Oxford i-Tree Eco Report

2021

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Executive Summary

The trees in our urban parks, gardens, housing, open spaces, woodlands, streets and transport infrastructure are collectively described as the 'urban forest'. This report provides the most comprehensive study to date on the structure and value of Oxford's urban forest.

An unstratified i-Tree Eco plot sample survey was carried out with 200 randomly allocated, tenth of an acre plots across the city. This assessment provides a quantitative baseline of the air pollution, carbon storage, carbon sequestration, stormwater benefits, and amenity value of the entire tree resource, accounting for the trees on both public and private land.

Oxford i-Tree Eco Sample Survey - Headline Figures		
Total Number of Trees	248,233	
Tree Canopy Cover	15.9%	
Shrub Cover	6.4%	
Total Canopy Cover	22.3%	
Most Common Species	Fraxinus excelsior, Salix fragilis, Populus alba	
Replacement Cost	£219,000,000	
CAVAT	£2.5 Billion	
Carbon Storage	76,000 tonnes	£18,800,000
Pollution Removal - Trees	41,000 kg	£1,120,000
Shrubs	24,030 kg	£656,429
Carbon Sequestration	2520 tonnes	£619,000
Avoided Runoff - Trees	53,700m³	£81,000
Shrubs	25,100m³	£39,000
Total Annual Benefits (Trees)	£2,476,429	

Table 1: Headline Figures

Total Number of Trees: The random sample figures are estimated by extrapolation from the sample plots.
Tree Canopy Cover: The area of ground covered by leaves when viewed from above (not to be confused with leaf area which is the total surface area of leaves). This is not the total canopy cover for Oxford as some tree canopy dimensions were conservatively estimated.
Shrub Cover: The area of ground covered by the leaves of shrubs when view from above (shrub cover also exists under tree cover so a total canopy cover figure will not be a sum of shrub cover plus tree canopy cover).
Canopy Cover: The area of ground covered by the leaves of trees and shrubs when viewed from above.
Replacement Cost: Value based on the physical resource itself (e.g. the cost of having to replace a tree with a similar tree) using the Council of Tree and Landscape Appraisers (CTLA) Methodology guidance from the Royal Institute of Chartered Surveyors
Capital Asset Value for Amenity Trees (CAVAT): A valuation method developed in the UK to express a tree's relative contribution to public amenity and its prominence in the urban landscape.
Carbon storage: The amount of carbon bound up in the above-ground and below-ground parts of woody vegetation.
Carbon sequestration: The annual removal of carbon dioxide from the air by plants.
Carbon storage and carbon sequestration values are calculated based on CO2e and the DECC figures of £67 per metric ton for 2019.
Pollution removal: This value is calculated based on the UK social damage costs (2019) for 'Transport outer conurbation' and the US externality prices where UK figures are not available; £0.98 per Kg (carbon monoxide - USEC), £8.77 per Kg (ozone - USEC), £12.99 per Kg (nitrogen dioxide - UKSDC), £6.27 per Kg (sulphur dioxide - UKSDC), £247.05 per Kg (particulate matter less than 2.5 microns - UKSDC). Values calculated using an exchange rate of $0.75 = £1.00.
Avoided Runoff: Based on the amount of water held in the tree canopy and re-evaporated after the rainfall event. The value is based on an average volumetric charge of £1.516 per cubic metre and includes the cost of the avoided energy and associated greenhouse gas emissions in treating the water.

Data processed using i-Tree Eco Version 6.1.29.

1.0 Introduction

1.1 The Urban Forest Concept

What is the Urban Forest? The very term 'Urban Forest' seems a contradiction in terms. How can an area be simultaneously urban, and forest?

The definition given by Sands (in Forestry in a Global Context 2005), explains… 'the trees found in streets, municipal parks, gardens and reserves, golf courses, cemeteries, around streams, on private property, on catchments, in greenbelts and indeed almost everywhere make up the urban forest. The urban forest is the ecosystem containing all of the trees, plants and associated animals in the urban environment, both in and around the city'.

Deneke (in Grey and Deneke's Urban Forestry) simply states that 'cities are forests' and by United Nations definition - Land with tree crown cover of more than 10 percent and area of more than 0.5 hectares - most cities and urban areas could indeed be classed as forests.

1.2 i-Tree Eco Valuation of Benefits and Methodology

To assess Oxford's urban forest across both public and privately owned land, an i-Tree Eco (v6) plot-based assessment was undertaken. 201 randomly allocated plots of 0.04ha (400m^2) were surveyed, representing 0.18% of the total survey area (of 4560ha). This equates to 1 plot every 22ha. Random plot selection ensures that trees on private land are included in the assessment.

Plot Information	Land use, ground cover, % tree cover, % shrub cover, % plantable space, % impermeable surface.
Tree Information	Tree species, shrub species (if known), height (m), trunk diameter at breast height (dbh), canopy spread (m), the health and fullness of the canopy, light exposure to the crown and distance and direction to the nearest building.

Table 2 : Data collected for each plot

This data was collected by trained Oxford City staff and Treeconomics during the summer of 2017. The field data was then input into the i-Tree Eco program to generate the data summarised in table 3 (below).

Urban Forest Structure and Composition	Land Use and Ground cover Importance Value. Leaf Area. Species and size class distribution.
Ecosystem Services	Air pollution removal by urban trees for CO, NO2, SO2, O3 and PM2.5. % of total air pollution removed by trees. Current Carbon storage. Carbon sequestered. Storm Water Reduction. Amenity Valuation.
Structural and Functional values	Replacement Cost in £. Carbon storage value in £. Carbon sequestration value in £. Pollution removal value in £.
Potential insect and disease impacts for any potential or existing pathogen including....	Acute oak decline, asian longhorn beetle, ash dieback, emerald ash borer, gypsy moth, oak processionary moth and plane wilt.

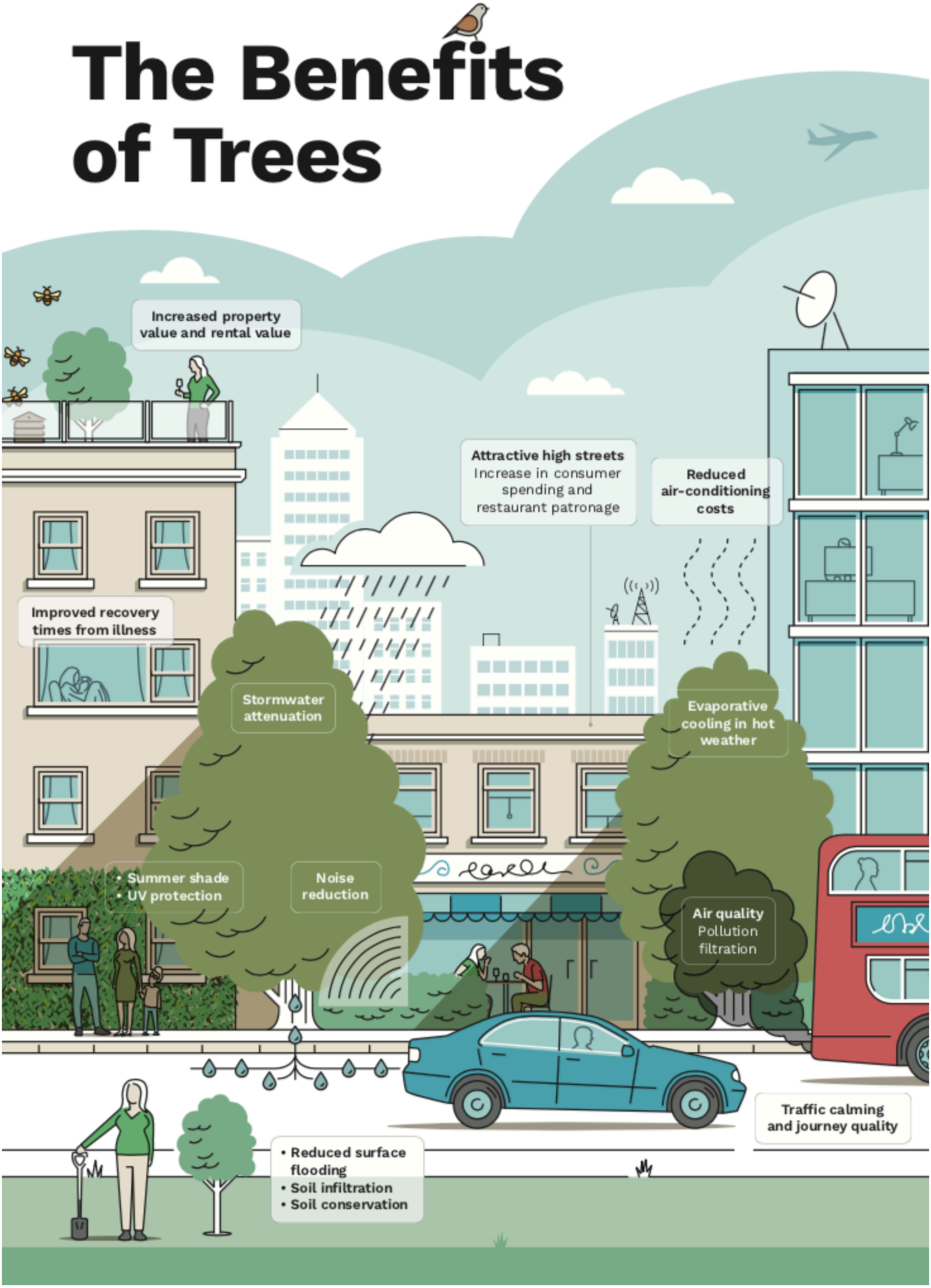
Table 3: Outputs calculated based on field collected data

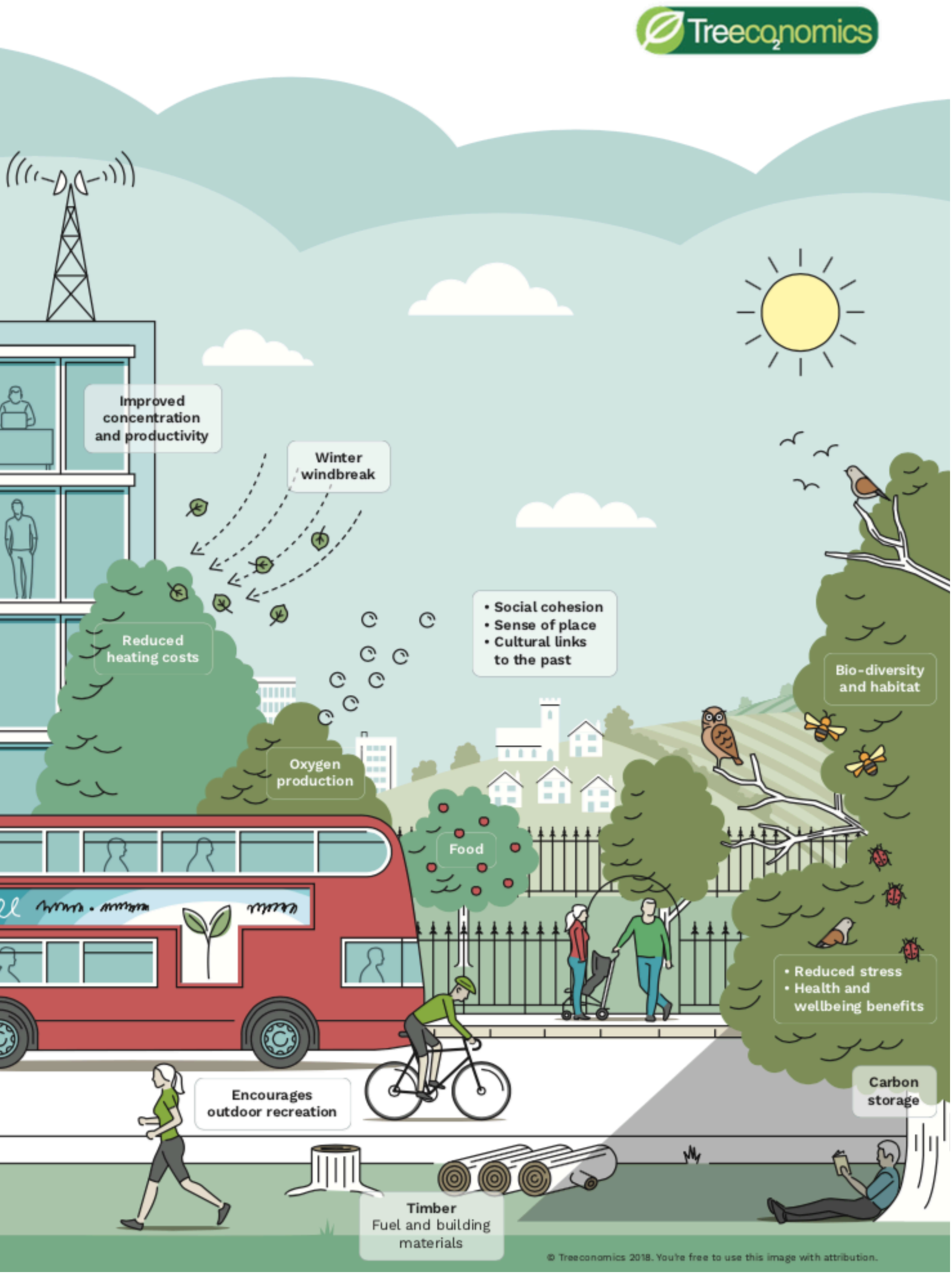
The values presented in this study represent only a portion of the total value of the trees within Oxford. This is because i-Tree Eco does not value all of the services that trees provide;

such as their roles in reducing building energy consumption and in moderating local air temperatures, in reducing noise pollution and improving health and well-being, providing wildlife habitat and, even, their ability to unite communities. The value of the ecosystem services provided in this report is therefore a conservative estimate the values in this report should be used to develop strategies for the long term management and sustainable development of the urban forest.

This report is only concerned with the trees (rather than shrubs) within Oxford that have a diameter at breast height (dbh) >7cm. Thus this report should be used only for generalised information on the urban forest structure, function, and value. Where detailed information for a specific area (such as an individual park, street or ward) is required, further survey work should be carried out.

The Benefits of Trees




Treeconomics
Improved concentration and productivity
Winter windbreak
Reduced heating costs
Oxygen production
• Social cohesion
• Sense of place
• Cultural links to the past
Bio-diversity and habitat
Food
• Reduced stress
• Health and wellbeing benefits
Encourages outdoor recreation
Carbon storage
Timber
Fuel and building materials
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2.0 Results

2.1 Tree Population Characteristics

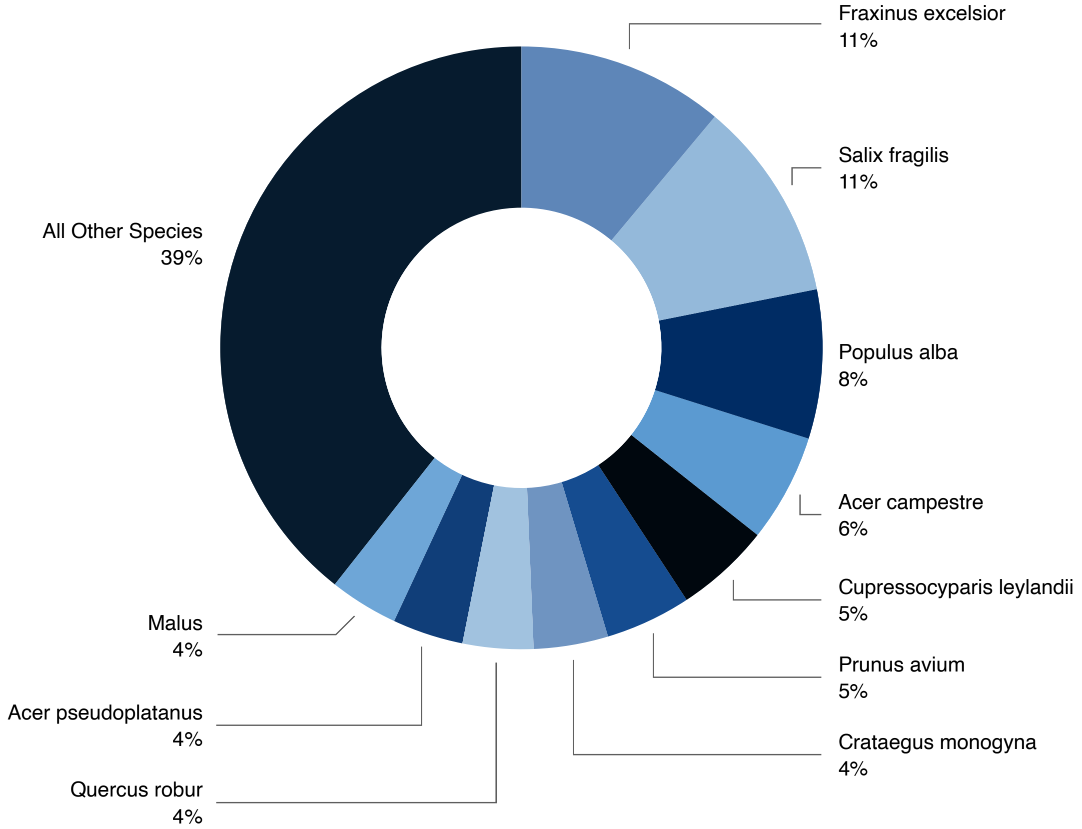

Figure 1: Percentage composition of tree species

Oxford has 74 tree and shrub species recorded as part of this survey. No one species particularly dominates the species palette. 11% of the trees in Oxford are Ash (*Fraxinus excelsior*) and the second, third and fourth most common trees are respectively: Crack willow (*Salix fragilis* – 10.8%), White poplar (*Populus alba* – 8.0%) and Field maple (*Acer campestre* – 5.8%).

Further detail on species diversity, country of origin and size distribution are also available within the i-Tree Eco program.

2.3 Pollution Removal

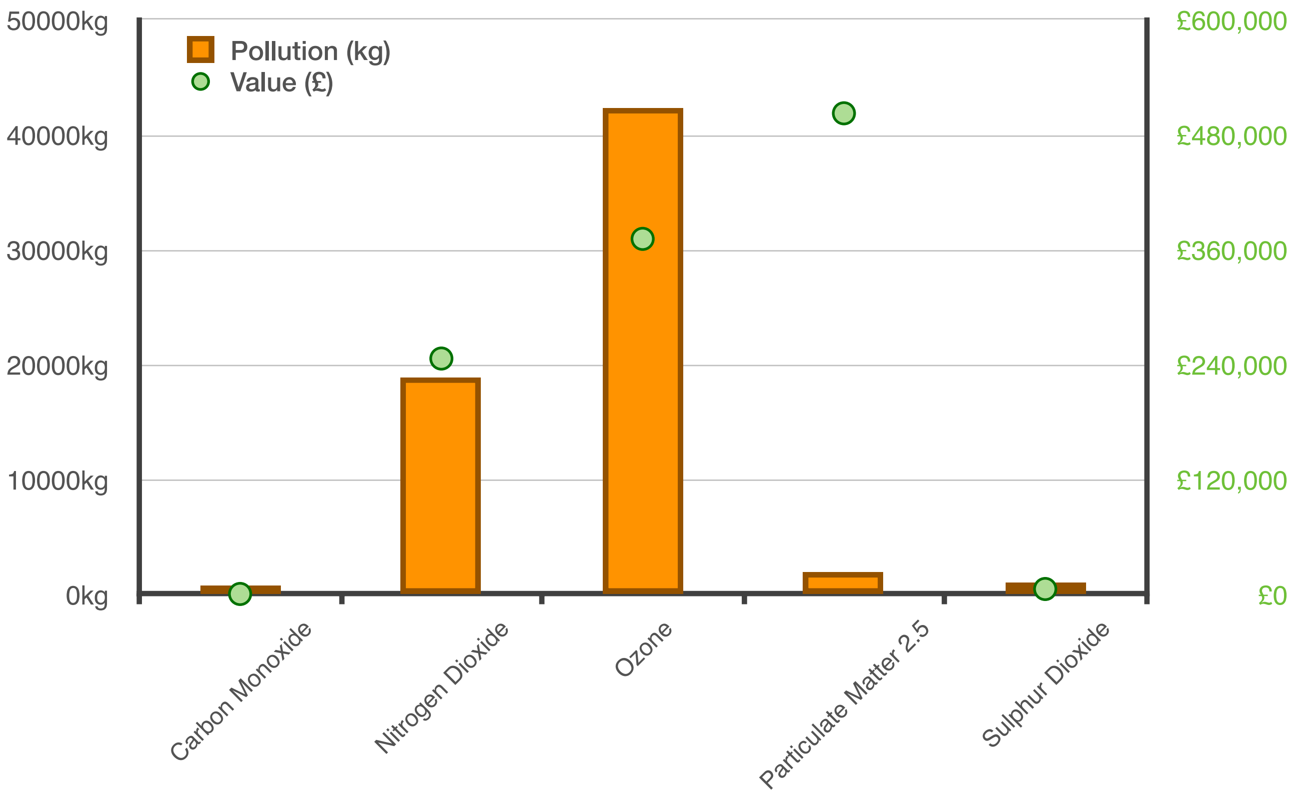

Figure 2: Value of the Pollutants Removed and Quantity Per-Annum within Oxford

Poor air quality is a common problem in many urban areas, in particular along the road network. Air pollution caused by human activity has become a problem since the beginning of the industrial revolution. With the increase in population and industrialisation, large quantities of pollutants have been produced and released into the urban environment. The problems caused by poor air quality are well known, ranging from severe health problems in humans to damage to buildings.

Urban trees can help to improve air quality by reducing air temperature and directly removing pollutants.[1] Trees intercept and absorb airborne pollutants on to the leaf surface.[2] In addition, by removing pollution from the atmosphere, trees reduce the risks of respiratory disease and asthma, thereby contributing to reduced health care costs.[3] Figure 2 (above) illustrates the pollution removal rates for all trees across Oxford for the study year.

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[1] Tiwary et al., 2009

[2] Nowak et al., 2000

[3] Peachey et al., 2009. Lovasi et al., 2008

Tree cover and leaf area and the levels of pollution are some of the factors affecting pollution filtration by trees. Additional tree planting will, in time, increase tree cover and leaf area and therefore the potential for pollution interception. Furthermore, because filtering capacity is closely linked to leaf area it is generally the trees with larger canopy potential that provide the most benefits. Additionally, it is generally conifer trees which reduce the most pollution as they have a greater surface area and are in leaf throughout the year.

Figure 3 (below) illustrates how pollution removal by trees changes over the year.

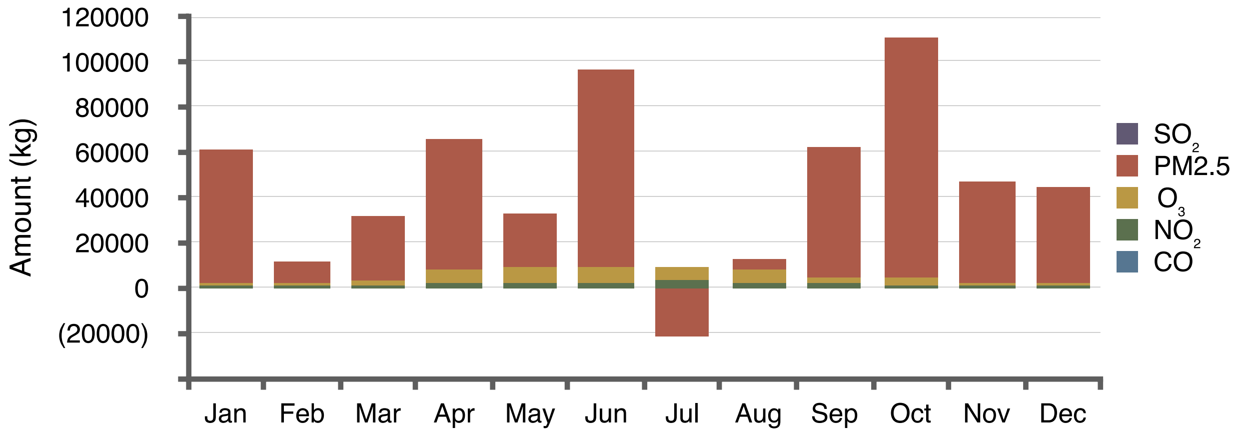

Figure 3: Monthly pollution removal

The negative value for the PM2.5 pollution removal in July is unusual. It can be explained by the fact that i-Tree Eco also accounts for ecosystem dis-services, and in July, Oxford's trees were emitting more BVOC's (isoprene and monoterpene) than those which were being removed by other tree species in addition to the high concentrations of pollution being emitted by traffic.

Significance in a Local Context

Within Oxford, traffic accounts for 75% of all pollution. Trees remove 43kg of pollutants annually, a service worth over £1.1 million every year. The annual nitrogen dioxide removal by trees is equivalent to that produced from 2,990 large family cars. For sulphur dioxide the removal rates provided by trees is equivalent to the emissions from 11,200 automobiles.

Trees can contribute significantly to improving air quality and in encouraging pollution free modes of transportation and commuting such as electric vehicles, cycling, and walking. In London trees filter 13% of all the transport emissions within the greater London area, a service worth £136 million every year.

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmospheric environment.[4] Four main ways that urban trees affect air quality are:

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities.[5] Local urban management decisions also can help improve air quality.

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[4] Nowak 1995

[5] Nowak 2000

2.4 Carbon Sequestration and Storage

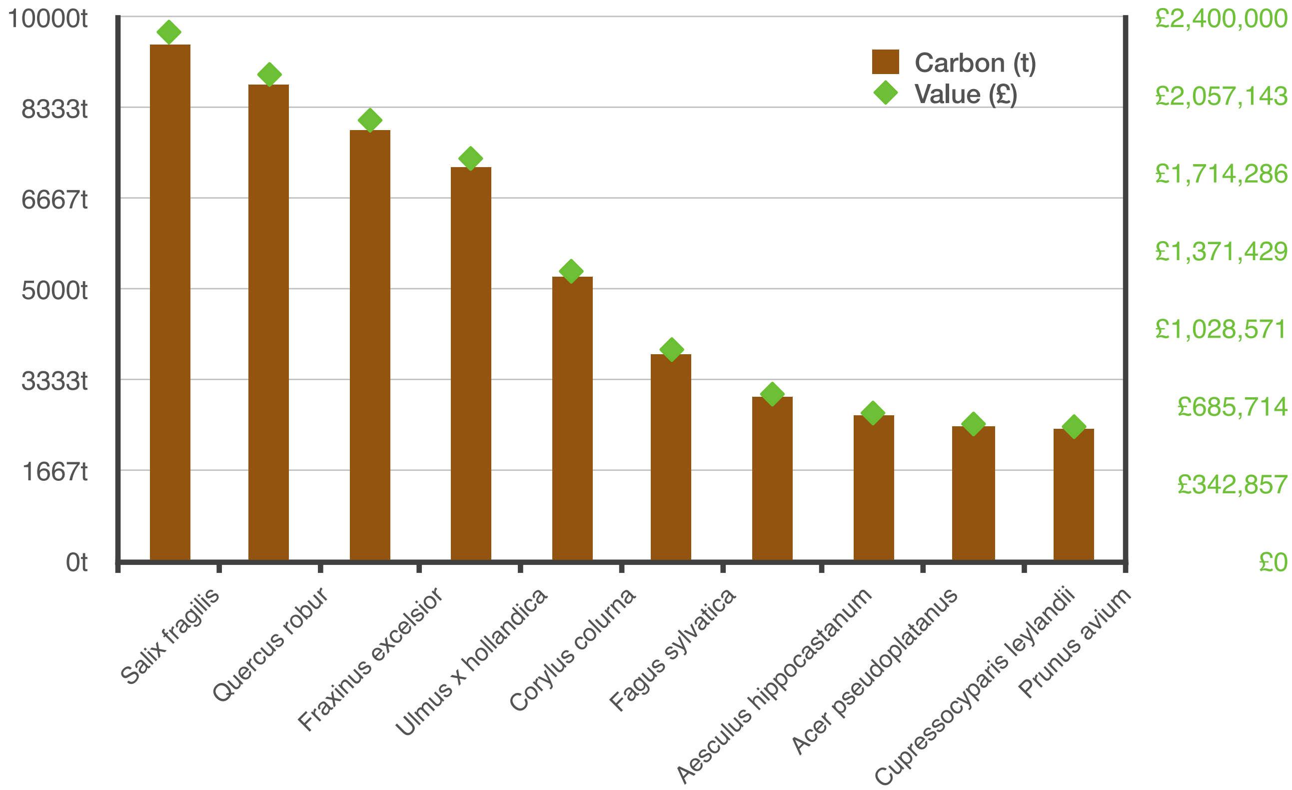

Figure 4: Top Ten Carbon Sequestration by Species

Oxford's trees sequester an estimated 2,519 tonnes of carbon per year, with a value of £619,133. Table 3 (above) shows Oxford's top ten trees in terms of carbon sequestration (annually), and the value of the benefit derived from the sequestration of this atmospheric carbon.

The main driving force behind climate change is the concentration of carbon dioxide (CO_2) in the atmosphere. Trees can help mitigate climate change by storing and sequestering atmospheric carbon as part of the carbon cycle. Since about 50% of wood by dry weight is comprised of carbon, tree stems and roots can store up to several tonnes of carbon for decades or even centuries.[6]

[6] Kuhns 2008, Mcpherson 2007

Species	Carbon Sequestration (tonnes/yr)	CO^2 Equivalent (Tonnes/yr)	Carbon Sequestration (£/yr)
Salix fragilis	290.36	1065	£71,338
Fraxinus excelsior	280.40	1028	£68,892
Quercus robur	194.46	713	£47,776
Prunus avium	123.45	453	£30,330
Acer pseudoplatanus	115.63	424	£28,408
Corylus colurna	111.05	407	£27,282
Acer campestre	105.68	388	£25,963
Cupressocyparis leylandii	89.58	328	£22,009
Aesculus hippocastanum	78.38	287	£19,258
Crataegus monogyna	74.67	274	£18,345
All Other Species	1,056.33	3,874	£259,533
Total	**2,519.99**	**9,241**	**£619,133**

Table 4: Carbon Storage (tonnes) for Top Ten Tree Species in Oxford

Overall the trees in Oxford store an estimated 76,414 tonnes of carbon with a value of £19 million. Table 4(above) illustrates the carbon storage of the top ten tree species.

Maintaining a healthy tree population will ensure that more carbon is stored than released. Utilising the timber in long term wood products or to help heat buildings or produce energy will also help to reduce carbon emissions from other sources, such as power plants.

Significance in Local Context

Carbon emissions for Oxford (as stated in the City Council's Climate Emergency Strategy Support report) equate to 718,000 tonnes of carbon dioxide per annum, an amount which is nearly 10 times the total carbon storage of Oxford's urban forest.

However the carbon stored in Oxford's trees is equivalent to:

- The amount of carbon emitted in Oxford in approximately 38 days.
- Annual carbon (C) emissions from 59,600 automobiles
- Annual C emissions from 24,400 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Oxford in 1.3 days
- Annual C emissions from 2,000 automobiles
- Annual C emissions from 800 single-family houses

Although the contribution Oxford's trees make with regard to mitigating carbon emissions may seem small, they still contribute positively to the carbon balance.

2.5 Storm water, localised flooding and avoided runoff

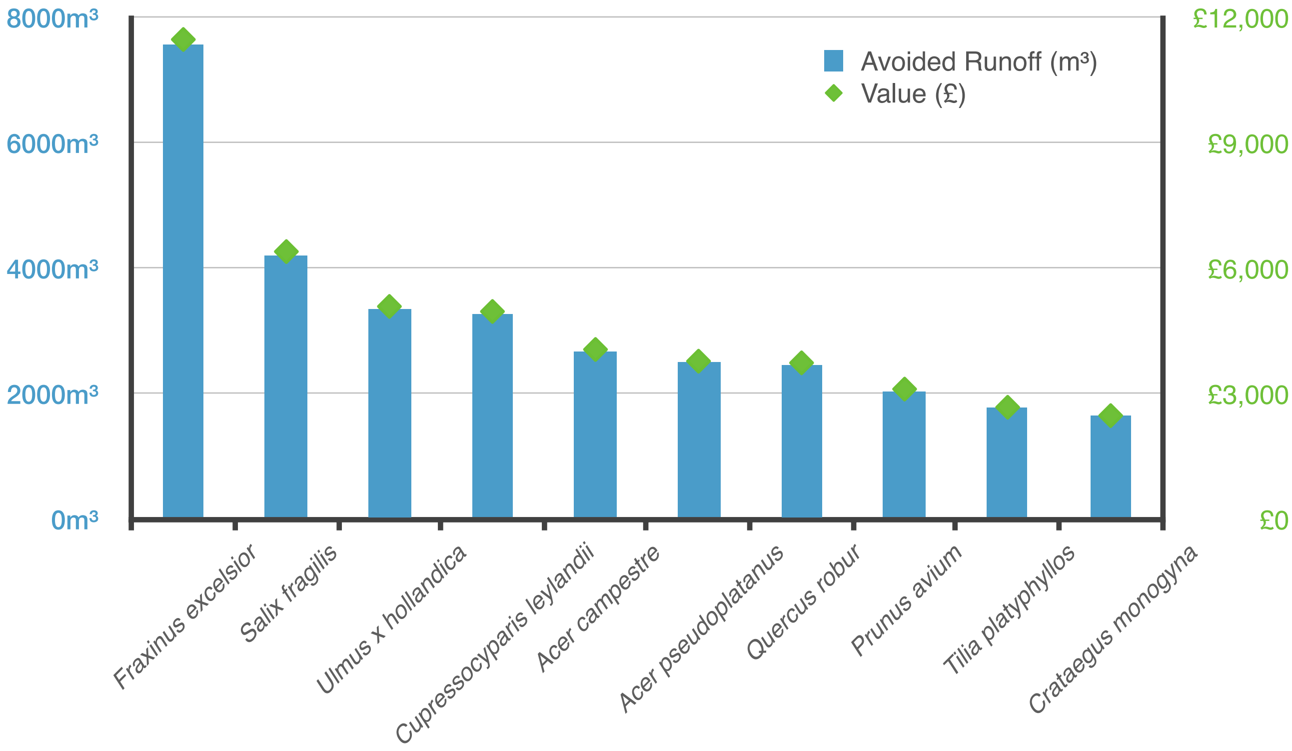

Figure 5: Avoided Runoff by Top Ten Species

Surface runoff can be a cause for concern in many areas as it can contribute to flooding and is a source of pollution in streams, wetlands, waterways, lakes and oceans. During precipitation events, a portion of the precipitation is intercepted by vegetation (trees and shrubs) while the remainder reaches the ground. Precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff.[7]

In urban areas, the large extent of impervious surfaces increases the amount of runoff. However, trees are very effective at reducing surface runoff.[8] The trees' canopy intercepts precipitation, while the root system promotes infiltration and storage of water in the soil.

Annual avoided surface runoff in i-Tree Eco is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. The trees within Oxford reduce runoff by an estimated 53,718m³ a year with an associated value

[7] Hirabayashi 2012

[8] Trees in Hard Landscapes (TDAG) 2014

of £81,455. Figure 5 (above) shows the volumes and values for the ten most important species for reducing runoff.

Significance in Local Context

Oxford has a history of flooding. During recent years (2007 and 2013/2014) flooding blocked the Abingdon Road, Botley Road and the local rail network.

The Oxford Flood Alleviation Scheme is a major project anticipated to cost around £150 million and is one of the biggest schemes within the UK. The scheme aims to reduce the risk of flooding to homes, businesses, services and the transport network. The scheme is not only intended to protect Oxford's growing economy, but also bring environmental benefits.

The scheme is led by the Environment Agency and is being delivered in conjunctions with other partner organisations including Oxford City and County Council, Vale of the White Horse District Council, Thames Water, Thames Regional Flood and Costal Committee, Oxford Flood Alliance, Oxfordshire Local Enterprise Partnership, University of Oxford, and Highways England.

The scheme will also include the creation of approximately 20 hectares of wetland habitat. The scheme is engaging with local stokeholds on an environmental vision for the project, and will include the planting of new trees and hedgerows.

As shown above, the ability of trees to improve our City's is multi-faceted. When considering the impacts of tree removals to facilitate the proposed scheme the forecasted environmental benefits of the new tree planting should be audited to ensure there is a long-term enhancement of Oxfords tree population.[9]

[9] Environment Agency Policy paper, Oxford Flood Scheme (Sept 2019)

3.0 Replacement Cost and Threats

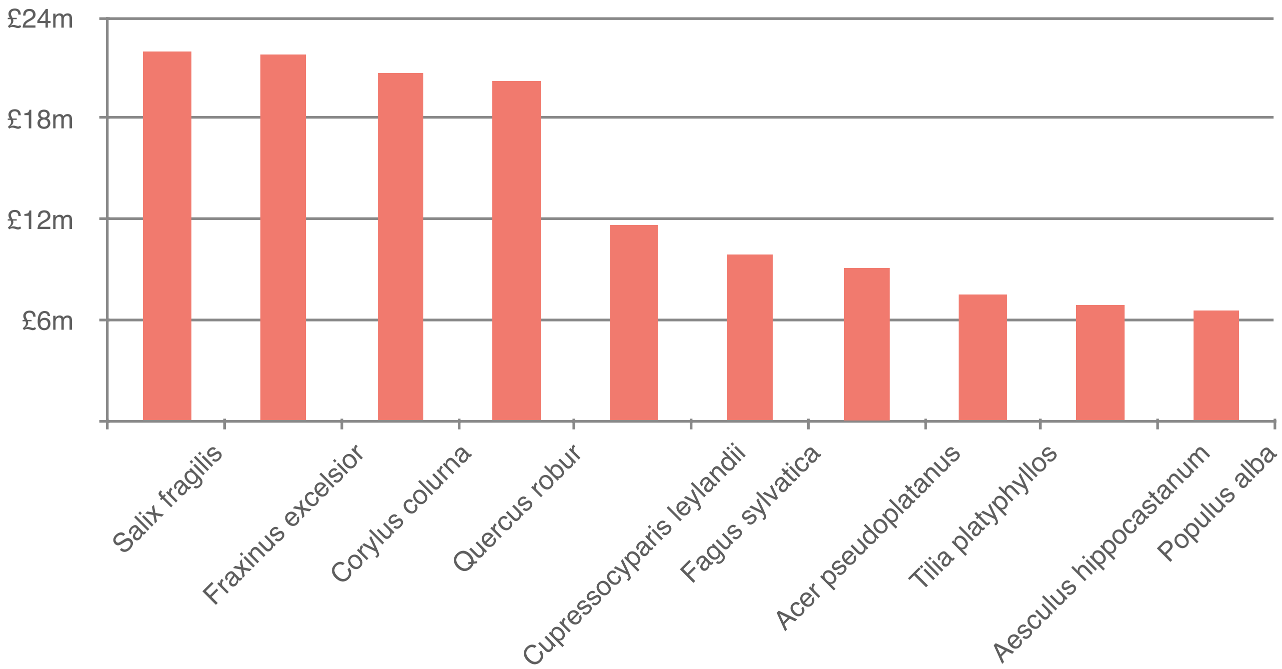

Figure 6: Top Ten Trees in Oxford by Replacement Cost

iTree Eco estimates the structural valuation of the trees in in the urban forest which is classified as a 'replacement cost'. This valuation is not a benefit provided by the trees but is a depreciated replacement cost of the tree based upon methodologies developed by the Council of Trees and Landscape Appraisers (CTLA). The formulae incorporates the suitability of the tree in the location and reflects nursery prices.

Replacement cost is a management tool which is used to calculate the estimated cost of replacing a tree by considering the species suitability and the depreciation if the tree were to ever become damaged or diseased.

The ten most valuable trees to Oxford based upon the replacement cost are shown in figure 6 (above).

Willow is the most valuable tree, on account of both its size and population, followed by Ash and Hazel. These three tree species account for £64,519,527 (30%) of the total replacement cost of the trees in Oxford.

Ash dieback, a fungal disease affecting the European species *Fraxinus excelsior* poses a significant threat to the most common and the 2nd most valuable tree species in Oxford. Ash dieback (explained in more detail in section 4.3 of this report), is predicted to affect up to 95% of the population. The total replacement cost for this species stands at £21,789,496.

3.1 Replacement Cost

In addition to estimating the environmental benefits provided by trees the i-Tree Eco model also provides a structural valuation which in the UK is termed the 'Replacement Cost'. It must be stressed that the way in which this value is calculated means that it does not constitute a benefit provided by the trees. The valuation is a depreciated replacement cost, based on the Council of Tree and Landscape Appraisers (CTLA) formulae.[10]

Replacement Cost is intended to provide a useful management tool, as it is able to value what it might cost to replace any or all of the trees (taking account of species suitability, depreciation and other economic considerations) should they become damaged or diseased for instance. The replacement costs for the ten most valuable tree species are shown in Table 5 (below).

Species	% Total Population	% Leaf Area	Number of Trees	Replacement Cost (£)
Salix fragilis	10.8	7.9	26691	£22,012,001.34
Fraxinus excelsior	11.1	14.1	27464	£21,789,496.82
Corylus colurna	2.5	0.3	6171	£20,718,028.84
Quercus robur	3.8	4.6	9416	£20,250,608.89
Cupressocyparis leylandii	5.1	6.1	12648	£11,592,288.25
Fagus sylvatica	0.7	2.8	1802	£9,813,726.09
Acer pseudoplatanus	3.8	4.6	9403	£9,030,785.48
Tilia platyphyllos	1	3.3	2462	£7,573,861.87
Aesculus hippocastanum	1	2.9	2399	£6,940,078.23
Populus alba	8	2.1	19849	£6,564,487.42
Prunus avium	4.6	3.8	11508	£6,480,476.41

Table 5: Replacement cost for the top ten trees in the inventory

[10] Hollis, 2007

3.2 CAVAT

CAVAT (Capital Asset Value for Amenity Trees) valuation, considers the health of trees and their public amenity value. For the urban forest of Oxford, the estimated total public amenity asset value is £2.5 billion. This equates to around £549,300 per hectare.

The fourth largest CAVAT value species is Ulmus x hollandica at £157,829,351 although the population is only 0.2%, this is due to their large stature and amenity value to the population of Oxford.

Table 6 (below) shows the top ten species by CAVAT value and the comparison to their respective population and replacement cost.

Species	CAVAT Value	Percent of Total Population	Replacement Cost
Quercus robur	£390,159,865	3.8%	£20,250,609
Fraxinus excelsior	£267,765,339	11.1%	£21,789,497
Salix fragilis	£256,624,475	10.8%	£22,012,001
Cupressocyparis leylandii	£175,482,338	5.1%	£11,592,288
Ulmus x hollandica	£157,829,351	0.2%	£6,290,687
Corylus colurna	£149,012,278	2.5%	£20,718,029
Populus alba	£123,391,045	8.0%	£6,564,487
Acer campestre	£90,977,769	5.8%	£5,345,806
Acer pseudoplatanus	£68,573,586	3.8%	£9,030,785
Aesculus hippocastanum	£68,515,825	1.0%	£6,940,078

Table 6: Top ten species by CAVAT value.

4.0 Tree Canopy Cover

4.1 Significance of Tree Canopy Cover

Despite the outstanding benefits of increased canopy cover, distribution varies greatly.[11] Quantifying tree canopy cover has been identified by many authors (Britt and Johnston, Escobedo, Nowak, Schwab) to be one of the first steps in the management of the urban forest.

"The first step in reincorporating green infrastructure into a community's planning framework is to measure urban forest canopy and set canopy goals".

James Schwab, Author, Planning the Urban Forest.

There can be a degree of variation in tree canopy cover estimates due to the type of cover assessed, variations in methodology, and resolution of aerial data. Some define canopy cover as the cover provided simply by trees, while others include both trees and shrubs.

The i-Tree Eco and i-Tree Canopy methodologies have distinct differences. i-Tree Eco estimates are calculated from data collected in the field, it can be said that this is a 'bottom-up' approach. i-Tree Canopy however, uses aerial imagery. i-Tree Canopy cover calculations will include both trees and shrubs (as they cannot be distinguished from each other using aerial imagery) and hidden understory will not be accounted for. Therefore it can be expected that results will be slightly lower than Eco.

4.2 Baseline Canopy Cover Estimate

According to i-Tree Eco, Oxford has a high canopy cover of 22.3% (includes both tree and shrub cover). This exceeds both the UK average of 17% and the London average of 21%. i-Tree Canopy estimates a slightly reduced estimate of 21.4%. With a 0.9% difference, these values are in line with other UK projects, and as explained above, is to be expected.

[11] Chuang *et al*, 2017

Canopy cover estimates provide Oxford with data required for the design of a strategic Urban Forest Masterplan to protect and enhance Oxford's urban forest. Canopy cover is threatened by a number of pests and diseases in addition to climate change, which is explored in more detail later in this report.

4.3 Threats to Oxford's Canopy Cover

European ash *(Fraxinus excelsior)* the most common tree species in Oxford, and accounts for around 11% of the tree population. The species is under great threat by the fungal disease, Ash dieback *(Hymenoscyphus fraxineus)*. Ash dieback is relatively harmless in its native range in Asia, associating with native ash species including *Fraxinus mandshurica*. However, European ash has shown to be highly susceptible to the pathogenicity of *H. fraxineus.* The Tree Council have reported, based on data from 2018, that mortality rates could be from 70% to 85%,[12] and the Woodland Trust suggest we could lose up to 95%.[13]

4.4 Opportunities for Oxford's Canopy Cover

Developing a Tree Planting Strategy (TPS) will enable Oxford to strategically map areas of potential plantable space by priority. The Multi Criteria Decision Analysis (MCDA) approach enables factors such as social deprivation, existing low canopy cover, and proximity to transportation networks (zones with increased air pollution) to be incorporated. A TPS will also provide evidence of funding being used to achieve the greatest impact, in turn creating opportunities to lever further tree planting funds. Tree plant strategies provide a visual platform to both map progress and engage with local communities.

[12] Tree Council, 2019

[13] Woodland Trust, Anon

5.0 Climate Change

5.1 Mitigation

As stated by the IUCN, forests mitigate climate change through their balancing effect on ecosystems. Trees store and sequester carbon, are pivotal for biodiversity, and trees can reduce storm water attenuation through holding water in the canopy and improve infiltration. The IUCN stated that "*halting the loss and degradation of natural systems and promoting their restoration have the potential to contribute over one-third of the total climate change mitigation scientists say is required by 2030*".

Bastin *et al*, 2019 states "*The restoration of trees remains among the most effective strategies for climate change mitigation".* The article concluded that global tree restoration has shown to be one of the most effect carbon reduction solutions and there is space for an extra 0.9 billion hectares of canopy cover globally. This could store 205 gigatonnes of carbon.[14] Canada are planting new forests to reduce their carbon emissions and have set a target to sequester carbon worth one-fifth of its international commitments, with a cost lower than simply reducing emissions

5.2 Adaptation

With the fast approaching effects of climate change posing such a great threat to our tree populations, strategies for long-term adaptation must become a pivotal part of planning. It is suggested by Forest Research that more southernly species are likely to be better at adapting to a hotter climate in future. A great deal of detail and thorough assessment will be required, however some of the following options could be successful start points: having species which are well matched to the site; taking into consideration climate change predictions before selecting new planting stock; and developing well connected woodland with a high species diversity.

[14] Bastin *et al,* 2019

5.3 Threat to the Urban Forest from Climate Change

A 2018 study found that if we assume certain parameters, most (of the studied) European species would have a "significant decrease in suitable habitat area" by 2061–2080. It also found that species further north would face the greatest threat level.[15]

6.0 Recommendations

It is recommended Oxford create an Urban Forest Strategy and Tree Planting Strategy. These two documents will lead the sustainable management and development of the urban forest in the face of challenges from urban intensification, climate change, and the spread of tree pests and disease. Society will then receive the greatest return, in terms of carbon absorption and sequestration, pollution removal, reduce storm water runoff and improved health and wellbeing.

6.1 Urban Forest Strategy

An Oxford Urban Forest Strategy is a vision of what the urban forest will become and provides a roadmap of how it will be achieved. A master plan shifts tree management from an amenity and risk-based approach, to more sustainable management focused on values, enhancement and increased resilience in the face of future threats. It looks holistically at public and privately owned trees, at a landscape scale, and it extends over a long period of time (20+ years) to affect lasting change.

Producing an Urban Forest Strategy demonstrates Oxford's commitment to deliver on international, European and national policies on urban liveability in the face of the climate emergency.

An Oxford Urban Forest Strategy will highlight the current structure and composition of the urban forest, its functions, and it's benefits based on this above i-Tree Eco study.

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[15] Dyderski *et al*, 2018

To be fully effective Oxford's Urban Forest Strategy should engage with all stakeholders in the urban forest, and be imbedded within and supported by other local policy documents on climate change, flood resilience, development management, future planning, sustainability, and health and wellbeing.

Based on our work within the UK, Europe and our international collaborations we would suggest this document included the following steps;

1. Create a vision for Oxford's public and privately owner trees (such as Singapore's 'City within a Garden').[16]

2. Set a realistic but ambitious goal, to increasing tree canopy cover, on both public and private land. This should be based on actual available space for tree planting and using Multi Criteria Decision Analysis to maximise the benefits of new tree planting. This is an urgent matter as 11% of Oxford's tree population is comprised of ash (See Section 4.3 above), which is largely anticipated to be lost to Ash dieback disease.

3. Minimise the loss of existing tree canopy cover. Plan to protect existing mature and maturing trees, together with increasing the planting of large-stature trees, (where possible) to increase canopy cover and the provision of greatest ecosystem services benefits.

4. Secure replacement tree planting within the regulatory frame work of the Environment Bill and Town and Country Planning Act. Create local planning policies which measure tree tree canopy cover by area[17] or amenity valuation metrics, to secure funding for offsite compensation in support of Urban Forest Strategy and Tree Planting Strategy.

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[16] National Parks Board Singapore (2014)

[17] The Plymouth & South West Devon Joint Local Plan (2020)

5. Supplement the i-Tree Eco study with a systematic and thorough inventory of all the trees under council ownership.

6. Create an online ‘dashboard’ to show current data and future changes to the urban forest.

7. Include a reporting framework so progress against the Urban Forest Master Plan can be communicated to stakeholders and the plan can be monitored and progress reviewed.

6.2 Tree Planting Strategy

New tree planting initiatives based on tree numbers, or canopy cover is high on the national and local political agenda. These aspirations need to be focused into structured and sustainable strategies, which support the long-term development of our urban forests and complement our Urban Forest Master Plans.

A Tree Planting Strategy will deliver on the tree canopy growth aspirations of the Urban Forest Strategy. The Tree Planting Strategy can be used as a guide of what to plant, where to plant, when to plant, how to plant, and how it will be managed and maintained once tree is in the ground.

A Tree Planting Strategy should:

1. Engage with and empower all local stakeholders in the urban forest to identify barriers to new tree planting early and seek solutions, and to help deliver tree planting on private and publicly owned land.

2. Use a Multi Criteria Decision Analysis (MCDA) approach which utilises factors such as social deprivation, existing low canopy cover and proximity to transportation networks (zones with increased air pollution) to identify the priority areas for new tree planting (See Section 4.4 above). The results should also be challenged by experts with local knowledge and experience as to maximise success.

4. Increase tree genus and species diversity within the planting matrix (with due consideration to local site factors) to reduce the likelihood and impact from any given pest or disease outbreak and northerly migration of species due to climate change. It should also look to increase the genetic diversity where common species are selected and reduce reliance on common colonial varieties (Refer to Section 4 above).

6. Ensure species are selected that are appropriate to the site to maximise tree benefit delivery and realise the full site potential. It is essential that trees are planted with some level of community engagement if planting initiatives are going to succeed.[18]

[18] Forest Research (2018)

Appendix I: Comparison with other UK and European Cities.

Project	% Tree cover	Number of trees	Carbon storage (tons)	Carbon sequestration (tons/yr)	Pollution removal (tons/yr)	Most common Species
Barcelona (Spain)	25.2	1,419,823	113,437	5,422	305	Holm oak, Aleppo pine and London plane.
Cardiff	18.9	573,442	131,045	3,231	147	Ash, sycamore and beech.
Edinburgh	11.8	638,000	179,000	4,885	195	Sycamore, holly and silver birch.
Glasgow	15.0	2,000,000	183,000	9,000	283	Ash, hawthorn and alder.
London (Inner)	13.0	1,587,000	499,000	15,900	561	Sliver birch, lime and apple.
London (Outer)	14.0	6,834,000	1,868,000	61,300	1,680	Sycamore, oak and Hawthorn.
Oxford	16.0	248,233	76,414	2,250	42	Ash, crack willow and white poplar.
Malmö (Sweden)	7.7	62,640	14,570	818	25	White willow, sweet cherry and small leaved lime.
Sheffield	18.4	3,864,630	545,315	21,837	374	Silver birch, sycamore and sessile oak (Urban trees)
Strasborg (France)	35.0	588,000	127,895	4,060	32	Beech, Ash and sycamore.
Torbay	11.8	818,000	98,100	3,320	50	Leyland Cypress, ash and sycamore.

Source: USDA Forest Service and Treeconomics

Appendix II: Species Importance Ranking List

Rank	Scientific Name	Common Name	% Population	% Leaf Area	DV[a]
1	Fraxinus excelsior	European ash	11.10	14.10	25.20
2	Salix fragilis	Crack willow	10.80	7.90	18.60
3	Cupressocyparis leylandii	Leyland Cypress	5.10	6.10	11.20
4	Acer campestre	Field maple	5.80	5.00	10.80
5	Populus alba	White poplar	8.00	2.10	10.10
6	Prunus avium	Wild cherry	4.60	3.80	8.50
7	Acer pseudoplatanus	Sycamore	3.80	4.60	8.40
8	Quercus robur	English oak	3.80	4.60	8.40
9	Crataegus monogyna	Hawthorn	4.00	3.00	7.10
10	Ulmus x hollandica	Dutch Elm	0.40	6.30	6.60
11	Betula pendula	Silver birch	3.60	2.70	6.30
12	Malus	Apple	3.70	1.90	5.60
13	Malus domestica	Apple	3.40	1.40	4.80
14	Tilia platyphyllos	Large leaved lime	1.00	3.30	4.30
15	Aesculus hippocastanum	Horse chestnut	1.00	2.90	3.90
16	Fagus sylvatica	Beech	0.70	2.80	3.50
17	Sorbus aria	Whitebeam	1.50	1.80	3.30
18	Tilia cordata	Small leaved lime	1.60	1.30	2.90
19	Corylus colurna	Turkish hazel	2.50	0.30	2.80
20	Tilia tomentosa	Silver lime	0.80	1.70	2.50
21	Corylus avellana	Hazel	1.90	0.60	2.50
22	Ilex aquifolium	Holly	1.10	1.20	2.40
23	Acer platanoides	Norway maple	0.90	1.40	2.30
24	Prunus pissardii	Cherry plum	1.50	0.80	2.30
25	Acer platanoides 'Crimson King'	Purple Norway maple	0.40	1.80	2.20
26	Metasequoia glyptostroboides	Dawn redwood	0.80	1.20	2.00
27	Tilia euchlora	Caucasian lime	0.20	1.60	1.80
28	Taxus baccata	Yew	0.40	1.40	1.80
29	Pinus sylvestris	Scots pine	0.70	1.10	1.80
30	Carpinus betulus	Hornbeam	1.30	0.60	1.80
31	Ulmus procera	English elm	0.40	1.00	1.40
32	Populus nigra	Black poplar	0.30	1.00	1.30
33	Chamaecyparis lawsoniana	Lawson cypress	0.70	0.60	1.30
34	Prunus cerasifera	Black cherry plum	0.50	0.70	1.20
35	Prunus domestica	Plum	0.80	0.40	1.20
36	Picea abies	Norway spruce	0.90	0.30	1.20
37	Sorbus aucuparia	Mountain ash	0.90	0.20	1.00
38	Eriobotrya japonica	Loquat	1.00	0.10	1.00
39	Aesculus x carnea 'Briottii'	Red horse chestnut	0.30	0.60	0.90
40	Salix alba	White willow	0.70	0.10	0.90

Rank	Scientific Name	Common Name	% Population	% Leaf Area	DV[a]
41	Aesculus x carnea	Red horse chestnut	0.20	0.60	0.80
42	Sambucus canadensis	American elder	0.50	0.30	0.80
43	Buddleja cordata	Butterfly bush	0.30	0.40	0.70
44	Prunus laurocerasus	Cherry laurel	0.30	0.40	0.70
45	Juglans nigra	Black walnut	0.20	0.40	0.60
46	Tilia x europaea	Common lime	0.10	0.40	0.60
47	Eucalyptus gunnii	Sweet gum	0.40	0.20	0.60
48	Laburnum anagyroides	Laburnum	0.50	0.10	0.60
49	Juglans regia	Walnut	0.10	0.30	0.50
50	Tilia americana	Basswood	0.10	0.30	0.50
51	Catalpa bignonioides	Indian bean tree	0.20	0.20	0.50
52	Pinus nigra	Black pine	0.10	0.30	0.40
53	Acer saccharum	Sugar maple	0.40	0.10	0.40
54	Cordyline australis	Torbay palm	0.30	0.10	0.40
55	Betula papyrifera	Paper birch	0.30	0.10	0.40
56	Prunus spinosa	Blackthorn	0.30	0.10	0.40
57	Prunus	Cherry	0.30	0.10	0.40
58	Magnolia grandiflora	Magnolia	0.10	0.20	0.30
59	Acer	Maple	0.10	0.20	0.30
60	Populus nigra v. italica	Lombardy polar	0.30	0.10	0.30
61	Sorbus sargentiana	Sargent's rowan	0.30	0.10	0.30
62	Prunus padus	Bird cherry	0.20	0.10	0.30
63	Larix leptolepis	Japanese larch	0.10	0.10	0.30
64	Cupressus sempervirens	Italian cypress	0.30	<0.10	0.30
65	Alnus glutinosa	Alder	0.30	<0.10	0.30
66	Quercus/live ilex	Holm oak	0.10	0.10	0.20
67	Prunus subhirtella	Winter-flowering cherry	0.10	0.10	0.20
68	Ceanothus	Ceanothus	0.20	<0.10	0.20
69	Myrtus communis	Myrtle	0.20	<0.10	0.20
70	Quercus cerris	Turkey oak	0.10	<0.10	0.20
71	Viburnum	Viburnum	0.10	<0.10	0.20
72	Robinia pseudoacacia	False acacia	0.10	<0.10	0.20

DV [a] = Dominance value (% population + % leaf area)

Appendix III: Tree Values by species

Species	Number of trees	Carbon stored (mt)	Gross Seq (mt/yr)	Avoided Runoff (m^3/yr)	Pollution Removal (mt/yr)	Replacement Cost (£)
Salix fragilis	26691	9501.11	290.36	4224.69	3.26	£22,012,001
Fraxinus excelsior	27464	7917.77	280.40	7569.43	5.85	£21,789,497
Corylus colurna	6171	5205.54	111.05	180.68	0.14	£20,718,029
Quercus robur	9416	8739.30	194.46	2470.24	1.91	£20,250,609
Cupressocyparis leylandii	12648	2462.80	89.58	3280.12	2.53	£11,592,288
Fagus sylvatica	1802	3798.81	52.21	1504.75	1.16	£9,813,726
Acer pseudoplatanus	9403	2659.86	115.63	2496.36	1.93	£9,030,785
Tilia platyphyllos	2462	1968.22	45.26	1769.32	1.37	£7,573,862
Aesculus hippocastanum	2399	2999.54	78.38	1550.11	1.20	£6,940,078
Populus alba	19849	2141.39	71.70	1136.13	0.88	£6,564,487
Prunus avium	11508	2414.43	123.45	2056.28	1.59	£6,480,476
Ulmus x hollandica	964	7230.91	12.05	3359.60	2.60	£6,290,687
Metasequoia glyptostroboide	1928	973.46	24.44	662.19	0.51	£5,510,840
Acer campestre	14438	2246.82	105.68	2681.01	2.07	£5,345,806
Taxus baccata	932	411.03	13.79	765.53	0.59	£3,919,738
Tilia euchlora	466	493.25	17.51	877.82	0.68	£3,570,510
Tilia cordata	3981	543.81	35.20	695.35	0.54	£3,376,322
Pinus sylvestris	1697	612.25	19.94	579.67	0.45	£3,160,052
Acer platanoides 'Crimson K	962	739.31	34.30	983.86	0.76	£3,040,582
Acer platanoides	2222	744.96	34.31	749.58	0.58	£2,930,011
Malus domestica	8519	814.67	59.59	745.37	0.58	£2,818,519
Betula pendula	8936	942.31	72.93	1440.24	1.11	£2,796,554
Tilia x europaea	334	475.65	14.88	230.17	0.18	£2,590,511
Crataegus monogyna	10022	1036.24	74.67	1637.67	1.27	£2,499,641
Malus	9089	875.87	59.46	1021.39	0.79	£2,334,167
Aesculus x carnea	435	624.79	24.49	337.76	0.26	£2,305,577
Chamaecyparis lawsoniana	1675	365.90	15.05	337.64	0.26	£2,121,476
Eucalyptus gunnii	964	746.88	37.49	122.08	0.09	£2,071,117
Sorbus aria	3798	538.13	41.19	954.51	0.74	£1,908,340
Ilex aquifolium	2801	511.13	39.06	659.55	0.51	£1,903,210
Populus nigra	647	801.06	16.78	539.66	0.42	£1,701,757
Populus nigra v. italica	647	404.90	21.07	44.09	0.03	£1,311,052
Pinus nigra	334	202.37	4.02	163.77	0.13	£1,111,182
Tilia tomentosa	1928	217.07	11.05	899.60	0.70	£1,088,429
Catalpa bignonioides	615	263.57	14.73	122.65	0.09	£1,088,295
Prunus cerasifera	1141	737.61	25.20	396.47	0.31	£959,712
Prunus laurocerasus	719	316.76	12.96	229.81	0.18	£867,758
Corylus avellana	4618	236.27	17.33	341.16	0.26	£693,569
Prunus pissardii	3705	262.80	26.68	408.58	0.32	£625,250
Carpinus betulus	3192	171.80	24.11	301.69	0.23	£616,585
Sambucus canadensis	1363	182.90	8.88	145.49	0.11	£615,678
Juglans nigra	466	149.34	6.64	205.90	0.16	£496,709
Prunus domestica	2053	221.18	19.52	219.48	0.17	£448,415
Aesculus x carnea 'Briottii'	647	159.79	7.27	321.61	0.25	£416,544
Buddleja cordata	782	139.52	9.73	221.08	0.17	£396,402
Cordyline australis	647	5.68	0.14	74.73	0.06	£370,368

Species	Number of trees	Carbon stored (mt)	Gross Seq (mt/yr)	Avoided Runoff (m^3/yr)	Pollution Removal (mt/yr)	Replacement Cost (£)
Ulmus procera	964	149.61	13.72	519.18	0.40	£350,470
Magnolia grandiflora	364	80.32	6.66	103.55	0.08	£319,397
Picea abies	2199	113.19	8.34	144.86	0.11	£258,737
Prunus	723	112.77	5.87	49.78	0.04	£247,472
Sorbus aucuparia	2126	45.08	5.80	93.05	0.07	£179,112
Prunus padus	555	86.92	4.90	52.32	0.04	£176,977
Laburnum anagyroides	1143	88.97	7.00	48.32	0.04	£167,009
Eriobotrya japonica	2401	23.56	7.43	42.74	0.03	£158,807
Prunus spinosa	638	80.76	4.97	74.48	0.06	£144,970
Larix leptolepis	334	83.77	2.54	79.79	0.06	£121,681
Tilia americana	371	26.73	3.03	169.83	0.13	£113,169
Salix alba	1858	77.09	4.02	75.70	0.06	£81,686
Juglans regia	359	28.70	3.75	185.33	0.14	£80,710
Acer saccharum	964	7.95	3.23	27.54	0.02	£72,309
Sorbus sargentiana	647	23.11	2.56	37.91	0.03	£55,316
Betula papyrifera	806	8.85	2.67	39.83	0.03	£54,026
Robinia pseudoacacia	359	18.68	2.92	7.68	0.01	£50,748
Cupressus sempervirens	647	12.68	2.03	9.28	0.01	£47,685
Quercus/live ilex	364	18.64	3.05	31.45	0.02	£45,849
Prunus subhirtella	291	22.00	3.20	37.71	0.03	£40,990
Quercus cerris	364	10.98	2.30	12.62	0.01	£31,095
Myrtus communis	435	7.27	1.07	20.55	0.02	£28,762
Viburnum	364	4.40	1.29	12.59	0.01	£27,294
Ceanothus	537	5.37	1.10	6.88	0.01	£23,794
Acer	291	12.94	1.20	111.26	0.09	£22,838
Alnus glutinosa	647	54.97	0.71	8.56	0.01	£12,794

Appendix IV: Methodology

i-Tree Eco is designed to use standardised field data from randomly located plots and local hourly air pollution and meteorological data to quantify forest structure and its numerous effects, including:

- Forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by trees, and its associated percent air quality improvement throughout a year. Pollution removal is calculated for ozone, sulphur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<2.5 microns and <10 microns).
- Total carbon stored and net carbon annually sequestered by trees.
- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as (but not limited too) Asian longhorned beetle, emerald ash borer, gypsy moth, and Ash Dieback.

In the field 0.04 hectare plots were randomly distributed. All field data were collected during the leaf-on season to properly assess tree canopies. Within each plot, data collection includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback.

To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations. To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O_2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of trees account for decomposition.

Recent updates (2011) to air quality modelling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulphur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models. As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere.

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis. The value of avoided runoff is based on estimated or user-defined local values. As the local values include the cost of treating the water as part of a combined sewage system the lower, national average externality value for the United States is utilised and converted to local currency with user-defined exchange rates.

Replacement Costs were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition and location information .

US externality and UK social damage costs

The i-Tree Eco model[19] [20] provides figures using US externality and abatement costs. Basically speaking this reflects the cost of what it would take a technology (or machine) to carry out the same function that the trees are performing, such as scrubbing the air or locking up carbon.

For the UK [21] however, the appropriate way to monetise the carbon sequestration benefit is to multiply the tonnes of carbon stored by the non-traded price of carbon, because this carbon is not part of the EU carbon trading scheme. The non-traded price is not based on the cost to society of emitting the carbon, but is based on the cost of not emitting the tonne of carbon elsewhere in the UK in order to remain compliant with the Climate Change Act .

This approach gives higher values to carbon than the approach used in the United States, reflecting the UK Government's response to the latest science, which shows that deep cuts in emissions are required to avoid the worst affects of climate change.

Official pollution values for the UK are based on the estimated social cost of the pollutant in terms of impact upon human health, damage to buildings and crops. Values were taken from the Interdepartmental Group on Costs and Benefits (IGCB) based on work by DEFRA. They are a conservative estimate because they do not include damage to ecosystems; SO2 negatively impacts trees and freshwater, and NOx contributes to acidification and eutrophication. For PM10s, which are the largest element of the air pollution benefit, a range of economic values is available depending on how urban (and densely populated) the area under consideration is. We used the 'transport outer conurbation' values as a conservative best fit, given the population density data above.

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[19] UFORE, 2010

[20] Nowake *et al*, 2010

[21] Rogers *et al,* 2012

For both carbon and air pollution removal, the assumption has been made that the benefit to society from a tonne of gas removed is the same as the cost of a tonne of the same gas emitted.

Bibliography

Barron, S., Sheppard, S. Condon, P. (2016). Urban Forest Indicators for Planning and Designing Future Forests. Forests. 7. 10.3390/f7090208.

Chuang, W.C., Boone, C.G., Locke, D.H., Grove, J.M., Whitmer, A; Buckley, G., Zhang, S (2017) Tree canopy change and neighborhood stability: A comparative analysis of Washington, D.C. and Baltimore, MD. Urban Forestry & Urban Greening. 27. pp. 363-372.

Clark, J.R., Matheny, N.P., Cross, G., Wake, J. A Model of Urban Forest Sustainability. Journal of Aboriculture. 23(1) pp 17-30.

Department for Environment, Food and Rural Affairs (2018) 25 Year environment Plan [online] Available at: https://www.london.gov.uk/sites/default/files/london_environment_strategy_0.pdf

Department for Environment, Food and Rural Affairs (2018) Consultation on Protecting and Enhancing England's Trees and Woodlands [online] Available at: https://consult.defra.gov.uk/forestry/protecting-trees-and-woodlands/

Department for Environment, Food and Rural Affairs (2018) Protecting and enhancing England's trees and woodlands. Consultation. [online] Available at: https://consult.defra.gov.uk/forestry/protecting-trees-and-woodlands/supporting_documents/TreeswoodlandsconsultdocumentRB.pdf

Department for Environment, Food and Rural Affairs (2019) Consultation outcome. Summary of responses and government response [online] Available at: https://www.gov.uk/government/consultations/tree-and-woodlands-introducing-measures-for-felling-street-trees/outcome/summary-of-responses-and-government-response

Dryerski, M. K., Paz, S., Lee, E., Andrezj, M., and Jagodzinki M. (2018) How much does climate change threaten European fires tree species distributions? Global change biology, 24(3), 1150-1163. [online] Available at: http://doi.org/10.1111/gcb.13925

Environment Agency (2017) Policy Paper Oxford Flood Scheme [online] Available at: https://www.gov.uk/government/publications/oxford-flood-scheme/oxford-flood-scheme

Harshaw, H., Sheppard, S., Lewis, J. (2007). A review and synthesis of social indicators for sustainable forest management. BC Journal of Ecosystems and Management. 8.

Kenney, W.A., van Wassenaer, P.J.E., Satel, A.L. (2011) Criteria and Indicators for Strategic Urban Forest Planning and Management. Arboriculture & Urban Forestry. 37 (3) pp. 108-117.

Ostberg, J., Delshammar, T., Wiström, B., Nielsen, A. (2012). Grading of Parameters for Urban Tree Inventories by City Officials, Arborists, and Academics Using the Delphi Method. Environmental management. 51. pp. 694-708.

gov.uk (2019) 25 Year Environment Plan [online] Available at: https://www.gov.uk/government/publications/25-year-environment-plan

gov.uk (2019) Environment Bill Policy Statement [online] Available at: https://www.gov.uk/government/publications/environment-bill-2019/environment-bill-policy-statement#restoring-and-enhancing-nature-and-green-spaces

Forest Research (2018) Urban Tree Manual[online] Available at: https://www.forestresearch.gov.uk/tools-and-resources/urban-tree-manual/

Greater London Authority (2018) London Environment Strategy [online] Available at: https://www.london.gov.uk/sites/default/files/london_environment_strategy_0.pdf

Leff, M (2016) The Sustainable Urban Forest. A Step-by-Step Approach. Davey Institute & The USDA Forest Service [online] Available at: https://www.itreetools.org/documents/485/Sustainable_Urban_Forest_Guide_14Nov2016_pw6WcW0.pdf

National Parks Board Singapore (2014) Singapore -City in a Garden. Enhancing Greenery and Biodiversity [online] Available at: https://www.cbd.int/doc/meetings/city/subws-2014-01/other/subws-2014-01-presentation-singapore-en.pdf

Plymouth City Council, South Hams District Council and West Devon Borough Council

(2020) The Plymouth & South West Devon Joint Local Plan [online] Available at:https://www.plymouth.gov.uk/planningandbuildingcontrol/plymouthandsouthwestdevonjointlocalplan

Rogers, K., Sunderland, T., and Coish, N. (2012) What proportion of the costs of urban trees can be justified by the carbon sequestration and air quality benefits they provide? Arboricultural Journal V34, 2.

Tree Council (2019) Ash Dieback: An Action Plan Toolkit. Summer 2019 update (first published February 2018) [online] Available at: https://www.treecouncil.org.uk/Portals/0/Chalara%20docs/Tree%20Council%20Ash%20Dieback%20Toolkit%202.0.pdf?ver=2019-09-10-140012-347

UFORE (2010) (i-Tree Eco) Analysis of Chicago. [online] Available at: https://www.fs.usda.gov/treesearch/pubs/34794

Woodland Trust (anon) Ash Dieback (Hymenoscyphus fraxineus) [online] Available at: https://www.woodlandtrust.org.uk/trees-woods-and-wildlife/tree-pests-and-diseases/key-tree-pests-and-diseases/ash-dieback/