[1] This community of students and staff (equivalent to the population of a small town) is in a compact space of 40 hectares.[2] A key challenge in such a dense urban setting is to provide a meaningful valuation of trees as urban assets to inform planning and decision making.

The trees on the main campus[3] were measured over the summers of 2017 and 2018 by teams of trained volunteers from the University community. Using natural capital valuation tools*, the main aims of the study are to calculate environmental benefits, (also known as ecosystem services) provided by the trees on campus, with an estimate of the economic value of those benefits.



Results

The 1450 campus trees store an estimated 540 tonnes of carbon (equivalent to the annual carbon footprint of 180 people in the UK).[4] The largest 100 trees, 7% of all the trees, provide around a third of the environmental benefits of carbon storage, sequestration and pollution removal. There is a good mix of tree species on campus for resilience. The overall tree canopy cover is 17.2%,[5] but most of the canopy cover is found in a few key areas of green space, such as St George's Field.

Recommendations

- To plant large stature, long lived trees where large soil volumes are available.
- To protect the existing mature tree stock, through a continuation and adoption of good practice measures in tree care and management.
- To increase the percentage tree cover from the existing 17.2% to a minimum of 20%.
- To increase resilience of the urban forest by planting no more than 5% of a single species, 10% of any genus and 20% belonging to the same family.

* *see glossary page 50*

2 EXECUTIVE SUMMARY

1450

trees on campus surveyed

Campus tree coverage is[5]

17.2%

with 137 different species identified

20% tree coverage is recommended by Forest Research for urban areas.[6]
City of Leeds 17.4% using i-Tree Canopy
Mean urban canopy cover 16.4% England[6]

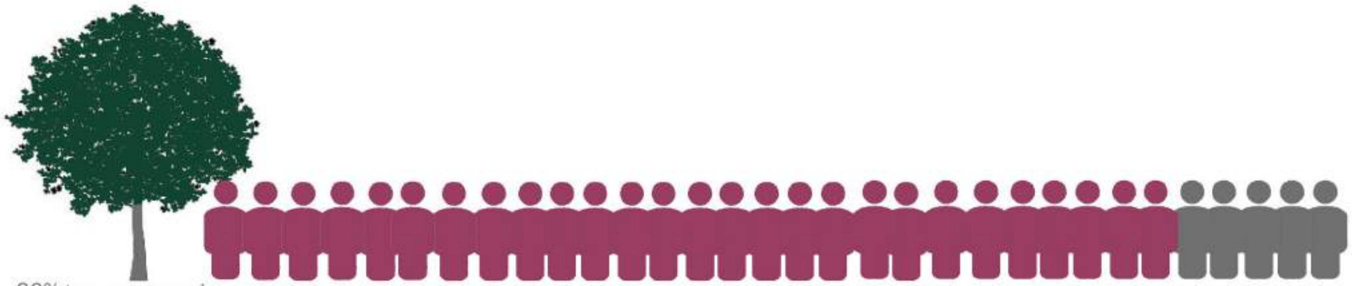


Figure 1: One tree to every thirty two people on campus

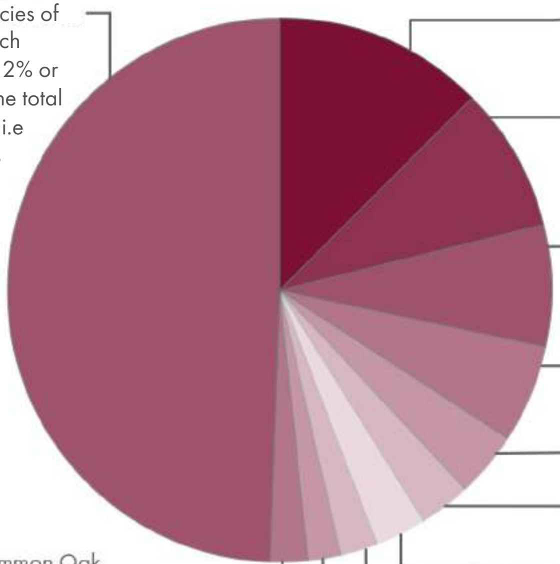


Figure 2

The trees on the main campus:

Carbon stored* (tonnes)	Estimated value carbon stored^	Equivalent to
540	£126,800	Annual carbon footprint of 180 people per year§
Carbon sequestered* (tonnes/year)	Value carbon sequestered^ (per year)	Equivalent to
18	£4,200	Annual carbon footprint of 6 people per year§
Pollution removed* (kg/year)	Value of pollution removed (range)¶ (per year)	Equivalent to
143	£3,800 (£700 - £12,000)	Annual journeys for 125 diesel cars or 1 million car journeys past the University (NO_x only)"
Runoff avoided (metre /year)*	Estimated costs avoided (per year)~	Equivalent to
550	£840	Water in one and a half 25m swimming pools.+

Table 1: The summary values of the trees on the main campus. * Estimated value calculated using i-Tree Eco using a complete coverage survey (Pollution figure is $PM_{2.5}$, NO_2 and SO_2 combined).[7] ^ UK Government's carbon valuation for 2018 £66 per tonne.[8] §Average carbon foot print for a UK citizen is estimated to be 11 tonnes of CO_2 per annum.[4] ¶ Central Estimate UK Social Damage Costs for Pollutants for Transport Inner Conurbation 2019 for $PM_{2.5}$, NO_x and SO_2 combined (range is low-high sensitivity), see section 3.4. "Assuming Euro5 and Euro6 emission standard[10] driving the 0.8km section of Woodhouse Lane by the University. ~ £1.61/m³ ~2017 Yorkshire Water sewerage volumetric charge with 5% discount for water not requiring treatment £1.53/m³.[11] + Assuming average depth of 1.5 metres and a width of 10.5 metres[12]

Chancellors Court

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3.1 PROJECT AIMS

Project context

The assessment of the trees on the main campus is part of a wider study including:

- This project of the trees on the main campus based on measuring every tree (complete coverage), using i-Tree Eco* and four other natural capital evaluation tools.
- In Middleton Park ward in Leeds, a project based on sample plots using i-Tree Eco and CAVAT.
- A city wide assessment of tree canopy cover of Leeds, by ward areas, using i-Tree Canopy.

The University of Leeds Landscape Development Plan, published in December 2018, had three key aims including campus to "be an exemplar of urban biodiversity".[14]

Project aims

1	Calculate the environmental benefits, also known as ecosystem services, provided by trees on the main campus
2	Calculate an estimated monetary value of the ecosystem services
3	Use this project as a pilot study for an ecosystem services valuation for the trees of the city of Leeds
4	Engage students, university staff and members of the public in valuing the trees on campus
5	Communicate the results to inform policy and to review the impact of the study

* *see glossary page 50*

3.2 CARBON STORAGE

How much carbon is stored in the trees on the main campus?

	Number of trees (%)	Carbon* (tonnes)	Carbon dioxide¶ (tonnes)	Carbon stored (%)	Estimated value of carbon stored^ (£)	Equivalent to the annual carbon footprint of§ -	Average trunk diameter (cm)
All 1450 trees	100	540	1980	100	£127,000	180 people	30
The top 100 trees	7	185	680	34	£43,500	61 people	78

Table 2: Carbon stored in the trees on main campus

*Estimated value calculated using i-Tree Eco using a complete coverage survey.[7] ^UK Government's carbon 2018 valuation £66 per tonne.[8] §Average carbon foot print for a UK citizen is estimated to be11 tonnes of CO_2 per annum. [4] ¶Carbon dioxide equivalent of carbon (a factor of 3.67).

The IPCC report in October 2018 highlighted the importance of capping the global temperature increase to 1.5°C above pre-industrial levels.[15] Rapid reduction of carbon emissions is required, but global CO_2 emissions continue to rise. Additional means of extracting carbon from the atmosphere are therefore a priority. Trees can make a positive contribution to the IPCC's aims, because they take carbon dioxide from the atmosphere and store carbon as they grow, forming biomass.

The total amount of carbon stored in the trees surveyed is estimated by i-Tree Eco software to be 540 tonnes which is valued at almost £127,000 based on the UK Government's valuation of the social cost of carbon dioxide at £66 per tonne. Of the 1450 trees, the top 100 trees, which are 7% of the trees on campus, store over one third of all the carbon in the study.

Analysis by species shows the top three tree species for carbon storage are Sycamore, Common Lime and Ash trees (Figure 4). Together, they store 47% of the carbon in the campus survey but form only 29% of the trees (418 out of 1450 trees). This difference reflects the relatively large size of these trees (Figure 3).

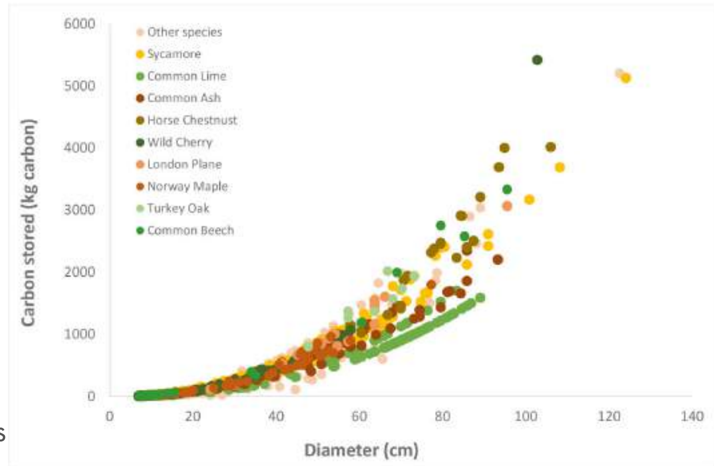


Figure 3: Carbon storage by trunk diameter at 1.3 m

3.2 CARBON STORAGE

Carbon stored by species

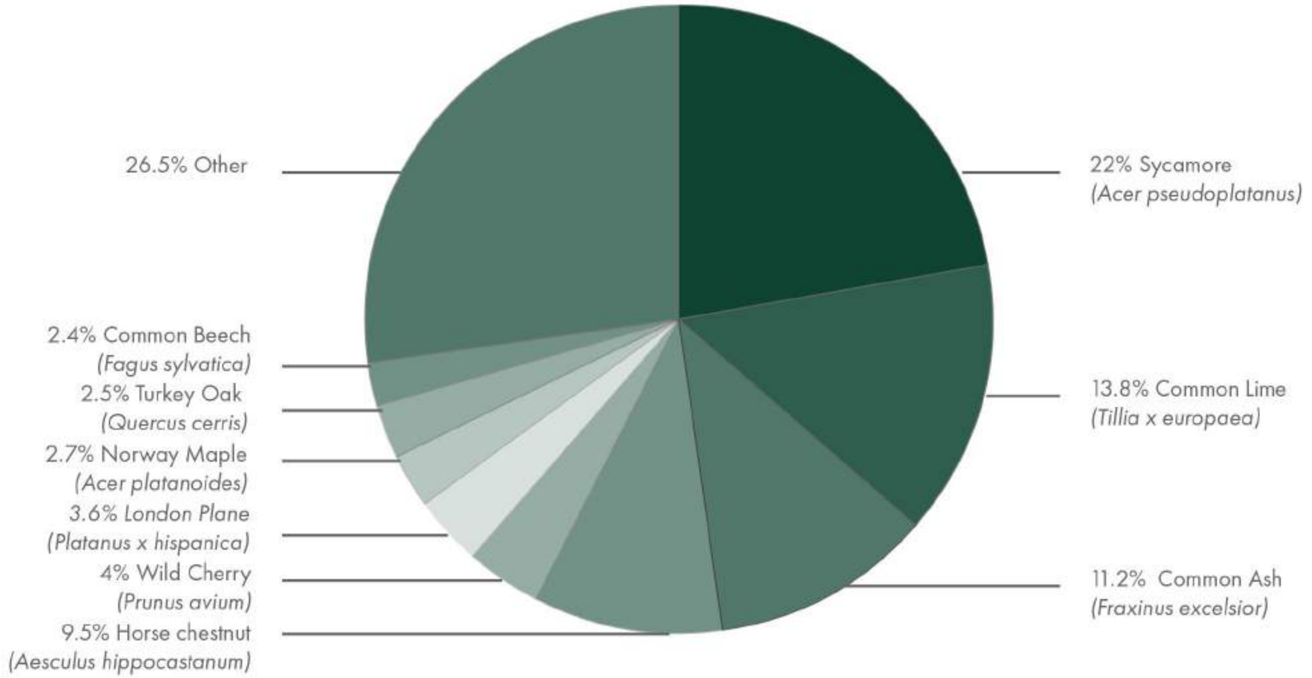


Figure 4: Carbon storage by species

Recommendations

- To plant large stature, long lived trees where large soil volumes are available.
- To protect the existing mature tree stock, through a continuation and adoption of good practice measures in tree care and management.
- To increase the percentage tree cover from 17.2% to a minimum of 20% so more carbon can be stored.
- To consider the use of the trees at the end of their lives because the stored carbon would be released if the wood is burned but will be contained for the long term if it is used for furniture or building.

3.3 CARBON SEQUESTRATION

How much carbon is sequestered by the trees on the main campus?

	Number of trees (%)	Carbon * (tonnes)	Carbon dioxide ¶ (tonnes)	Carbon sequestered (%)	Estimated value of carbon sequestered^ (£)	Equivalent to the annual carbon footprint of§ -	Leaf biomass* (kg)	Leaf biomass* (%)	Average leaf biomass * (kg)
All 1450 trees	100	18	66	100	£4,200	6 people	24700	100	17
The top 100 trees	7	5	18	28	£1,100	2 people	6600	27	66

Table 3: Carbon sequestered annually in the trees on main campus

*Estimated value calculated using i-Tree Eco using a complete coverage survey.[7] ^UK Government's carbon 2018 valuation £66 per tonne.[8] §Average carbon foot print for a UK citizen is estimated to be 11 tonnes of CO_2 per annum.[4] ¶Carbon dioxide equivalent of carbon (a factor of 3.67).

As trees grow they take carbon from the atmosphere and convert it into biomass. This process is called sequestration and is assessed in i-Tree as an annual benefit. How much trees sequester depends on the species of tree.[16] Trees also sequester carbon at different rates over their life time.[16] The trees surveyed sequester approximately 18 tonnes of carbon per year (gross sequestration). This carbon removal, which has an estimated value of £4,200 per year, assumes a social cost of carbon dioxide of £66 per tonne[8].

The top 100 trees for carbon sequestration take in 5 tonnes of carbon annually. These trees sequester 28% of the total carbon demonstrating that the biggest trees on campus are sequestering a large amount of carbon.

Of all the trees surveyed, the Sycamore sequester more carbon than any other species sampled, approximately 13% of all the carbon sequestered (Figure 6). As with carbon storage data, the larger trees tend to sequester carbon at a greater rate than the smaller trees (Figure 5).

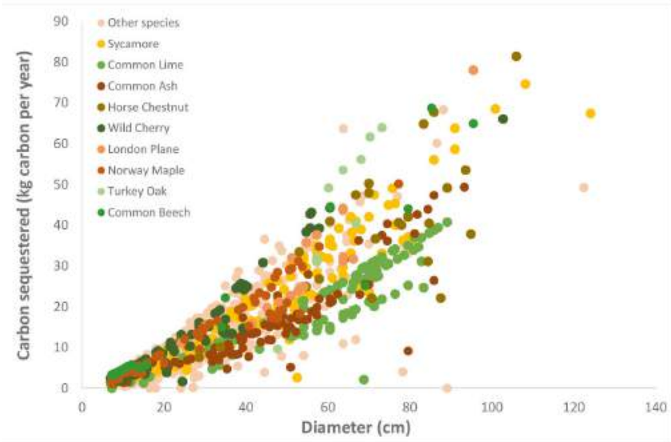


Figure 5: Carbon sequestered by trunk diameter at 1.3m

3.3 CARBON SEQUESTRATION

Carbon sequestered by species

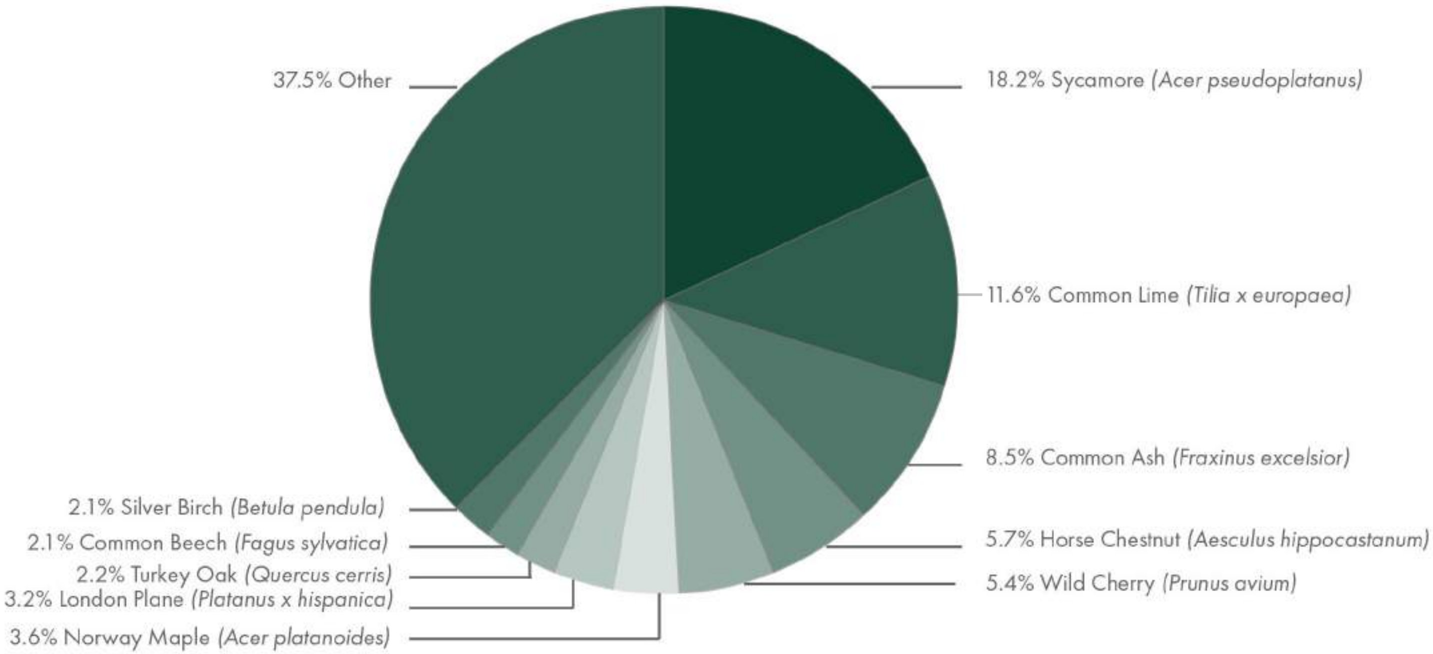


Figure 6: Carbon sequestered by tree species

Recommendations

- To plant long lived trees of large stature.
- To protect the existing mature tree stock, through a continuation and adoption of good practice measures in tree care and management.
- To increase the percentage tree cover from 17.2% to a minimum of 20% so more carbon can be sequestered.

3.4 AIR POLLUTION MITIGATION

How much pollution is removed by the trees on the main campus?

	Pollution removed* (kg/year)	Value of pollution removed¶ Central damage costs (figures in brackets denote the low-high sensitivity) (£)
Particulate matter $PM_{2.5}$	7	**£2,945** (£614 - £9,078)
Nitrogen dioxide NO_2^	124	**£769** (£79 - £2,873)
Sulphur dioxide SO_2	12	**£75** (£18 - £214)
Ozone O_3	210	
Carbon monoxide CO	4	

Table 4: Pollution removed by the trees on main campus

¶ Calculated using central estimate, low and high values for UK Social Damage Costs for Pollutants for Transport Inner Conurbation 2019 values.[9] No UK social damage cost for O_3 or CO. *Estimated value calculated using i-Tree Eco using a complete coverage survey.[7] ^ Value of NO_2 using Social Damage Costs for NO_x and therefore likely to be an underestimate.

Air pollution impacts the health of the urban population, particularly children, pregnant women, the elderly and those with respiratory and cardiac health problems.[17] Legal limits on air quality pollution levels are set by national[18] and European legislation[19], although there is no safe limit for air pollution for the whole population.[17] High levels of nitrogen dioxide (NO_2) pollution resulted in the UK Government mandating that a Clean Air Zone should be introduced, in Leeds. Here, the value of pollution removed by trees has been quantified using social damage costs published by the UK Government (see page 41). These damage costs take into consideration the damage to human health as well as buildings and ecosystems.[9]

Trees can help to mitigate the impacts of air pollution by absorbing pollution through the stomata in their leaves and by particles being deposited on the surface of the leaf and bark.[20] Large trees have a greater impact on pollution because of the greater leaf area they have available to intercept gases and particles.[21] The precise impact of the trees on the pollution depends on many factors including the season (Figure 7), the amount of rainfall, the design of the street and the tree species. Trees provide most benefits when there is large leaf area for pollution removal, as well as good air movement.[22]

The total amount of NO_2 pollution absorbed by the trees on campus is 124 kg per year, which is the equivalent of approximately one million cars[10] driving up the 0.8 km section of the Woodhouse Lane which forms the eastern boundary of the University.

3.4 AIR POLLUTION MITIGATION

How much pollution is removed by the trees on the main campus?

The top 100 trees

The top 100 trees for air pollution mitigation removed 31% of all the pollution removed annually by the trees surveyed.

$PM_{2.5}$
- All trees: 7 kg per year
- Top 100 trees: 2 kg per year (£920)[9]

NO_2
- All trees: 124 kg per year
- Top 100 trees: 39 kg per year (£240)[9]

SO_2
- All trees: 12 kg per year
- Top 100 trees: 4 kg per year (£23)[9]

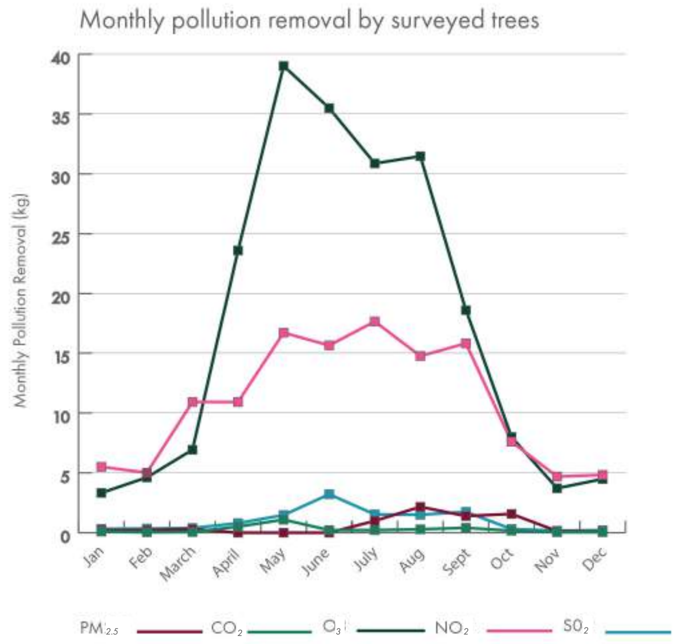


Figure 7: Monthly pollution removal showing seasonal effect of deciduous trees

Recommendations
- To consider the street design of the polluted areas on campus to ensure good air circulation and appropriate vegetation for pollution removal.
- To incorporate in the design long lived trees, with large crowns and large leaves.
- To include large evergreen trees near pollution hotspots for pollution removal all year.
- To ensure large trees have appropriate soil volumes and water to maximise tree size and environmental benefits.

Since the survey, this tree (CL106) has had the crown removed. It was the third best tree for pollution removal on campus.

3.4 AIR POLLUTION MITIGATION

Campus map of air pollution

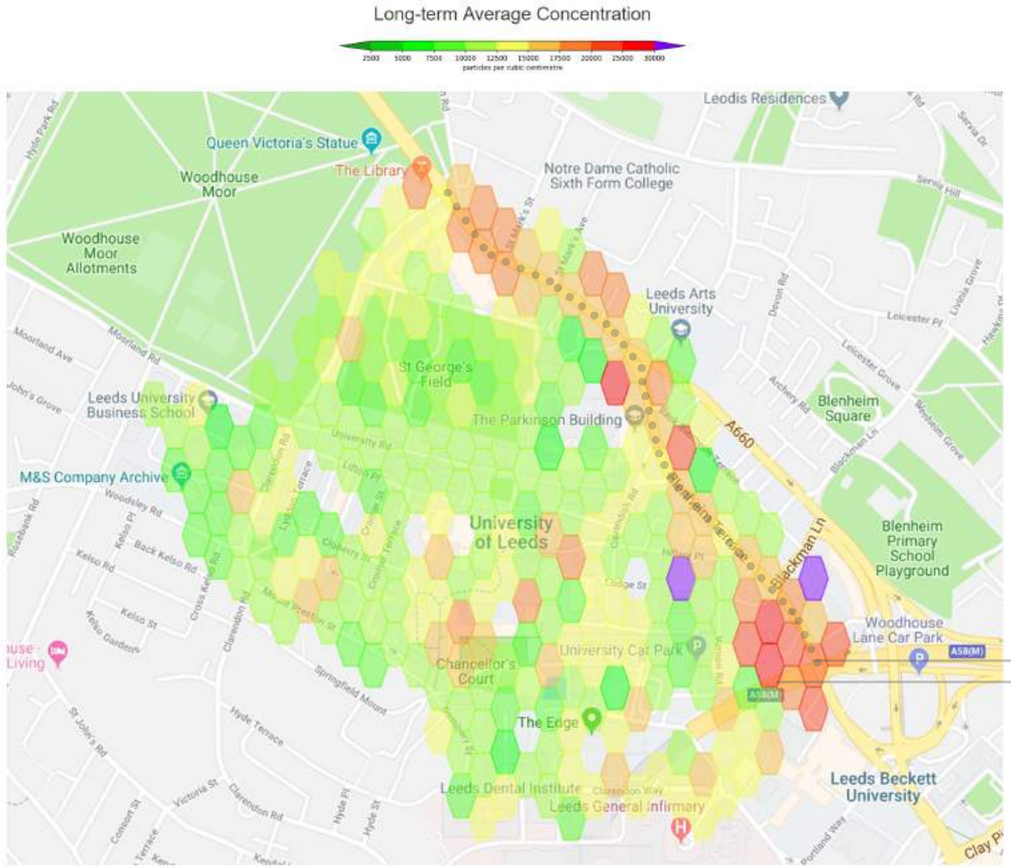


Figure 8: Campus map of air pollution [23]

The Living Lab for Air Quality[24] is a University of Leeds project where staff and student volunteers regularly walk around campus with portable monitors to map air quality. The results of all the data collected during 2018 is combined into this map. The aim of the project is to understand how pollution levels vary across campus.

The 0.8 km section of Woodhouse Lane forming the east boundary of the University.
The trees on campus remove 124 kg of NO_2 per year.
Equivalent to:
Euro5 emissions standard (0.18 g/km)
860,000 cars or
1,937,500 cars at
Euro6 emission standard (0.08 g/km).[10]

Woodhouse Lane
New Nexus building

3.5 RUNOFF PREVENTION

How much rainfall water is intercepted by the trees on the main campus?

	Number of trees (%)	Runoff prevented* (m^3)	Runoff prevented (%)	Estimated costs avoided~ (per year)	Volume equivalent+
All 1450 trees	100	550	100	£840	1.5 x 25m swimming pool
The top 100 trees	7	170	31	£260	0.5 x 25m swimming pool

Table 5: The estimated amount of water intercepted by the trees on campus, preventing surface runoff.
*Estimated value calculated using i-Tree Eco using a complete coverage survey[7].
+Assuming average depth of 1.5metres and a width of 10.5 metres.[12]
~Assumming 2017 Yorkshire Water sewerage volumetric charge with 5% discount for water not requiring treatment £1.53/m^3.[11]

Unpredictable changes to rainfall is one of the consequences of climate change, which increase the risks of flood events .[25] The University of Leeds Campus Development Plan[14] includes Sustainable Urban Drainage Systems to slow the flow of storm water and reduce the impact of sudden heavy rain.

The trees on the main campus contribute to the reduction of surface water, by intercepting rainfall. Every year approximately 550 m^3 of water is intercepted by the trees surveyed, which is equivalent to one and half 25 m swimming pools of water.[12] The top 100 trees for runoff prevention remove 170 m^3 of water which is 31% of the total estimate runoff prevented.

Recommendations

- To use trees that can cope with wet conditions, such as Alder (*Alnus glutinosa)*, as part of the Sustainable Urban Drainage Systems.
- To plant long lived trees, with large crowns, large leaves and heavily rutted bark for rainfall interception.
- To ensure large trees have appropriate soil volumes and water to maximise tree size and environmental benefits.

3.6 URBAN FOREST RESILIENCE

What is the composition of the trees on the main campus?

The resilience of the urban forest on campus depends upon the age, condition and species mix of the trees on campus and in the wider urban forest.[26] The urban environment has additional stresses for trees including the higher temperatures, reduced soil volumes, soil compaction and reduced access to water.[27] Healthy trees can be attacked by pests and diseases, so the additional stresses of the urban environment make the campus trees more vulnerable.[28]

Native trees versus planting for resilience

The risk to the urban forest can be reduced by using a mixture of species prioritising natives[29] but including regionally appropriate non-natives trees with a planting mix of no more than 5% of a single species, 10% of any genus and 20% belonging to the same family.[30] This planting formula has been adopted by the city of Melbourne where the urban stress and the pressure of climate change on the city's temperatures has reduced the life expectancy of the city's urban forest. Since 2012, a strategy for improving the tree canopy cover to 40% with increased tree resilience has been implemented in Melbourne.[30]

Species near or > 5%	No.	%	Genus near or > 10%	No.	%	Family near or > 20%	No.	%
Sycamore *Acer pseudoplatanus*	185	12.7	Maple *Acer*	288	19.8	*Aceraceae*	288	19.8
Common Lime *Tilia x europaea*	124	8.5	Lime *Tilia*	181	12.5	*Rosaeceae*	270	18.6
Common Ash *Fraxinus excelsior*	108	7.4	Cherry *Prunus*	141	9.7			
Wild Cherry *Prunus avium*	84	5.8						
Total	501	34.4		610	42.0		558	38.5

Table 6: The trees on campus that are near or breech the planting for resilience formula.

Native trees

Using the Woodland Trust's classification of native trees[29], 47% of the trees on campus were classified as native species. Some native species, such as Yew (*Taxus baccata*) and quaking Aspen (*Populus tremula*), were not found on campus (as trees rather than hedging).

3.6 URBAN FOREST RESILIENCE

There are 137 different species on campus. Nearly half of the tree population is made up of species in low numbers (28 trees or less). Figure 9 shows the distribution of the tree population by tree trunk diameter. Only 6 trees have a trunk diameter in the highest two categories (100 to 130cm).

The University maintenance team has an active planting and management programme for the campus landscape.[31] This active management programme is reflected in the high number of young trees in the trunk diameter class distribution (45% in the 0 to 30cm class). Analysis of the small trunk diameter size trees (30cm or less) shows that 41% (357 out of 877) were tree species that should eventually grow to large trees.[32]

Figure 9: Tree trunk diameter at 1.3m from the ground

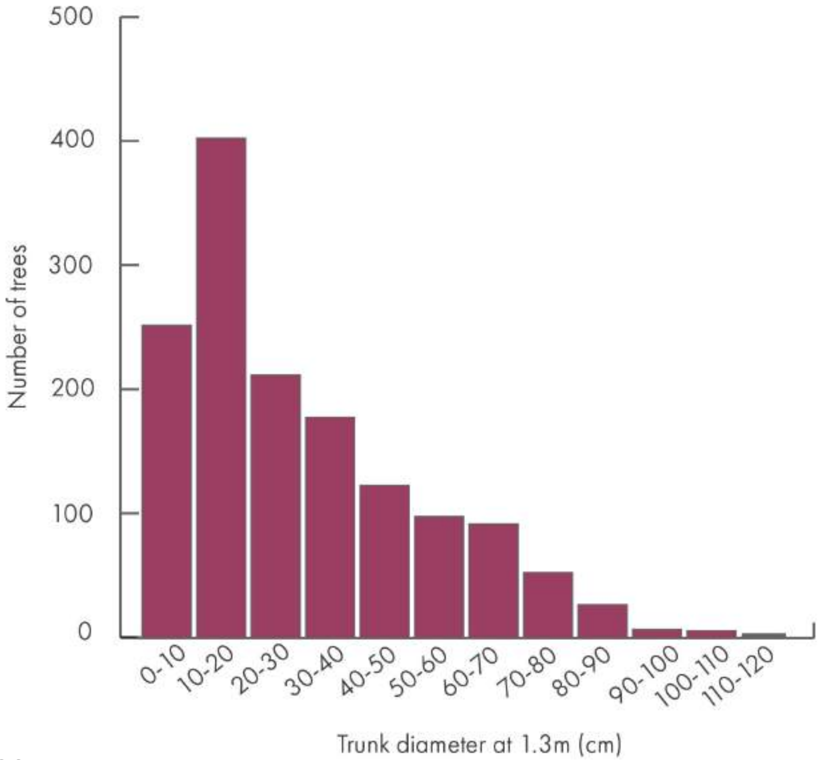
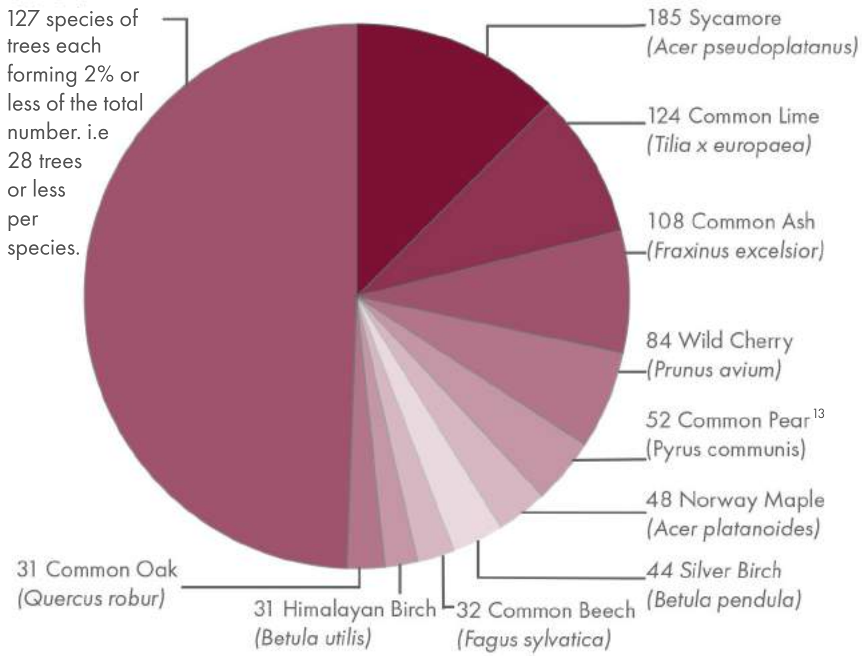


Figure 10: The most common species of tree on campus and the numbers recorded



3.6 URBAN FOREST RESILIENCE

The condition of the trees

Almost 80% of the trees on campus were classified as excellent or good category (1,143 trees), which is a positive reflection of the maintenance programme on campus.

Condition	No. of trees	%
Excellent	684	47.2
Good	459	31.7
Fair	209	14.4
Poor	75	5.2
Critical	12	0.8
Dying	6	0.4
Dead	5	0.3
Total	1450	

Table 7: The condition of tree on campus

Pest and disease impacts

Two current threats to Ash trees could lead to the loss of 8% of the trees on campus; Chalara Ash die back and the spread of the Emerald Ash Borer from Europe.[33]

The Ash trees (*Fraxinus sp.*) on campus are relatively mature and already large in stature (Figure11), so their loss would impact the delivery of environmental benefits of the campus trees significantly. These Ash trees currently store around 61 tonnes of carbon, sequestering 1.6 tonnes annually; an equivalent of the annual carbon foot print of approximately twenty people.[4] The carbon stored has an estimated value of £14,400.

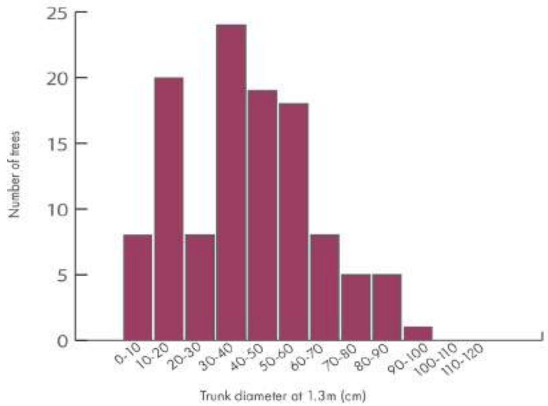


Figure 11: Diameter at 1.3m of Ash tree trunks

Recommendations

- To follow the example of the city of Melbourne's strategic approach to the urban forest and increase the tree canopy coverage to ambitious levels, as well as improving the health and life expectancy of existing trees to help mitigate the impact of climate change.
- To plan for the potential loss of 8% of the campus trees because of Chalara Ash die back.
- To increase resilience of the urban forest by planting no more than 5% of one species, 10% genus and 20% family.
- To pro-actively manage the trees to ensure the percentage of large trees increases; i.e. so the young and semi-mature trees reach maturity, and beyond.

3.7 PUBLIC PERCEPTION OF URBAN TREES

What do people value most about urban trees?

Four studies have considered the public perception of urban trees:

- The Woodland Trust interviewed 2,400 people in 8 cities[34] and found that people living in urban areas had a strong connection to their local trees. They found that street trees divided opinion with the leaf litter and damage to pavements as an issue the public disliked. Overall, however, "80% of those surveyed strongly agree that trees and woods give colour and texture to cities and towns".[34]

- The Public Opinion of Forestry Survey by the Forestry Commission questioned 1,685 people in England in 2009. "Providing a place for wildlife to live" (80% of respondents) was the highest scoring reason for spending public money on forestry. 77% of those surveyed had "visited forests or woodland in the last few years". Of those people, more had visited "woodlands in the countryside" (84%) than visited "woodlands in and around towns" (61%).[35]

- Birch[36] questioned 156 people at Leeds University about the campus green space, with some specific questions about trees. The study considered the natural capital value of campus green space using the ORVal[37] software (see section 4.1). More than half the participants preferred to see one large mature tree than a row of small trees.

- Mooney[38] considered the perceived financial value of trees, using i-Tree,[7] CAVAT[39] and by surveying 30 people on campus and in Middleton woods in south Leeds. Mooney asked if the value of trees should be monetised (Figure 13), and the majority of participants answered positively. The higher values participants assigned, however, reflected the amenity and aesthetic qualities of the trees (measured in CAVAT) rather than the regulating services provided by trees (such as pollution removal) assessed by i-Tree Eco. The survey respondents valued trees more highly than the financial benefits estimated by CAVAT or i-Tree Eco.

Results from the Woodland Trust survey

"78% strongly agreed that trees and woods have a positive effect on peoples health and well being.
75% agreed that trees and woods help our environment by reducing air pollution".[34]

3.7 PUBLIC PERCEPTION OF URBAN TREES

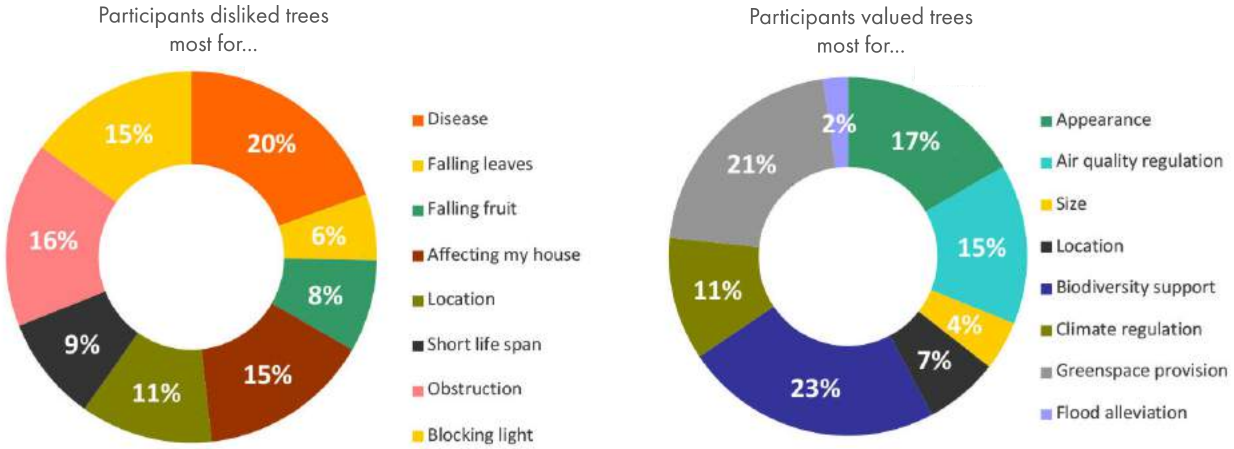


Figure 12: Participant's perspectives on factors that are most valuable and least valuable with regards to trees. (Extract from Mooney, 2019)[38]

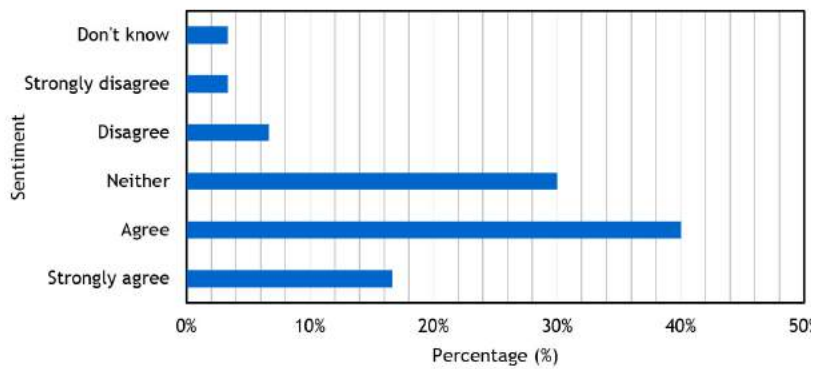


Figure 13: Responses to question "Trees should be given a financial value so that we can justify planting/felling/replacing." (Extract from Mooney, 2019)[38]

3.7 PUBLIC PERCEPTION OF URBAN TREES

Changing the language of urban trees from risk to value

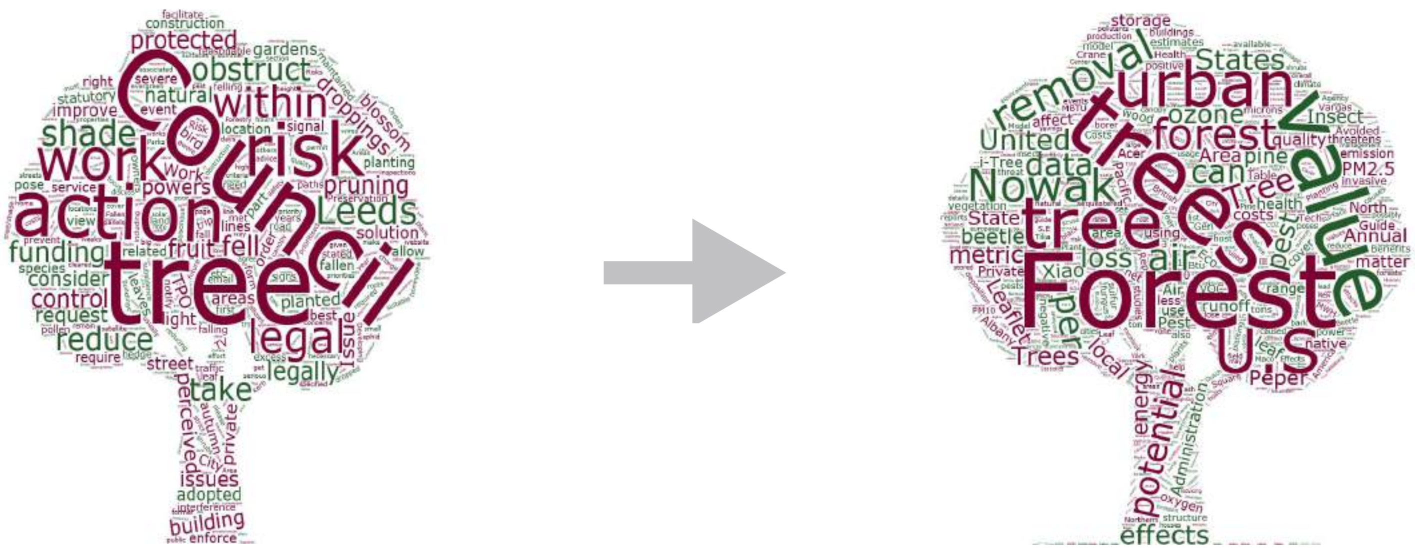


Figure 14: Leeds City Council receive around 4,500 request for work on council trees, or requests for removal, every year.[40] An advisory document [41] explaining what work will be carried out was used as the basis for the word cloud on the left. The i-Tree report for campus was also converted into the word cloud on the right, which highlights the more positive language around trees (*n.b.* the word "removal" refers to pollution removal).

Recommendations

- To use interpretation boards on campus to explain the benefit of urban trees to the public.
- To highlight the wider benefits such as carbon storage and the role trees play in mitigating climate change.
- To continue to engage the campus community, through events such as Light Night (see page 35), to explain the less well known benefits of trees.

The Maurice Keyworth Building, Leeds Business School

University of Leeds Image Library

4.1 ST GEORGE'S FIELD

How do the mature trees of St George's Field compare to the rest of the main campus trees?

	Trees	Trees (%)	Carbon stored* (tonnes)	Carbon dioxide (tonnes)	Carbon stored (%)	Value of carbon stored^ (£)	Equivalent to annual carbon footprint of§ (people)	Mean trunk diameter (cm)	Area (ha)
St George's Field	271	19	190	690	35	44,200	63	44	4
Campus trees outside St George's Field	1179	81	350	1300	65	82,500	118	22	36
All campus results	1450	100	540	1980	100	126,800	180	30	40

Table 8: The example of the trees in St George's Fields compared to the rest of the campus trees. *Estimated value calculated using i-Tree Eco using a complete coverage survey.[7] ^UK Government's carbon 2018 valuation £66 per tonne.[8] §Average carbon foot print for a UK citizen is estimated to be 11 tonnes of $C0_2$ per annum.[4] ¶Carbon dioxide equivalent of carbon (a factor of 3.67).

Large, mature trees dominate St George's Field in a park environment. The area was Leeds General Cemetery from 1835 but was landscaped into a park and opened to the public as an area for recreation in 1969.[42] The size and age of these trees results in a high level of environmental benefits provided; 9% of the area of campus containing 19% of the tree total yet providing 35% of the carbon stored. The average tree trunk diameter in St George's Field is double the average of the rest of campus (44 cm compared to 22 cm).

St George's Field in winter

The park environment provides the resources these trees need to thrive (good soil volumes, moisture and lack of soil compaction) so the environmental benefits are maximised, compared to a tree with restricted root zone and soil volumes in hard landscaping.[43]

Using the natural capital valuation tool ORVal[37], Birch[36] valued the amenity value of St George's Field at £230,000 per year. The density of the campus population led Birch to conclude this valuation maybe an underestimate. The students and staff that responded to the survey in the same study selected St George's Field as a preferred location to go to in good weather because it provided an "immersive experience".

St George's Field

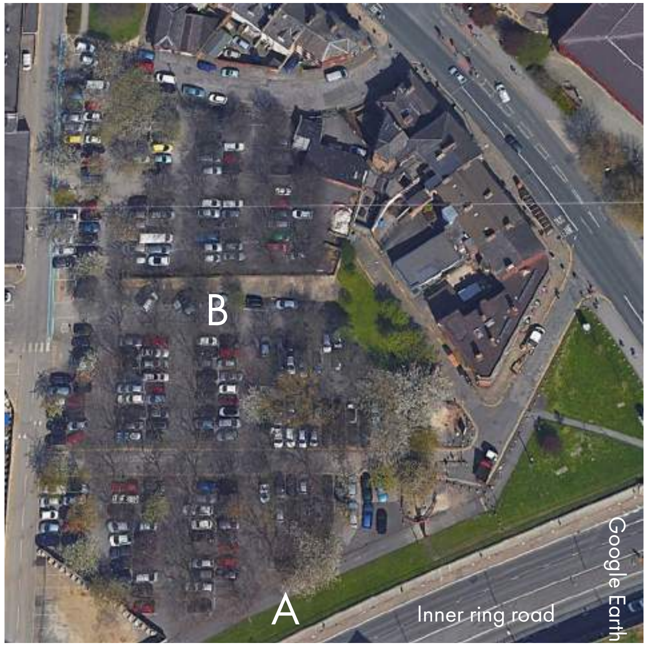
High Resolution (25cm) Vertical Aerial Imagery [JPG geospatial data] Scale 1:500, Tile [se2934] Updated 5 November 2017, Getmapping Using EDINA Aerial Digimap Services, http://digimap.edina.ac.uk> Download 2019-02-19

4.2 DEVELOPMENT ON CAMPUS

What are the impacts of campus developments on the trees?

The University of Leeds campus is a dynamic place with new buildings and landscape changes frequently occurring. The area to the south east of main campus was a car park with a canopy of Cherry and Maple trees. A new innovation and enterprise centre (Nexus) has replaced most of those trees. The area around the building has been re-landscaped with 105 trees replanted.[44] The planting plan is a mix of small trees, 58% of which are from the *Rosaceae* and *Acerceae* family which are the dominant families for the campus trees (see page 21 and Appendix iii). The largest three species of trees selected (*Carpinus betula* 'Frans Fontaine', *Tilia cordata* 'Steetwise' and *Quercus robur* 'Fastigiata') are column shaped with narrow crowns and a low leaf area index. This area is a pollution hotspot (see page 19) and where there are sufficient soil volumes (in area A) the selection of tree species with a large crown (including some evergreen varieties) could help to improve the air quality in the immediate area.

Before development; the screened car park



Before development; standing at place B

After development; standing at place A

4.2 DEVELOPMENT ON CAMPUS

Cooney[16] assessed the impact of development for two areas on campus[45] , in an MSc using the i-Tree data. A summary of the findings are outlined below, based on an assumption that all the trees in the area have to be removed.

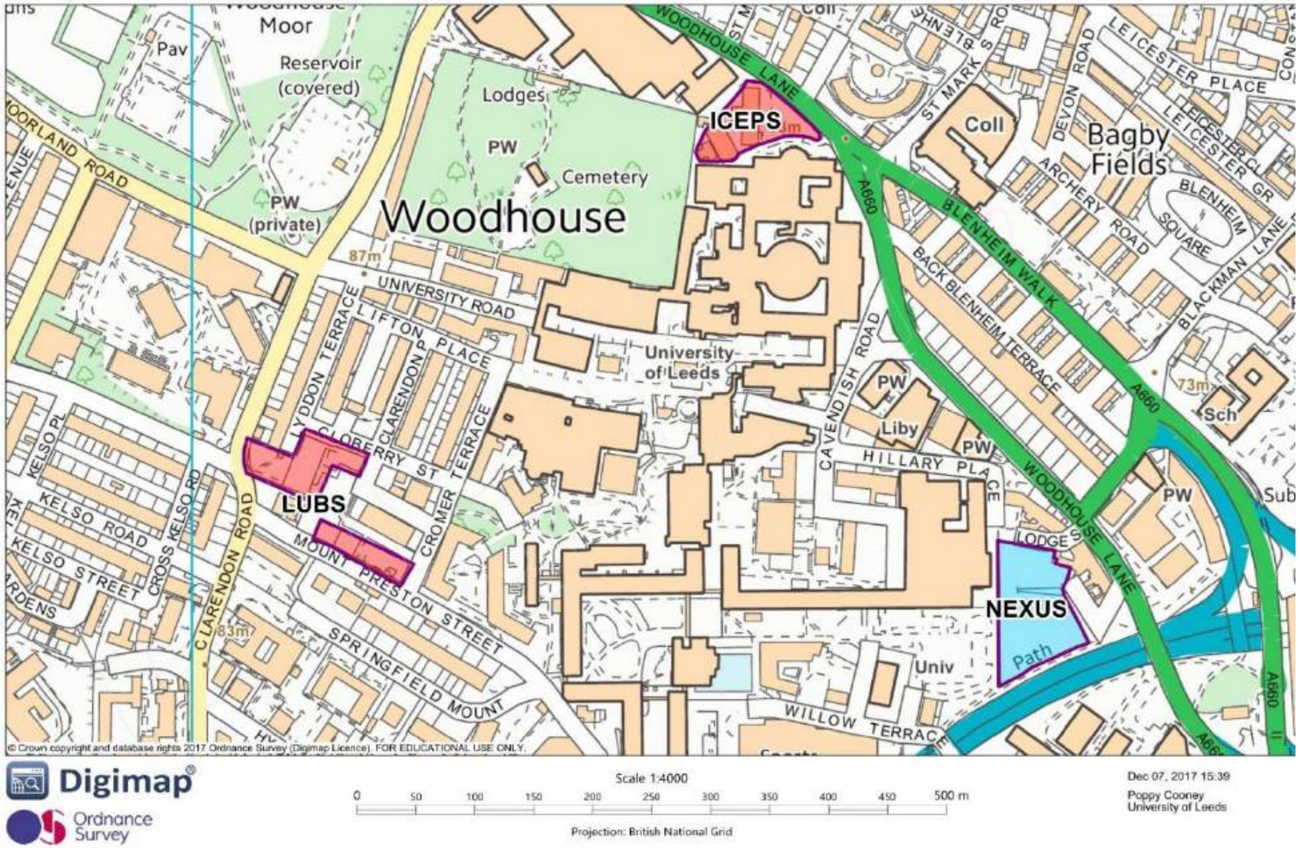


Figure 15: Map showing areas of development on campus(Extract from Cooney, 2018)[16]

Integrated campus for Engineering and Physical Science (ICEPS)

The 9 trees identified:

- approx. 3 kg pollutants removed annually
- around 120 kg carbon sequestered annually

The carbon stored was around 2,800 kg with an approximate value of £685.[8]

Leeds University Business School (LUBS)

The 16 trees identified:

- approx. 5 kg pollutants removed annually
- over 180 kg carbon sequestered annually

The carbon stored was around 4,300 kg, with an approximate value of £1,045.[8]

Figure 16: Impact of trees removed for development.(Extract adapted from Cooney, 2018).[16]

4.3 REPLACING THE BEECH TREE

Across the city of Leeds in the hot, dry summer of 2018, there was an increase in the damage and loss of trees from the effects of the fungi *Meripilus giganteus* and *Kretzschmaria deusta*.[46] The damage caused increases the risk of the trees becoming unstable, hence the requirement to remove them when the fruiting bodies of the fungi are identified.[47] One particular example on campus was a mature Beech tree behind the Student Union building. Measured before it was removed, it stored around £650 worth of carbon and was 22 metres high. Removal required a crane because of the compact environment.

The fungus on the Beech tree

The University has a policy of replacing removed trees with three new ones.[48] To meet the demands of space on campus and to enhance the pedestrian environment, newly planted trees are often small-stature and relatively short-lived specimens such as ornamental Cherries. The newly-planted trees do not immediately provide the same magnitude of benefits as large mature trees which they sometimes replace (Figure 16). There is also a time lag between the removal of the large tree and the growth to maturity of newly planted trees during which pollution absorption, carbon sequestration, and carbon storage are reduced, e.g. the largest Beech tree on campus (3 tonnes of carbon, value £780) stores one hundred times more carbon to compared to three replacements (0.03 tonnes value £6) using the measurements of the smallest Beech on campus (Figure 16).

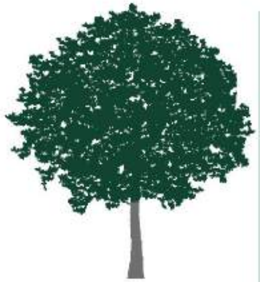
Cooney[16] modelled the growth rates of six tree species found on campus, and found that the quickest three newly planted trees reached the average annual benefit value for a single tree found on campus was 20 years for a Silver Birch (*Betula pendula*), and the average time was 25 years. Silver Birch is a short lived pioneer species of tree, compared to slower growing larger species such as Oaks (*Quercus sp.*) and Sycamores (*Acer pseudoplatanus*) which were only 15m high at 40 years growth using the growth rates used in Table 9. The greatest benefits in the longer term, Cooney concludes, are achieved by planting the slower growing larger trees (Figure 17).

Recommendations

- To protect the existing mature tree stock, through continuation and adoption of good practice measures in tree care and management.
- To investigate alternatives to open trenching around mature trees.[49]
- To consider existing large trees, when designing new buildings and developments on campus to minimise loss.
- To consider the use of the trees at the end of their lives to retain the stored carbon in the wood by using it for furniture or building rather than burning.

4.3 REPLACING THE BEECH TREE

The largest Beech tree on campus



- The tree dimensions are 25 m high with a trunk diameter (at 1.3 m) of 96 cm.
- Stores approximately 3 tonnes of carbon with an estimated value of £780
- Sequesters around 65 kg per year of carbon with an estimated value of £15

The three replacement Beech trees*

The combined totals for the three trees:

- The tree dimensions are 5.2 m high with a trunk diameter (at 1.3 m) of 7.3 cm.
- Store approximately 0.03 tonnes of carbon with an estimated value of £6
- Sequester around 10 kg per year of carbon with an estimated value of £2

**Based on field measurements of a newly planted Beech, also the smallest beech tree on campus.*

Figure 16: The environmental benefits of a mature Beech compared to three replacement trees.

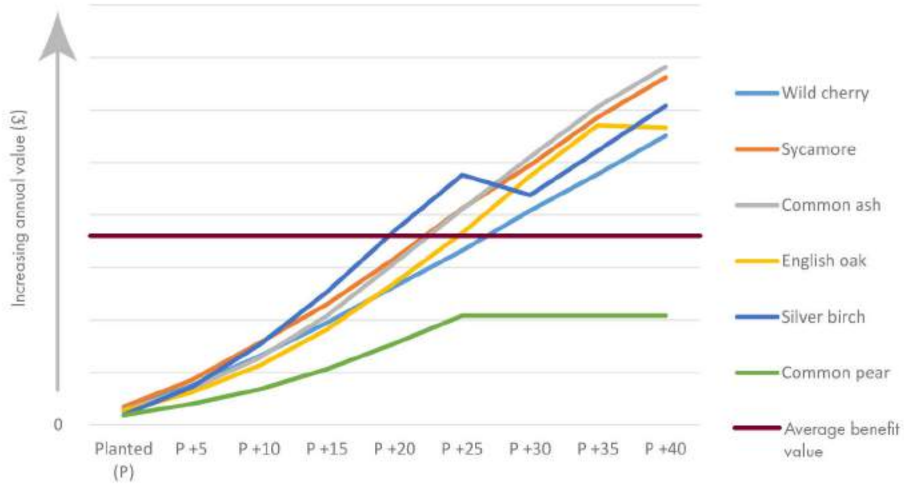


Figure 17: Total annual benefits of 3 planted trees at 5 year intervals for 40 years (Extract adapted from Cooney, 2018)[16]

Species	Growth rates: Diameter at 1.3 m (cm/yr)	Growth rates: Height (m/yr)
Common pear *(Pyrus communis)*[^]	0.83	0.3
Wild cherry *(Prunus aviumn)*[§]	0.86	0.65
Sycamore *(Acer psuedoplatanus)*[¶]	0.76	0.26
Common ash *(Fraxinus excelsoir)*[¶]	0.88	0.34
Silver birch *(Betula pendula)*[¶]	1.26	0.6
English oak *(Quercus robur)*[¶]	0.86	0.29

Table 9: Tree growth figures from three sources, (extract adapted from Cooney, 2018).[16 ^ 50 § 51 ¶ 52]

Chancellors Court on Light Night Leeds, 2017

University of Leeds Image Library

5 CONCLUSION

Based on the project aims, the five conclusions are:

1. Calculate the environmental benefits (ecosystem services) of the trees on the main campus.

The trees on the main campus store approximately 540 tonnes of carbon[7], the equivalent carbon for 180 people[4] and sequester 18 tonnes of carbon[7], the carbon footprint for 6 people every year.[4] The overall tree canopy cover is 17.2%[5], but most of the canopy cover is found in a few key areas of green space, such as St George's Field. 17.2% is above the national average for urban areas but short of Forest Research's 20% recommended target,[6] so additional tree planting on campus is required. The mature trees of large stature provide a far greater amount of environmental services than younger or smaller trees. There is a good mix of tree species on campus for resilience with evidence of a wide range of tree trunk diameter size reflecting a proactive planting programme.

Recommendations

- To plant large stature, long lived trees where large soil volumes are available.
- To protect the existing mature tree stock, through a continuation and adoption of good practice measures in tree care and management.
- To increase the percentage tree canopy cover from 17.2% to a minimum of 20%.

2. Calculate an estimate of the monetary value of the ecosystem services.

The value of carbon stored by the trees on campus is £126,800[8], sequestered carbon £4,200[8] per year and pollution removed £3,800[9] per year (estimated using i-Tree Eco[7]). Values estimated using ORVal[37] for the green space and trees of St George's Field were £230,000 per year.

3. Use the project as a pilot study for an ecosystem services valuation for the trees of the city of Leeds

The study demonstrated the opportunities and challenges of data collection with volunteers.
The opportunities were the ability to complete the study within the budget and to provide wider understanding of the environmental benefits of trees through the surveying process. Some of the

* *see glossary page 50*

5 CONCLUSION

challenges were the more technical assessments of the tree measurements, such as tree identification to species level. These assessments took additional surveying time and required confidence gained from the training and experience. Outcomes from the experiences of surveying the campus trees are outlined in Appendices i and ii. Full details will be passed to Leeds City Council for any potential city wide study.

The trees by the Edge Sports Centre.

4. Engage students, university staff and members of the public, in valuing the trees on campus.
Events have been run to inform the campus and wider community of the less well known benefits of the trees (see Appendix iv). The top performing trees highlighted in this report will have information labels explaining their positive contribution to campus.

5. Communicate the results to inform policy and to review the impact of the study.
The results of the study will be communicated through this report to stakeholders, social media and additional events on campus. Reviews of the impact of the study will be made. The environmental benefits of the trees potentially affected by a proposed extension to the Edge Sport Centre car park were included in the cost benefit analysis and the plan did not go ahead.

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Recommendations

- To increase resilience of the urban forest by planting no more than 5% of a single species, 10% of any genus and 20% belonging to the same family.
- To plan for the potential loss of 8% of the campus trees because of Chalara Ash die back.
- To follow the example of the city of Melbourne's strategic approach to the urban forest and set a target with associated milestones for increasing the tree canopy levels.
- To consider the street design of the polluted areas on campus to ensure good air circulation and incorporate in the design long lived trees, with large crowns and large leaves.
- To include large evergreen trees near pollution hotspots for pollution removal all year.
- To plant long lived trees, with large crowns and large leaves for enhanced rainfall interception and reduce surface runoff.
- To consider existing large trees, when designing new buildings and developments on campus to minimise loss.
- To pro-actively manage the trees to ensure the percentage of large trees increases; i.e. so the young and semi-mature trees reach maturity, and beyond.

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Appendices

i TECHNICAL DETAIL

Preparation

A paper map of the University of Leeds campus was prepared using open source mapping.[23] This map was divided into manageable sections or 'plots', and each section labelled with a unique code, for example SG100 for the western-most portion of St George's Field. Plots were designed to be manageable by a surveying team of two or three. A digital map of the campus plots was created in Digimap.[2] This enabled printing of paper maps for individual plots and record keeping of completed plots.

About the i-Tree software

i-Tree is a peer-reviewed software suite for analysis of urban and rural forests and the benefits they provide, created by the United States Department of Agriculture (USDA) Forest Service.[7] The tools are freely available for users to download.

i-Tree Eco is designed for use in urban areas and provides analysis of pollution removal, carbon sequestration, carbon storage, avoided rainfall runoff, and species composition. i-Tree Eco v6 has been adapted for use in the UK for most effects, with location-specific pollution and weather data available in the program. The versions of i-Tree Eco used were v6, up to v6.0.14.

i-Tree Canopy v6.1 was also used in the calculation of the tree coverage on campus. The campus boundary was defined using GIS and 10 i-Tree Canopy assessments were performed using 800 sample points each time. This gave a standard error for tree cover of less than 1.5% each time. The mean canopy cover was found to be 17.2%, with a standard deviation of 1.25%, across the 10 assessments.

Project configuration

The University of Leeds campus i-Tree project was configured as follows:

- Type of project: Complete inventory
- Pollution and weather year: 2013
- Weather station location: Church Fenton

Pollution absorption monetary values in this report were calculated using UK Social Damage Costs for transport-related air pollutants in an inner conurbation area[9], given in Table 10. There are no UK social damage costs for CO and O_3 so those values have not been reported.

Pollutant	Value per tonne of emission change Central damage cost (£/tonne)	Low -High damage cost sensitivity range (£/tonne)	
Nitrogen oxides (NOx)	£6,199	£634	£23,153
Particulate matter ($PM_{2.5}$)	£420,523	£87,626	£1,296,397
Sulphur oxides (SOx)	£1,95	£1,491	£17,861

Table 10: UK Social Damage Costs for Pollutants from Transport in Inner Conurbation[9]

Carbon dioxide values used were the UK Government's 2018 value for non-traded carbon at £66 per tonne.[8] Carbon values reported by i-Tree were converted to carbon dioxide for the valuation by multiplying the carbon value by 3.67.

i TECHNICAL DETAIL

Practical aspects of the survey

A core team received training in the i-Tree software and in surveying techniques from Treeconomics. Additional in-house training days were run for new volunteers.

The surveying was conducted by teams of 2 or 3. The position of the trees was marked on an A4 map of the plot being surveyed and each tree labelled on the map with a unique identifying code, for example SG101, SG102, etc. for the trees in plot SG100. Each survey session was 2 hours long. Following i-Tree guidance, trees with circumferences of less than 22 cm (diameter of less than 7 cm) were not included in the survey. Shrubs, such as rhododendrons, with individual stems of 22 cm circumference or more were included.

For each tree surveyed the following parameters were recorded:

- Tree species
- Circumference
- Land use
- Tree status (planted or ingrown)
- Street tree or non-street tree
- Total height
- Live height
- Height of crown base above ground
- Percentage condition of crown
- Percentage of crown missing
- Width of crown in north-south and east-west direction
- The trees unique identifier (e.g. SG101) was stored in i-Tree's "photo id" column

Tree heights (total height and live height) and, where necessary, height of crown base were measured using a surveying tape and clinometer. Circumference, widths of crown in north-south and east-west directions, and, where possible, height of crown base were measured using the tape. The percentage of crown missing (branches and leaves) and the percentage condition of the crown were estimated by comparing the missing or dead portion to the size of the whole crown. The Collins Tree Guide was used for tree identification.[53]

Surveying equipment

ii QUALITY ASSURANCE

Any tree survey provides a snapshot of the state of the trees at the point of measurement. Using a complete inventory method provides increased confidence in the results compared to a sample based method where only a subset of trees are surveyed. Large field studies like this require many hours of labour which are expensive so volunteers are required. For volunteers, the assessments of each tree required skills. All volunteers had training, with a core group having a training day with Treeconomics.

In order to assess the data quality, 5% of the trees were re-measured without reference to the original data. Every 50th record was sampled from the survey data file, with only the tree identification code recorded on the new survey sheets. Due to building works not all trees were re-surveyed, but 73 trees were compared.

For some areas of campus, such as St George's Field, being certain the remeasured tree was the original tree was a challenge, because of the lack of landmarks in the wooded area. Some trees were either close to another ingrown tree or had two trunks. In the original survey the consequences of this assessment were not significant because everything was being measured. It made a difference to the results in the selective quality assurance tests. Overall 70% (51) of the trees were clearly the same tree with values such as diameter at breast height very similar.

Difficult elements in the assessments

1) Tree identification

Roman *et al.*[54] considers the role of citizen science in research and concluded that it is best for volunteers to identify trees to genus level (e.g. *Tilia, Acer, Quercus*). Identification took a lot of time and required experience and confidence. One example was the identification of the common or wild Pear on campus which was probably an misidentification of *Pyrus calleryana* 'Chanticleer', a tree commonly used in urban landscape.

To assess the impact of misidentification at species level, one set of tree measurements for a Lime (*Tilia*) and a Cherry (*Prunus*) was assigned to every species of Lime and Cherry listed as an option in i-Tree. For the eight species of Lime, the carbon storage, sequestration and pollution removal results were exactly the same. Varying between the twenty species of Cherry species resulted in a small variation in carbon values for two trees(*Prunus laurocerceraus* and *P. serotina*), and a replacement cost difference in one (a value disregarded in this survey).

ii QUALITY ASSURANCE

2) Tree condition and percentage of crown missing

Tree condition is an important determinant of the leaf area. Our surveyors classified the health of each tree to belong to a 5% condition band with e.g., 95-100% indicating excellent condition. Choosing the appropriate band was often a point of discussion during surveying. Also discussed when surveying is percentage of the crown that is missing and the difference between missing and condition depending on where the crown base is measured. The comparative leaf areas of the two surveys were widely different even on trees whose trunk diameter measurements were very similar. It was more difficult for the surveyors to consistently assess the condition of the trees with a small to moderate amount of die back.

3) Surveying errors

Roman *et al.*[54] highlighted frequent errors when identifying the tree to be measured. Errors encountered included: should a tree should be included in the survey (diameter at breast height >7cm), missing trees out as a result of map reading issues and measuring the same tree twice. In the campus survey four trees out of 1450 were recorded twice with the same number (the result of multiple groups working at once).

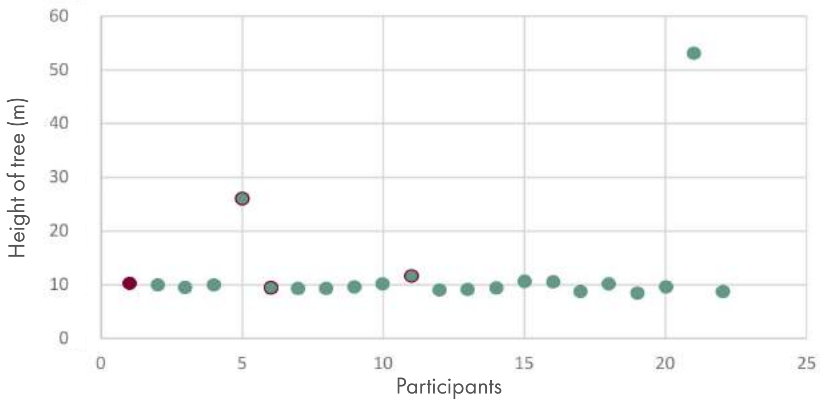
4) Height variation

Using the clinometer to assess the height of the tree was another surveying area which required training and practise for consistent answers. Using one tree, the height was increased and decreased by five degrees at one degree increments. When estimating the tree height, variation of one degree in the angle measured leads to a change of half a metre in tree height.

A follow up test was carried out, where one tree was measured by twenty one different people. Everyone was given training on how to use a clinometer if they had not used one before (Figure18). Recording an angle on survey sheets does not allow for an on-site common sense check of the tree height.

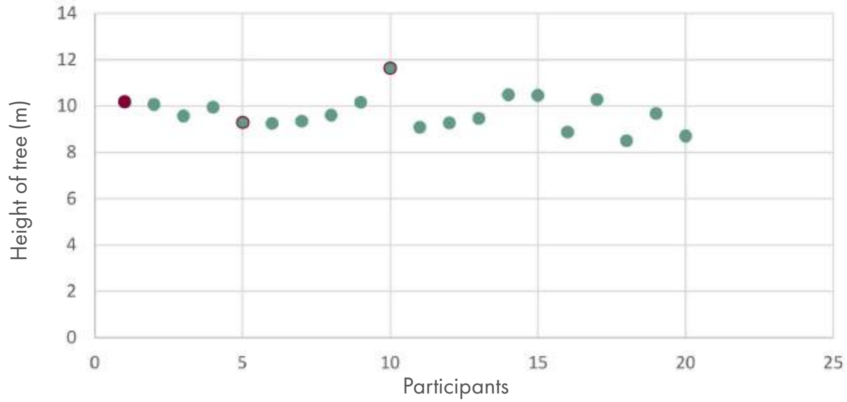
ii QUALITY ASSURANCE

Figure 18: Holly tree (UR401) height measurements: All data



All data points: Mean 12.4m, standard deviation 9.8m

Figure 19: Holly tree (UR401) height measurements: Without outliers



Without outliers (numbers 5 & 21): Mean 9.7, standard deviation 0.7m.

Recommendations

- Depending on the overall aims of the project, use genus only for identification instead of species level.
- To simplify tree condition assessments for volunteers by providing wider ranges to choose from e.g., 0-25%, 25-50%, 50-75%, 75-100%.
- Have a reference sheet or calculator to sense check the height of the tree on-site to improve data quality.
- To teach the use of the clinometer carefully.

iii LIST OF SPECIES

Species	Number	%	Species	Number	%	Species	Number	%
Acer pseudoplatanus	185	12.76	Alnus cordata	12	0.83	Ulmus glabra	5	0.34
Tilia x europaea	124	8.55	Prunus serrula	12	0.83	Betula pubescens	4	0.28
Fraxinus excelsior	108	7.45	Acer campestre	11	0.76	Fraxinus angustifolia 'Raywood'	4	0.28
Prunus avium	84	5.79	Acer saccharum	10	0.69	Ginkgo biloba	4	0.28
Pyrus communis	52	3.59	Malus sylvestris	10	0.69	Malus domestica	4	0.28
Acer platanoides	47	3.24	Robinia pseudoacacia	10	0.69	Prunus serrulata 'Kwanzan'	4	0.28
Betula pendula	44	3.03	Chamaecyparis lawsoniana	9	0.62	Pyrus calleryana 'Chanticleer'	4	0.28
Fagus sylvatica	32	2.21	Cupressocyparis leylandii	9	0.62	Salix caprea	4	0.28
Betula utilis	31	2.14	Liriodendron tulipifera	9	0.62	Acer platanoides 'Crimson King'	3	0.21
Quercus robur	31	2.14	Prunus sargentii	9	0.62	Cercidiphyllum japonicum	3	0.21
Ilex aquifolium	28	1.93	Quercus cerris	9	0.62	Gymnocladus dioicus	3	0.21
Tilia cordata	28	1.93	Quercus rubra	9	0.62	Magnolia x soulangeana	3	0.21
Aesculus hippocastanum	26	1.79	Sorbus intermedia	9	0.62	Rhododendron	3	0.21
Sorbus aria	24	1.66	Fagus sylvatica 'Purpurea'	8	0.55	Salix alba 'Tristis'	3	0.21
Tilia platyphyllos	24	1.66	Laburnum anagyroides	8	0.55	Sambucus racemosa	3	0.21
Sorbus aucuparia	23	1.59	Prunus domestica	8	0.55	Thuja plicata	3	0.21
Sambucus nigra	22	1.52	Alnus incana	7	0.48	Acer cappadocicum	2	0.14
Corylus colurna	21	1.45	Cotoneaster salicifolius	7	0.48	Acer griseum	2	0.14
Platanus hybrida	21	1.45	Ulmus procera	7	0.48	Acer palmatum var. dissectum	2	0.14
Betula papyrifera	19	1.31	Acer platanoides 'Schwedleri'	6	0.41	Acer rubrum	2	0.14
Carpinus betulus	19	1.31	Crataegus laevigata	6	0.41	Aesculus x carnea	2	0.14
Crataegus monogyna	18	1.24	Amelanchier	5	0.34	Carpinus betulus 'Fastigiata'	2	0.14
Cotoneaster frigidus	16	1.10	Juglans regia	5	0.34	Crataegus	2	0.14
Alnus glutinosa	14	0.97	Metasequoia glyptostroboides	5	0.34	Crataegus persimilis	2	0.14
Corylus avellana	13	0.90	Quercus petraea	5	0.34	Fraxinus ornus	2	0.14
Prunus laurocerasus	13	0.90	Salix fragilis	5	0.34	Ligustrum lucidum	2	0.14
Acer saccharinum	12	0.83	Tilia euchlora	5	0.34	Ligustrum ovalifolium	2	0.14

Table 11: Species list of trees measured in the main campus survey

Native tree [29]

iii LIST OF SPECIES

Species	Number	%	Species	Number	%	Species	Number	%
Magnolia stellata	2	0.14	Alnus rubra	1	0.07	Parrotia persica	1	0.07
Olea europaea	2	0.14	Betula alleghaniensis	1	0.07	Picea abies	1	0.07
Pinus pinea	2	0.14	Betula ermanii	1	0.07	Pinus strobus	1	0.07
Populus nigra	2	0.14	Betula maximowicziana	1	0.07	Pinus sylvestris	1	0.07
Prunus incisa	2	0.14	Buddleja davidii	1	0.07	Populus nigra betulifolia	1	0.07
Prunus padus	2	0.14	Cedrus atlantica v. glauca	1	0.07	Populus x canadensis 'Aurea'	1	0.07
Prunus subhirtella	2	0.14	Chamaecyparis nootkatensis	1	0.07	Prunus	1	0.07
Prunus x schmittii	2	0.14	Chamaecyparis obtusa	1	0.07	Prunus maackii	1	0.07
Quercus coccinea	2	0.14	Eucryphia x nymansensis	1	0.07	Prunus yedoensis	1	0.07
Rhus	2	0.14	Euonymus europaeus	1	0.07	Pyrus salicifolia	1	0.07
Rhus hirta	2	0.14	Fraxinus angustifolia	1	0.07	Salix	1	0.07
Salix alba	2	0.14	Fraxinus excelsior 'Aurea'	1	0.07	Salix viminalis	1	0.07
Sequoiadendron giganteum	2	0.14	Gleditsia triacanthos	1	0.07	Sorbus domestica	1	0.07
Sorbus commixta	2	0.14	Griselinia littoralis	1	0.07	Sorbus thuringiaca	1	0.07
Tamarix parviflora	2	0.14	Juglans nigra	1	0.07	Sorbus torminalis	1	0.07
Trachycarpus fortunei	2	0.14	Juniperus chinensis	1	0.07	Syringa vulgaris	1	0.07
Abies veitchii	1	0.07	Juniperus communis	1	0.07	Ulmus x hollandica	1	0.07
Acer	1	0.07	Laburnum x watereri	1	0.07	Grand Total	1450	100
Acer negundo	1	0.07	Larix decidua	1	0.07			
Acer opalus	1	0.07	Liquidambar styraciflua	1	0.07			
Acer palmatum	1	0.07	Malus	1	0.07			
Acer pensylvanicum	1	0.07	Nothofagus antarctica	1	0.07			

Table 11: Species list of trees measured in the main campus survey

Native tree [29]

iii LIST OF SPECIES

Table 12: The tree planting list used in the Nexus development, showing ultimate tree height and tree family.[44]

Species	No.	Final height (m)	Final spread (m)	Family	% of Total
Red Maple (*Acer rubrum*)	6	10	7	*Aceraceae*	17.1%
Field Maple (*Acer campestre*)	12	12	8		
Fastigiate Hornbeam (*Carpinus betula* 'Frans Fontaine')	24	17	3	*Betulaceae*	33.3%
Silver Birch (*Betula pendula*)	11	12	8		
Flowering Dogwood (*Cornus kousa* 'Miss Satomi')	6	4	4	*Cornaceae*	5.7%
Small leaved Lime (*Tilia cordata* 'Street Wise')	3	10	6	*Tiliaceae*	2.9%
Tibetan Cherry (*Prunus serrula*)	13	12	8	*Rosaceae*	41%
Pryamid Oak (*Quercus robur* 'Fastigiata')	2	12	8		
Mountain Ash (*Sorbus acuparia*)	15	12	8		
Snowy mespilus (*Amelanchier lemarkii*)	6	4	4		
Smooth Serviceberry (*Amelanchier laevis* 'Snowflakes')	7	4	4		

iv PUBLIC ENGAGEMENT

1. Volunteer surveyors: The volunteer team was recruited from University staff and students and from non-University personnel who had an existing connection with the project. In total the 40 volunteers completed the survey of two summers of 2017 and 2018.

2. Chevin Forest Park open day and apple pressing day: Friends of Chevin Forest Park Heritage Group open day 1st July 2017 & 8th October 2017. The Fantastic Forest Tree Trail and the Fantastic Forest Carbon Calculator.

3. i-Tree Leeds Community Day: The core team invited members of the public to two separate events held in the School of Earth and Environment at the University of Leeds on 17th August 2017 highlighting the preliminary results from the campus study and training attendees in tree surveying.

4. Light Night Leeds 2017: The Urban Forest at Night for Leeds Light Night on 6th October 2017. The aim was to encourage visitors to notice trees in the urban forest and learn about the benefits they provide so that the trees of Leeds are more widely valued by the general public.

5. i-Tree workshop: Students on the Sustainable Cities Masters degree, had a lecture about this study, with a workshop using i-Tree canopy to assess the tree canopy cover for the wards of Leeds.

6. How tall is that tree? As part of the quality assurance tests, the same tree was measured twenty one times by volunteers one lunch time in February 2019.

7. Green Streets Seminar: The results of the survey were presented to urban foresters, transport planners, landscape architects and urban regeneration specialists on 12th June 2019.

8. The Royal Town Planners Institute (RTPI): As part of the RTPI Yorkshire 2019 Conference Series, the results from this study were presented on 20th June, at the Planning for Green Space conference.

How tall is that tree? Volunteers were trained to use the clinometer and then asked to measure the height of the Holly tree (UP401) as part of the quality assurance tests.

v GLOSSARY

Allometric: calculations of the growth and form of trees
CAVAT: (Capital Asset Value for Amenity Trees) - software to assess the amenity value of a tree to people.[39]
Carbon storage: Long term store of carbon, a function performed by trees which keeps it out of the atmosphere.
Carbon dioxide: Gas produced in excess by burning of fossil fuels which is the key contributor to climate change.
Carbon sequestration: Removal of carbon dioxide from the atmosphere.
Climate change: Warming of the atmosphere and alteration to the climate as a result of emissions of harmful gases from human activity.
Ecosystem services: These are benefits ecosystems provide to people and they are categorised as regulating services (e.g. removing pollution from the air), supporting services (biodiversity),provisioning services (e.g. providing food) and cultural services (e.g. making a landscape more attractive).[55]
i-Tree: A peer reviewed suite of software tools to assess the environmental benefits of trees, including Eco and Canopy used in this study.[7]
Natural capital valuation tools: Methods of assign monetary and other values to natural resources.
NO_{2}: Nitrogen dioxide a pollutant emitted from motor vehicles, which forms part of NO_x
ORVal: Outdoor recreation and valuation tool created by the Land, Environment, Economics and Policy Institute at Exeter University.[37]
Particulate matter ($PM_{2.5}$ PM_{10}): Small particulates emitted into the atmosphere (particular from vehicles) which are tiny enough to cross into the blood system in humans and impact health.
SOx : Sulphur oxides
Tree: A single stemmed woody perennial of a diameter of 7cm or greater (measured at a height of 1.3m)[56] . Mutli-stemmed trees had up to seven stems measured if the stems were over 7cm in diameter. Some large multi stemmed shrubs such as Laurel where included in the study.
Urban forest: A collection of street and parkland trees within an urban area of of a town or city.

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Thank you to the surveying team who made the project a success:

Manpreet Aulakh, Jess Baker, Sarah Barker, Nathan Betts, Apoorva Bhattacharya, Tom Bliss, Claire Booth, Carls Caraza, Felisha Chong, Abyed Chowdhury, Eva Cizkova, Thom Cooper, Becky Ewan, Kelly Forster, Pete Foulston, Jonny Gleadell, Ailish Graham, Hetasha Gopalani, Arminah Javeed, Tim Knighton, Vishnu Kumar, Jacob Lawson, Ryan Leeming, Clare Martynski, Issy Petersen-Adams, Richard Pope, Claire Richards, Nicola Rieg (and son) Suzanne Robinson, Reshmy Prasad, Freya Smeets, Stella Spriggs, Antonia Stewart, Jane-Marie Stocks, Robin Styles, Nick Tabler, Joey Ting, Nidhee Venkatesh, Julie Waddington, Charlotte Weaver, Joshua West, Angela Whitham, Jacob Wilson, Jamie Wilson, Yijing Xia, Ying Ye, and Xinyi Yu.