Sandwell's Natural Capital Valuation

The Authors

Catherine Vaughan-Johncey - Treeconomics

Harry Munt - Treeconomics

Kris Sales - Forest Research

Alex Chambers-Ostler - Forest Research

Kieron Doick - Forest Research

Ian McDermot - Birmingham Tree People

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Finally, we wish to thank all landowners and members of the public who allowed access to their properties for the collection of the field data.

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Executive Summary

The Black Country is an area within the West Midlands with a rich past rooted in its industrial heritage. The West Midlands is the most built up region in the UK, with a population of nearly 3 million people; the four districts of the Black Country support a population of around 1.2 million people. While the outskirts of the sub-region are part of the designated West Midlands Green Belt, with green belt land also forming green wedges which encroach into the major urban area, the BC, in the main, may be considered urban in character. Sandwell covers an area of 8,556 ha and has a population of 341,900[1].

The urban forest of Sandwell is a vital resource for the West Midlands. It provides a number of benefits to the residents, and the ecosystem services reported here are just a few of them as it is currently not possible to value and report all ecosystem services. This study captures an immediate snapshot of the urban forest at the present time in relation to the plots sampled. It does not consider how the urban forest has or might change over time, or the reasons for this change. Its purpose is to provide a means to make informed decisions on how the urban forest could and should change in the future, and how to ensure that it is healthy and resilient.

This report is supplementary to the complete Black Country Natural Capital Valuation report, and complemented by the individual reports for Dudley, Walsall and Wolverhampton.

The objectives of the study were to:

- Illustrate the structure of the urban forest, including the species composition, diversity, and condition.
- Calculate the ecosystem service values provided by the trees using the i-Tree Eco software suite.
- Promote the urban forest and emphasise the benefits it provides.
- Calculate the economic value of the urban forest.
- Conduct a risk analysis of susceptibility to pests and diseases.

The recommendations from this study include:

- Continue to plant a wide diversity of species and consider producing a tree planting strategy.
- Retain large, mature trees wherever possible.
- Increase planting in areas that have lower canopy cover to achieve a greater green equity.
- Use CAVAT to highlight amenity values to developers and communities.
- Set up community tree care schemes to engage local people and help to ensure the good health of young trees.
- Using the data within this report to inform further reports, strategies, and policies.

[1] ONS census (2021)

Key findings include:

- i-Tree Eco estimates that there are approximately 265,000 trees in Sandwell. Tree cover stands at an estimated 18.1% and shrub cover at an estimated 17.2%.
- 108 species of tree were recorded across Sandwell study area. The most common tree species are Field maple and English oak, each with an estimated 17,800 trees, and Bird cherry, with an estimated 9,790 trees.
- These trees and shrubs have the potential to remove over 15.3 tonnes of air pollution annually at a value of £828,000. These pollutants include sulphur dioxide (SO_2), particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_2).
- These trees reduce surface water runoff by over 130,000 m^3 per year. This volume is equivalent to 52 Olympic swimming pools of surface runoff being averted every single year, and it is worth an estimated £128,000 in avoided water treatment costs.
- In total, the trees store around 361,000 tonnes of carbon and sequester 5,550 tonnes of carbon annually with associated values of around £328 million and £5 million respectively.
- Trees also confer many other benefits such as habitat provision, soil conservation and noise reduction which currently cannot be valued, but should be considered in conjunction with this document to shape policy or strategy documents.
- The amenity value of the trees was calculated to be £9.4 billion, as determined using an amended CAVAT valuation approach.
- There is a good distribution of both semi-mature and mature trees, however there are comparatively few young trees. Planting of young trees is vital to replace dying or removed trees and to further enhance the urban forest.
- Sandwell's urban forest performs well in terms of its structure, with a wide variety of species. No single species exceeds 10% of the total population, which is in line with the 10:20:30 guideline[2], indicating that the urban forest will be more resilient to pests and diseases. The most prominent threats in this regard are Ash Dieback, Asian Longhorned Beetle, Ramorum disease and Phytophthora kernoviae.
- Managing trees to ensure they reach their full potential, namely in their stature is important. Large trees provide far more benefits than small trees, so allowing enough space for trees to reach their full canopy potential is key.
- It is recommended that this data is used to develop plans for the urban forest at neighbourhood level within Sandwell to assess and improve green equity.

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[2] Santamour, 1990

Highlights

Structure and Composition Headline Figures		
Number of Trees (estimate)	265,000	
Tree Density (trees/hectare)	31	
Tree Canopy Cover	18.1% (1,540 ha)	
Shrub Cover	17.2%	
Most Common Tree Species	Field maple (6.7%), English oak (6.7%), Bird cherry (3.7%)	
Replacement Cost (CTLA)	£684 million	
Amenity Valuation (CAVAT)	£9.4 billion	
Proportion of Trees in Good or Excellent Condition	81%	
Ecosystem Services Headline Figures		
Total Carbon Storage	361,000 tonnes	£328,000,000
Annual Carbon Sequestration	5,550 tonnes	£5,040,000
Annual Pollution Removal	15.3 tonnes	£828,000
Annual Avoided Runoff	130,000 m^3	£128,000
Total Annual Benefits	**£5,996,000**	

	Dudley	Walsall	Wolverhampton
Total area (ha)	9,796	10,397	6,944
Canopy cover (ha)	1,670 (17%)	1,140 (10.9%)	1,150 (16.5%)
Total Carbon Storage	174,000 tonnes	141,000 tonnes	168,000 tonnes
Annual Carbon Sequestration	5,870 tonnes	6,900 tonnes	6,150 tonnes
Annual Pollution Removal	17.7 tonnes	14.5 tonnes	14.5 tonnes
Annual Avoided Runoff	162,000 m^3	172,000 m^3	151,000 m^3

Table 1: Headline figures for Sandwell and a comparison of outputs from the other i-Tree Eco studies in the Black Country

Reference Values and Methodology Notes for Calculations:

Number of Trees: The sample inventory figures are estimated by extrapolation from the sample plots. For further details see the methodology section.

Tree Canopy/Shrub Cover: The area of ground covered by the leaves of trees and shrubs when viewed from above (not to be confused with leaf area which is the total surface area of leaves). As shrubs can be underneath trees these two figures ‘overlap’ and have not been added together.

Replacement Cost: The cost of having to replace a tree with a similar tree using the Council of Tree and Landscape Appraisers (CTLA) methodology from the Royal Institute of Chartered Surveyors.

Capital Asset Value for Amenity Trees (CAVAT): A valuation method with a similar basis to the CTLA Trunk Formula Method, but one developed in the UK to express a tree’s relative contribution to public amenity and its prominence in the urban landscape. For i-Tree Eco studies the amended quick method is used.

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 the CO_2 equivalent multiplied by the Department for Business, Energy and Industrial Strategy figures for the non traded central estimate cost of CO_2. This is currently £248 per metric ton for 2022.

Pollution Removal: This value is calculated based on the 2020 UK social damage costs for ‘Road Transport Urban Large’; nitrogen dioxide - £11.973 per kg, sulphur dioxide - £6.926 per kg, particulate matter less than 2.5 microns - £224.525 per kg.

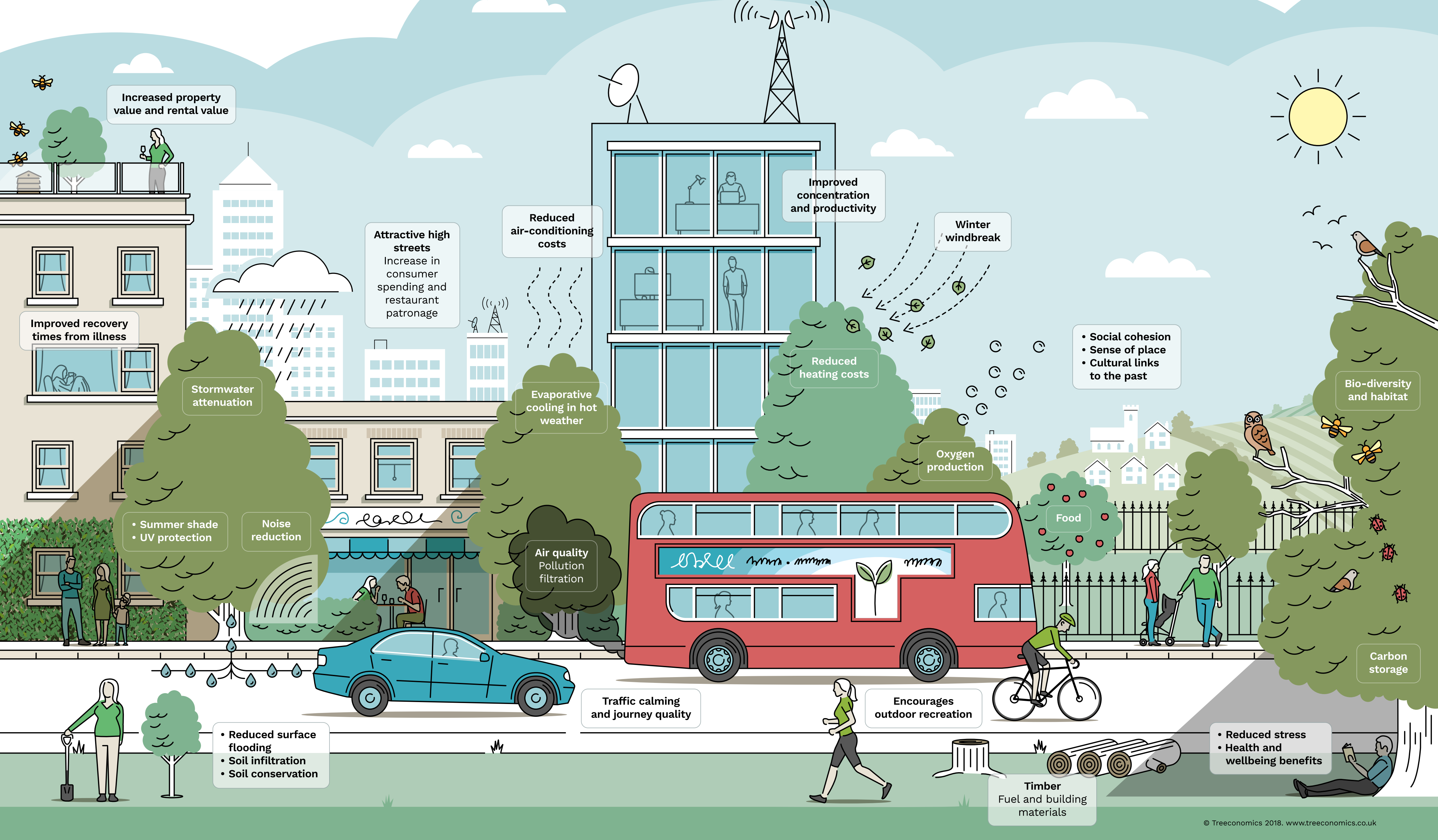
Avoided Run-off: Based on the amount of water held in the tree canopy and re-evaporated after the rainfall event. The value is based on a volumetric charge from Severn Trent Water of £0.98 per cubic metre and includes the cost of avoided energy and associated greenhouse gas emissions.

Total Annual Benefits: Sum of the monetary values of carbon sequestration, pollution removal and avoided run-off. Carbon storage is not included since it is not an annual benefit, rather it is a portion of all of the carbon that has been sequestered over the lifespan of the tree.

Data was processed using iTree Eco Version 6.0.21.

The Benefits of Trees

Treeconomics



Introduction and Background

The pressure on our natural environment, especially in areas where ‘the green meets the grey’, is increasing.

Unfortunately, ‘green infrastructure’ or 'natural capital’ is often poorly understood and undervalued, and the benefits it provides are often inadequately described and quantified. Consequently, our natural capital is rarely seen as the asset it is and the benefits, public good or ecosystem services it provides remain poorly expressed.

Economic valuation of the benefits provided by our natural capital can help to mitigate this undervaluation. Furthermore, with improved information on the performance of our natural assets we can make better decisions.

A first step in the management of this natural capital is to evaluate its current structure and distribution, obtaining a baseline from which to set goals and to monitor any changes.

This 2021-2022 i-Tree Eco study was commissioned by the Black Country Consortium and provides detailed information on the scale of benefits provided by the natural capital in Sandwell and the other districts in the Black Country, expressing the value of some of those benefits in monetary terms. For the purposes of this report natural capital refers to trees, shrubs, soil and grassland.

Report Scope

This study investigates the structure and composition of Sandwell's urban forest and the benefits it delivers. The report provides baseline information which can be used to inform future decision making and strategy. Understanding the structure and composition of the urban forest is vital to its conservation and development, and by showcasing the economic value of benefits provided by Sandwell's trees, increased awareness can be used to encourage investment in Sandwell's natural capital and wider environment.

The assessment presented in this report provides the opportunity to explore several areas of interest including:

- Maintaining and improving current tree cover in Sandwell.
- Identifying areas vulnerable to loss of tree cover (e.g. as a result of pests, diseases, or development) which would benefit from new planting or enhanced protection.

This report can be used by:

- those writing policy.
- those interested in the conservation of local nature.
- those involved in strategic planning to build resilience or planning the sustainable development and resilience of Sandwell.
- those who are interested in local trees for improving their own and others' health, wellbeing, and enjoyment across Sandwell.

Sandwell i-Tree Eco project aims to:

- Illustrate the structure of Sandwell's urban forest, including the species composition, population diversity, and tree condition.
- Calculate the ecosystem service values provided by Sandwell's urban forest and rank the importance of different trees in terms of ecosystem service provision using the i-Tree Eco software suite.
- Promote Sandwell's urban forest to all, and emphasise the benefits it provides.
- Establish values that can be used in cost-benefit analysis to better inform asset and risk management.
- Conduct a risk analysis of the susceptibility of Sandwell's urban forest to pests and diseases.

Methodology

To gather a collective representation of Sandwell's urban forest across both public and private land, an i-Tree Eco plot-based assessment was undertaken. 238 randomly allocated plots of 0.04ha (400m^2) were surveyed in Sandwell. This equates to 1 plot every 36 ha.

The field data, combined with local hourly pollution and meteorological data, was submitted to the i-Tree server which calculates the outputs listed in Table 2 below. There are in excess of 100 reports that can be generated by i-Tree Eco and not all are listed here or referenced in this report.

This data was collected by volunteers and surveyors during 2021.

Structure and Composition	Species diversity; Tree canopy cover; Age class; Leaf area; Ground cover types; % leaf area by species.
Ecosystem Services	Air pollution removal by trees for NO_2, SO_2, and $PM_{2.5}$; % of total air pollution removed by trees; Current carbon storage; Carbon sequestration; Stormwater attenuation.
Structural and Functional Values	Replacement cost in £; Carbon storage value in £; Carbon sequestration value in £; Pollution removal value in £.
Additional Information	Potential insect and disease impacts; Oxygen production; Forest food production; UV Screening values.

Table 2: Study outputs.

As the plots were randomly allocated to ensure a statistically significant distribution across Sandwell, they fall on both public and private land. While most areas could be accessed with permission, some could not. In the event that the plot landed in an area that was inaccessible, a back-up plot was used. This was a randomly allocated plot within the same grid square as the original.

Data Limitations

While Sandwell's trees provide a plethora of benefits. i-Tree Eco does not quantify all of the services that trees provide; hence, the value of the ecosystem services provided in this report are a conservative estimate. The methodology has been devised to provide a statistically reliable representation of Sandwell's urban forest in 2022. This report is concerned with the trees and shrubs within Sandwell. It should be used only for generalised information on the urban forest structure, function, and value. Where detailed information for a specific area is required, further detailed survey work should be carried out.

Field Survey Data Collected

Plot Information:

- Land use type
- Percent tree cover
- Percent shrub cover
- Percent plantable space
- Percent ground cover type

Tree information:

- Species
- Stem diameter (DBH)
- Total height
- Height to crown base
- Crown spread
- Percent foliage missing
- Percent dieback
- Crown light exposure

The Urban Forest Resource

Ground Cover

Ground cover refers to the types of surface or vegetation within each plot. Within Sandwell the most common ground cover types are grasses (39%), buildings (24.2%), tar (13.6%) and cement (13%). Other ground covers including bare soil, herbs and water were also present in low quantities and recorded.

Of the surveyed area, 18.1% of Sandwell is under tree canopy cover, with 17.2% under shrub cover (note that shrubs are also present under tree cover and so these two figures 'overlap').

The survey also showed that a further 40% of land within the plots could (in theory) be planted with trees. Utilising available space to increase the tree canopy cover is one way to reduce air and noise pollution, and increase carbon sequestration.

Sandwell has a tree canopy cover of 18.1%. The average for the UK is 16%, though coastal and rural areas are often lower, and peri-urban areas are often higher.

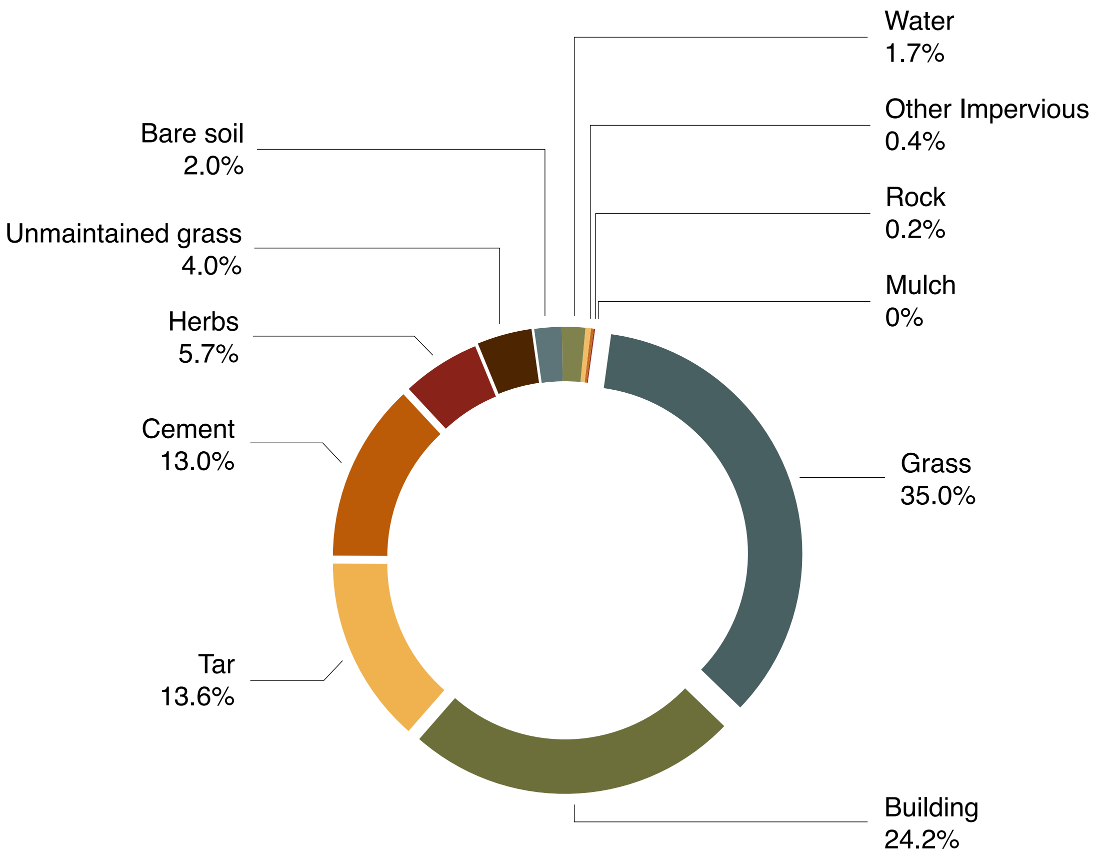


Figure 1: Ground cover types within plots.

Land Use

Figure 2 shows the average land cover across Sandwell. Surveyed plots indicate that on average Sandwell's largest land use is residential (41.5%) and commercial/industrial (17.9%). Parkland accounts for 10.7% of land cover across Sandwell.

Sandwell has considerably less agricultural land than the other districts, even the City of Wolverhampton, and it also has the lowest amount of green space cover.

2.6% of land in Sandwell is vacant-this could be repurposed for green spaces!

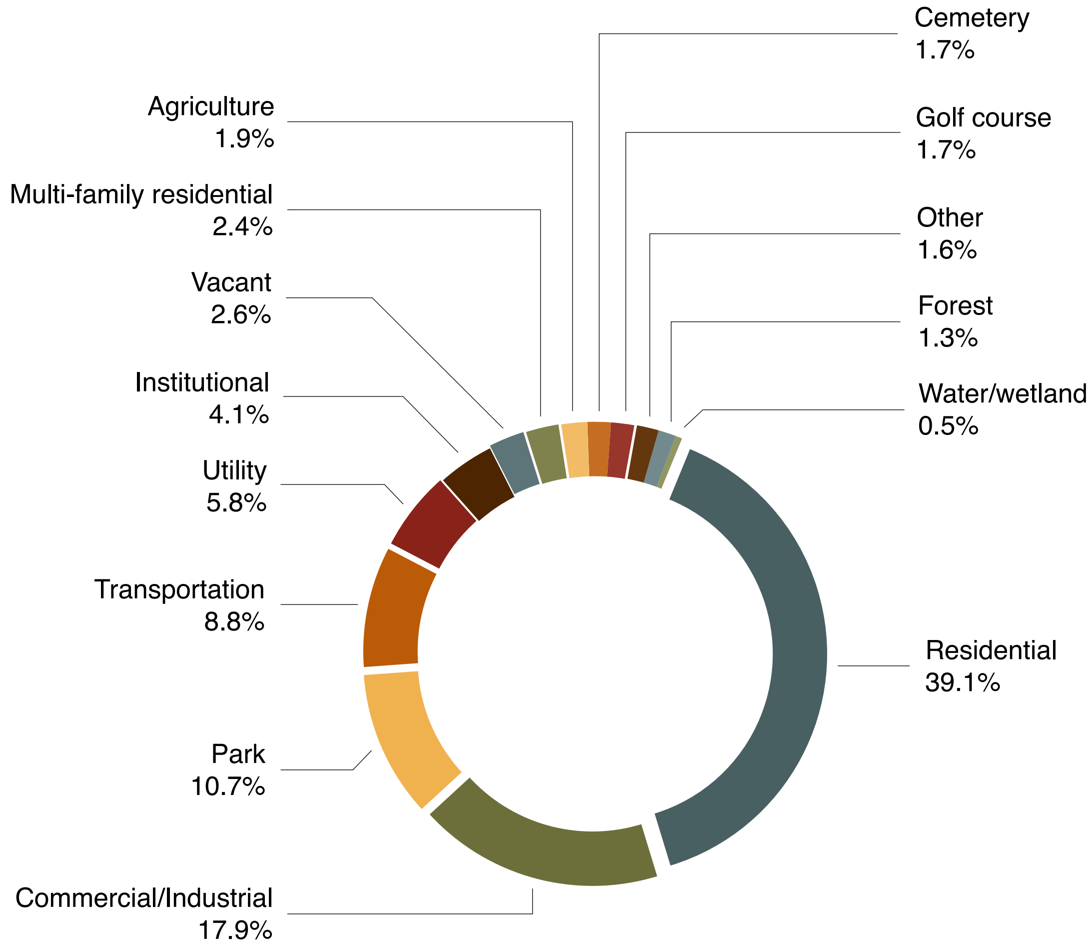


Figure 2: Percentage Land Use across Sandwell estimated by Eco

Green spaces make up 16.2% of land use in Sandwell; that is significantly less than the average for Inner London (21%).

Tree Diversity

Challenges exist in valuing biodiversity because it is difficult to identify and measure the passive, non-active use values of biodiversity[3]. However, biodiversity is important because it provides a wide range of indirect benefits to humans.

Although i-Tree Eco does not yet calculate a valuation of biodiversity it does provide an indication of tree species diversity using diversity indexes. This is important because the diversity of species within Sandwell (both native and non-native) will influence how resilient the tree population will be to future changes, for example by minimising the overall impact of exotic pests, diseases and climate change. These values are provided in Table 3.

Many native species are not able to thrive in the artificial environments of our landscaped areas, and the effects of climate change will exacerbate the situation[4]. Maintaining a careful balance of native and non-native species within the population will ensure that habitats are protected whilst providing resilience to our ever-changing climate.

Species	Species/ha	SHANNON	MENHINICK	SIMPSON	EVENNESS
108	11	4.1	6.20	34.30	0.90

Table 3: Species richness and diversity Indexes for Sandwell

- **Species:** is the number of species sampled.
- **Species/ha:** is the average number of species found per hectare of area sampled.
- **SHANNON:** is the Shannon – Wiener diversity index, which assumes that all species within the area have been sampled. It is an indicator of species richness and has a moderate sensitivity to sample size (on this scale, below 1.5 is considered low and over 3.5 is considered high).[5]
- **MENHINICK:** is the Menhinick's index. It is an indicator of species richness and has a low sensitivity to sample size and therefore may be more appropriate for comparison between cities.
- **SIMPSON:** is Simpson's diversity index. It is an indicator of species dominance and has a low sensitivity to sample size and therefore may be more appropriate for comparisons between land use types.
- **EVENNESS:** is the Shannon diversity index, which assumes that all species within the area have been sampled. It is an indicator of species evenness and has a moderate sensitivity to sample size and therefore land use and/or cities may not be comparable.[6]

Sandwell has a good level of diversity, and strong populations of native tree species. These species are important for biodiversity and the ecology of the landscape; however the population of non-native trees will become increasingly important in a changing climate.

[3] Nunes et al, 2001

[4] Gill et al 2007

[5] Gazis, R., Chaverri, P., 2010

[6] i-Tree, 2021

Species Richness

The three most common named species are Field maple, English oak, and Bird cherry (Figure 3). Some trees were identified at genus level only, however these have not been included in this species level analysis to avoid mixing metrics, and are instead included in ‘other’.

The ten most common species account for over 40% of the total population. In total, 108 tree species were recorded in the survey. Increased tree diversity has the potential to minimise the impact upon or destruction of species by specific pathogens and diseases as well as from the effects of climate change; however, there can also be an increased risk to the native tree population and surrounding biodiversity.

Sandwell has an estimated tree population of 265,000 trees (31 trees per hectare).

It should be considered that over time the associated benefits of the trees will increase as the trees grow to a larger size, if there are extensive thinning or felling operations or significant damage to the tree population the benefits may fall accordingly.

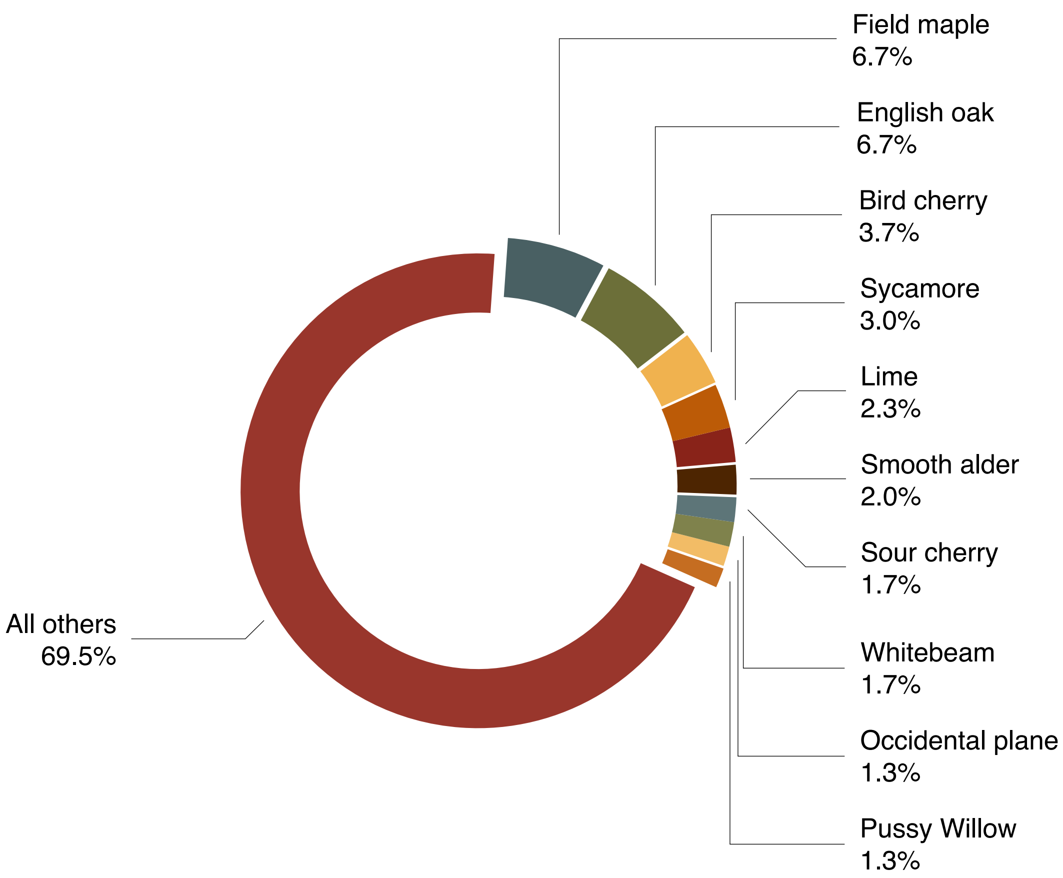


Figure 3: Species composition (most common species).

Sandwell has a good range of species diversity. It does not rely too heavily on just a few species. Continuing to even the population with planting selection will help secure the future of this urban forest.

“It is that range of biodiversity that we must care for - the whole thing - rather than just one or two stars.” -David Attenborough

Dominance

Numerous benefits derived from trees are directly linked to the amount of healthy leaf surface area that they have.

A high value shows which species are currently delivering the most benefits based on their population and leaf area. These species currently dominate the forest structure and are therefore the most important in delivering benefits.

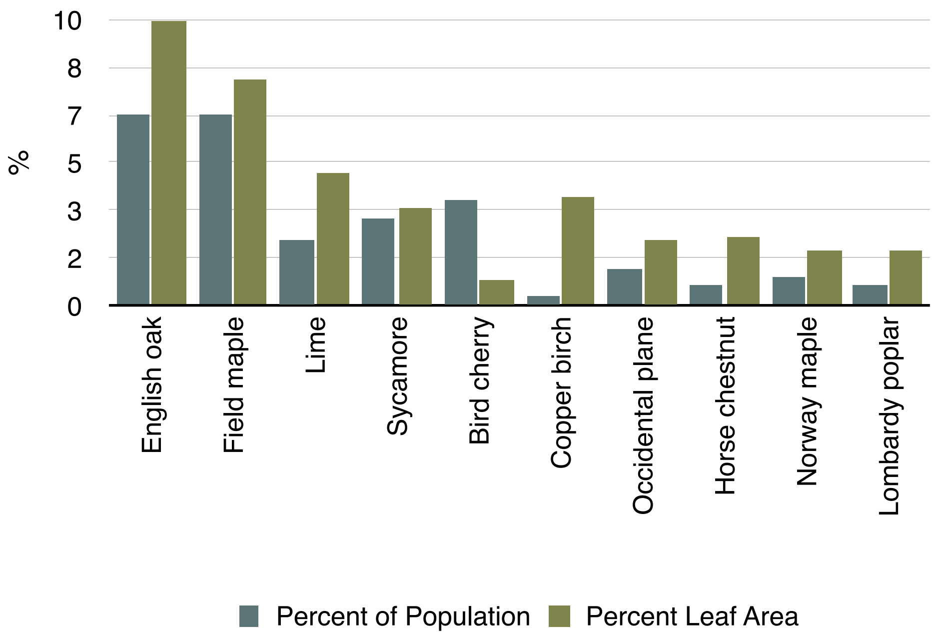


Figure 4: Leaf area and population of Sandwell by most dominant tree species.

The Dominance Value is calculated by taking into account the leaf area and relative abundance of the species. In Sandwell the most dominant species are English oak, field maple, and lime, predominantly because they have the largest leaf area (Figure 4). The most dominant genus is Ash.

Trees such as copper birch have a very high dominance value due to the expansive leaf area even though they represent a relatively low proportion of the population, the opposite can be true for species with high population but a smaller leaf area such as bird cherry.

Species	Leaf area (ha)	Dominance Value
English oak	741	16.7
Field maple	588	14.6
Lime	341	6.9
Sycamore	255	6.4
Bird cherry	65	4.6
Copper beech	284	4.2
Occidental plane	169	3.6
Horse chestnut	177	3.1
Norway maple	143	2.9
Lombardy poplar	144	2.6

Table 5: List of the ten most dominant tree species in Sandwell.
*See appendix IV for the full list of tree dominance value ranking in Sandwell

Urban Forest Structure

In this survey trees were sized by their stem diameter at breast height (DBH) at 1.3m. DBH can be considered a proxy for age, bearing in mind species and potential ultimate size and form.

Trees with a DBH of 7-15 cm constitute 9.7% percent of the tree population of Sandwell's urban forest. Larger trees have a greater functional value and provide increased benefits (details of functional value and the resulting benefits are discussed later). It has been estimated in previous studies[7] that a 75cm diameter tree can intercept 10 times more air pollution, can store up to 90 times more carbon and contributes up to 100 times more leaf area to the tree canopy than a 15cm tree[8].

Size class distribution is also an important factor in managing a sustainable tree population. Having a large population of smaller trees is important as this will ensure that there are enough young trees to replace those older specimens that are eventually lost through old age or disease (Figure 5).

Most regions in England only have 10-20% of trees with a DBH that is greater than 30cm*, but in Sandwell it is 70%!
*Trees in Towns II

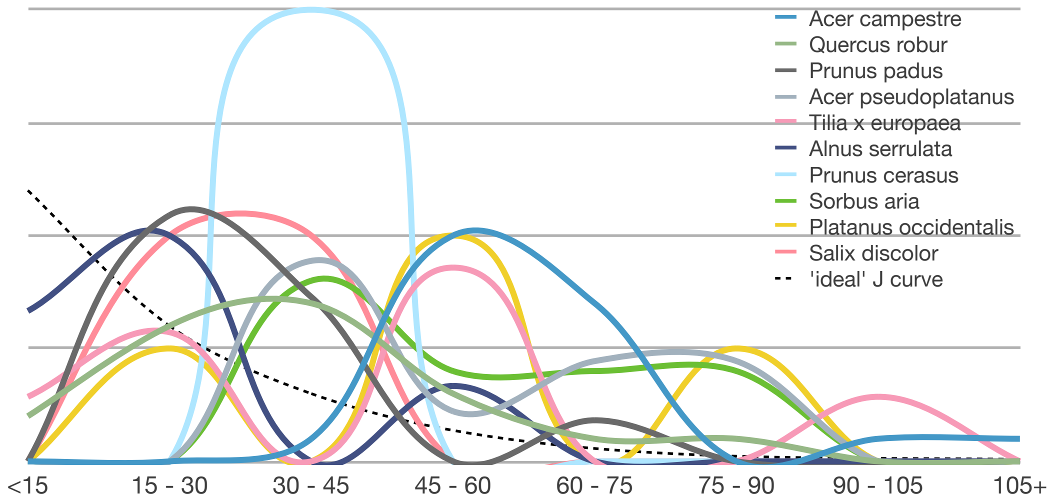


Figure 5: Spread of size classes amongst the top ten species, showing comparison to 'ideal' J-curve
'ideal' J-curve values reduce by half for each increase in DBH class

Where the goal is to continually maintain tree cover within a landscape, a guiding principle is an inverse J-curve of age going from many young to few mature trees[9] (Figure 5). Forests are unique and there is no 'one size fits all' target distribution. However, it is noted that Sandwell will benefit from a greater proportion of smaller trees to support its maturing population.

[7] Every Tree Counts - A portrait of Toronto's Urban Forest

[8] Hand and Doick, 2019

[9] Kimmins, 2004

Origin of Tree Species

The map below shows the original continent of origin of the tree species found in Sandwell. In total, around 37% of the tree population are native to Europe. Of those, it is expected that a smaller population are native to the British Isles. Diversity is key to resilience, yet native species are key to local biodiversity.

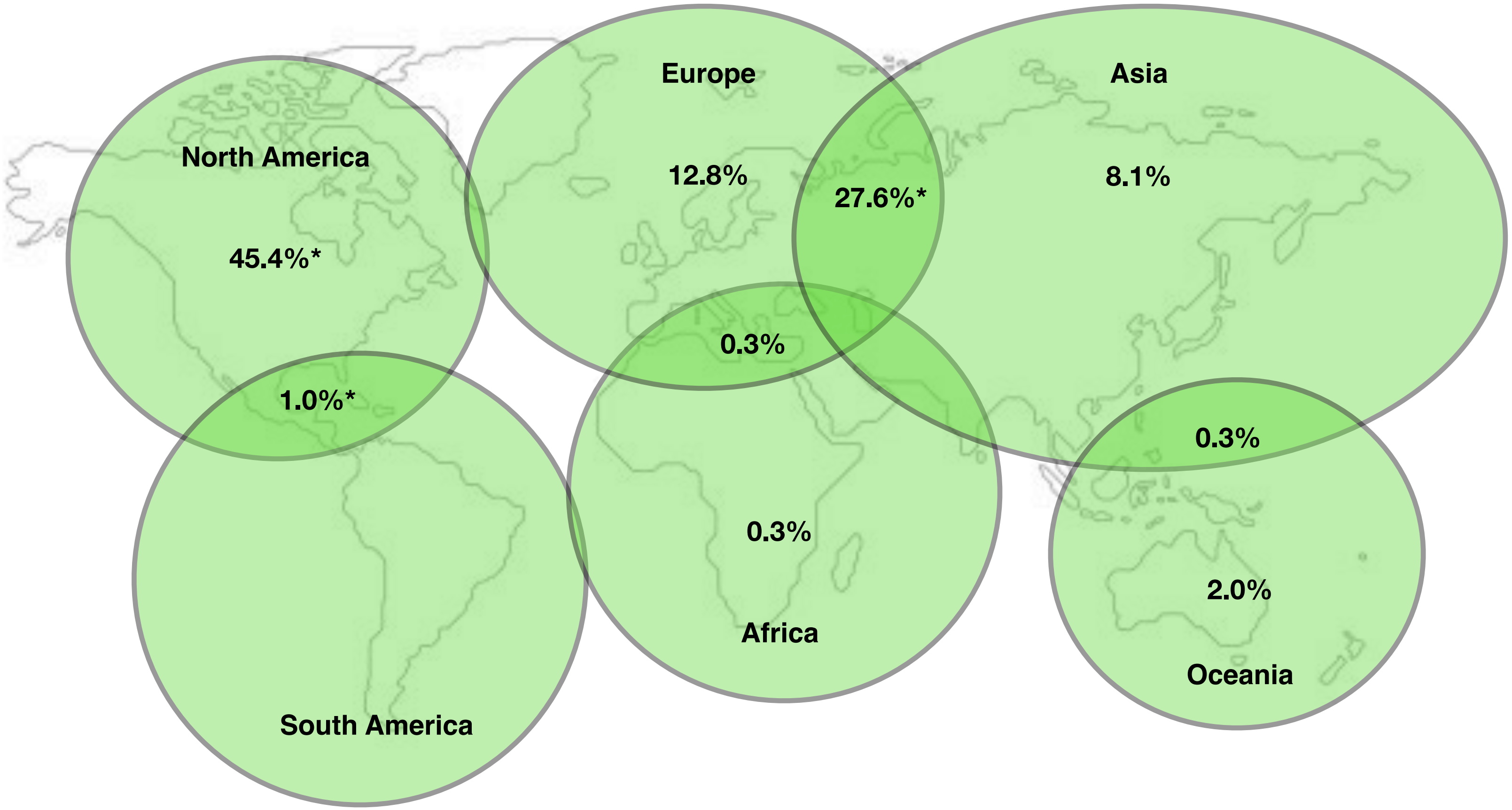


Figure 6: Origin of Tree Species; the share of trees native to different geographical regions. Overlaps indicate origins within both continents

*In these cases, where only genus is available, the proportion in brackets may include additional regions.
**2.0% of trees have unspecified origin as it is unclear which region they originate from, or they are hybrids and therefore from multiple regions.

Valuing the Resource

Air Pollution Removal

Poor air quality is a particular problem in many urban areas and along road networks. Air pollution caused by human activity has become a problem since the beginning of the industrial revolution. With the increase in population and industrialisation, and the use of transport based on fossil fuels, large quantities of pollutants have been produced.

The problems caused by poor air quality are well known, ranging from human health impacts to damage to buildings. Trees make a significant contribution to improving air quality by reducing air temperature (thereby lowering ozone levels), directly removing pollutants from the air, absorbing them through the leaf surfaces and by intercepting particulate matter (eg: smoke, pollen, aerosols created in the atmosphere, and dusts). They also indirectly reduce energy consumption in buildings, leading to lower air pollutant emissions from power plants.

Particulate matter <2.5 microns ($PM_{2.5}$) can be incredibly damaging to health, as these particulates are small enough to enter the bloodstream. As such, they have superseded PM_{10} in importance, and policies increasingly focus on reducing $PM_{2.5}$.

Pollutant	Tonnes removed by trees per year	Value (approx)
Nitrogen dioxide (NO_2)	11.4	£136,000
Particulates (<$PM_{2.5}$)	3.1	£686,000
Sulphur dioxide (SO_2)	0.9	£5,970
Total	**15.4**	**£827,970**

Table 6: Quantity and value of the pollutants removed per-annum within Sandwell. Valuation methods used are UK social damage cost (UKSDC).

As well as reducing ozone levels, some tree species also emit the volatile organic compounds (VOCs) that lead to ozone production in the atmosphere. The i-Tree Eco software accounts for both reduction and production of VOC's within its algorithms, and the overall effect of Sandwell's trees is to reduce ozone through evaporative cooling[10], however this is not valued in this report as there is no UK Social Damage Cost for this pollutant.

Total pollution removal per ha in Sandwell is equivalent to 0.002 tonnes ha^{-1} yr^{-1}.

10 Nowak et al, 2000.

Greater tree cover, air pollution concentrations and leaf area are the main factors influencing pollution filtration and therefore increasing tree planting has been shown to make further improvements in air quality[11]. Furthermore, because filtering capacity is closely linked to leaf area it is generally the trees with larger canopy potential that provide the most benefits.

The annual values for the pollution removal by trees are given in Figure 7.

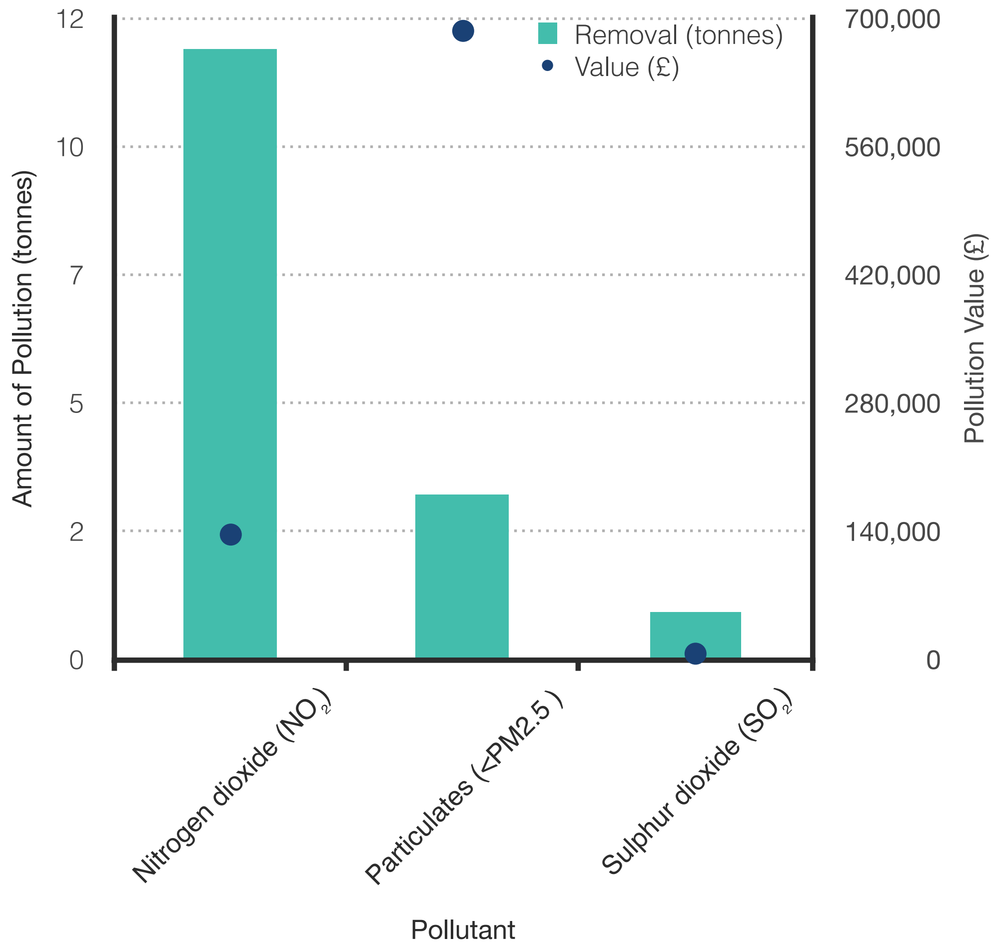


Figure 7. Annual Pollution Removal by trees and Associated Value.

11 Escobedo and Nowak (2009)

Avoided Run-Off

Surface run-off can be a cause for concern in many areas as it can contribute to pollution in streams, wetlands, rivers, lakes, and oceans as well as adding to flood risk and thereby exacerbating the impacts of Climate Change.

During precipitation events, a portion of the precipitation will be intercepted by vegetation (trees and shrubs) while a further portion reaches the ground. Precipitation that reaches the ground and does not infiltrate into the soil becomes surface run-off[12].

Within an urban area the large extent of impervious surfaces increases the amount of run-off. However, trees are effective at reducing this[13]. Trees intercept precipitation, whilst their root systems promote infiltration and storage in the soil. Interception slows down rainwater reaching the ground, and some water will be evaporated off without ever touching the ground.

The trees of Sandwell help to reduce run-off by an estimated 614,000 cubic metres a year with an associated value of £604,000.

English oak trees intercepts the most water, removing a total of 12,900 m³ of water per year; a service worth £12,700 (Figure 8). Oak trees have an expansive canopy with large leaves to capture/intercept rainfall and represent a relatively high proportion of trees within Sandwell.

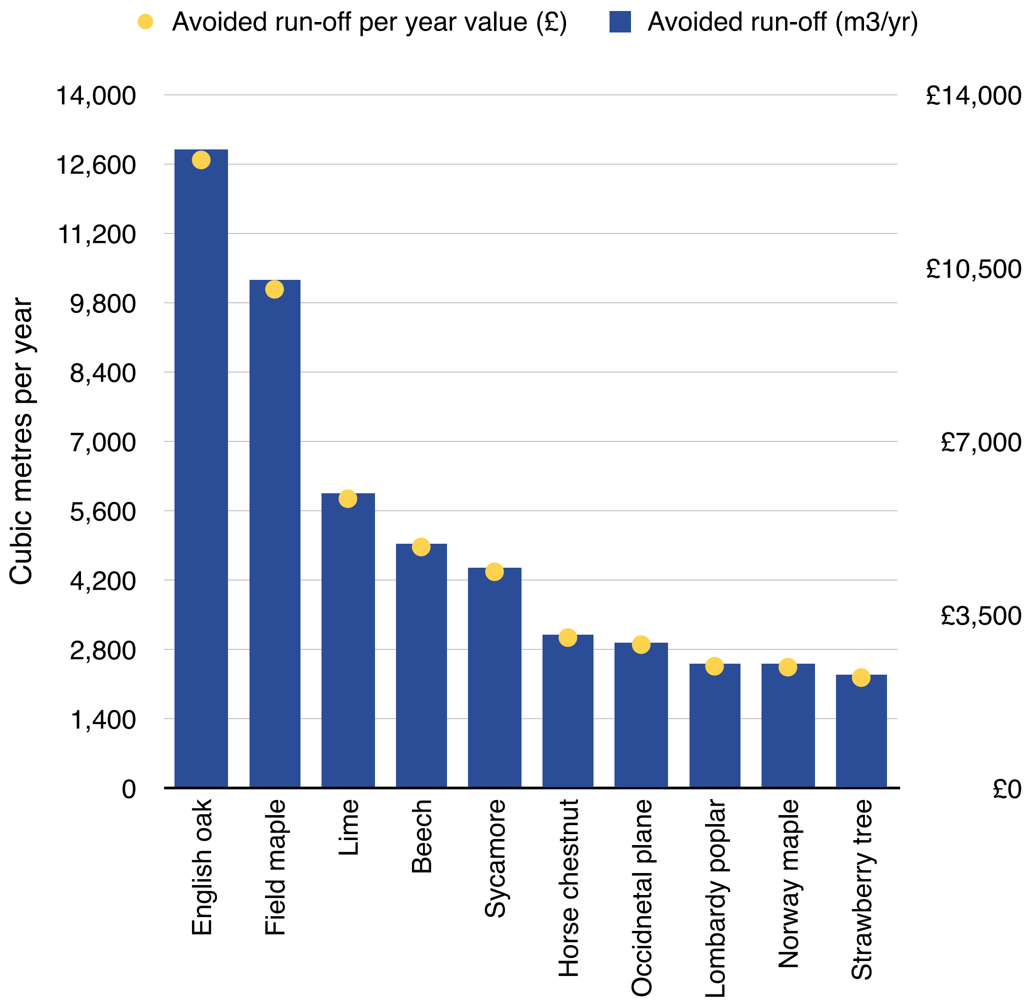


Figure 8: Avoided run-off by the top ten species.

[12] Hirabayashi (2012).

[13] Trees in Hard Landscapes (2014)

Carbon Storage and Sequestration

Trees can help mitigate climate change by sequestering atmospheric carbon. Since about 50% of wood by dry weight is comprised of carbon, tree stems and roots can store up carbon for decades or even centuries[14]. Over the lifetime of a tree, several tonnes of atmospheric carbon dioxide can be absorbed[15].

The gross sequestration of Sandwell's trees is about 5,550 tonnes of carbon per year (approximately 0.65 tonnes/ha/yr). The value of the carbon sequestered is estimated at £5 million per year. This value will continue to increase as the trees grow.

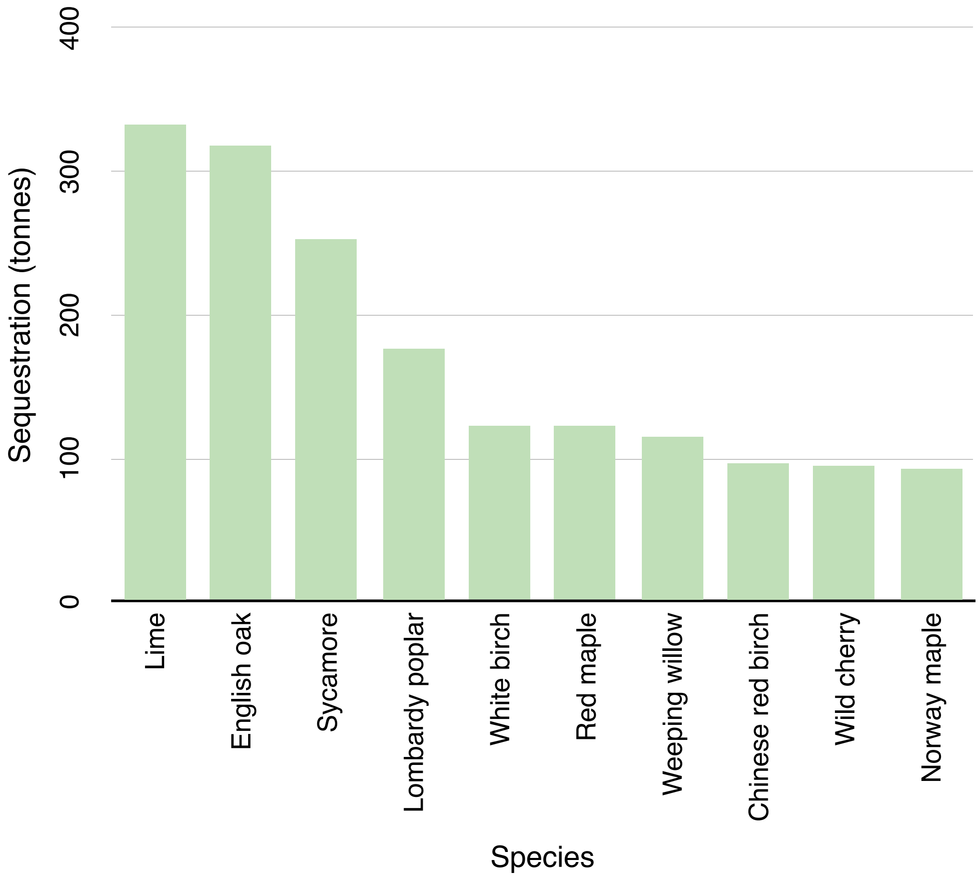


Figure 9: Ten most significant tree species for carbon sequestration in Sandwell.

Carbon sequestration and storage is a key part of achieving any net-zero target. In 2020, the Sandwell area produced a total of 1,259 kt CO_2e emissions*, meaning that sequestration by trees offset 1.6% of the total annual emissions.

*BCC-Carbon Dioxide Emissions 2020 report

14 Kuhns, 2008

15 McPherson, 2007

Carbon storage by trees is a way in which trees can influence global climate change. As trees grow they store more carbon by holding it in their tissue. As trees die and decompose they release this much of this carbon back into the atmosphere. Therefore, the carbon storage of trees is an indication of the amount of carbon that could be released if all the trees died.

An estimated 360,000 tonnes (approximately 4.2t/ha) of carbon is stored in Sandwell's trees with an estimated value of over £328 million (based on current carbon figures from Department for Business Energy and Industrial Strategy)[16].

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.

Trees also play an important role in protecting soils, which are one of the largest terrestrial sinks of carbon. Soils are an extremely important reservoir in the carbon cycle because they contain more carbon than the atmosphere and plants combined[17].

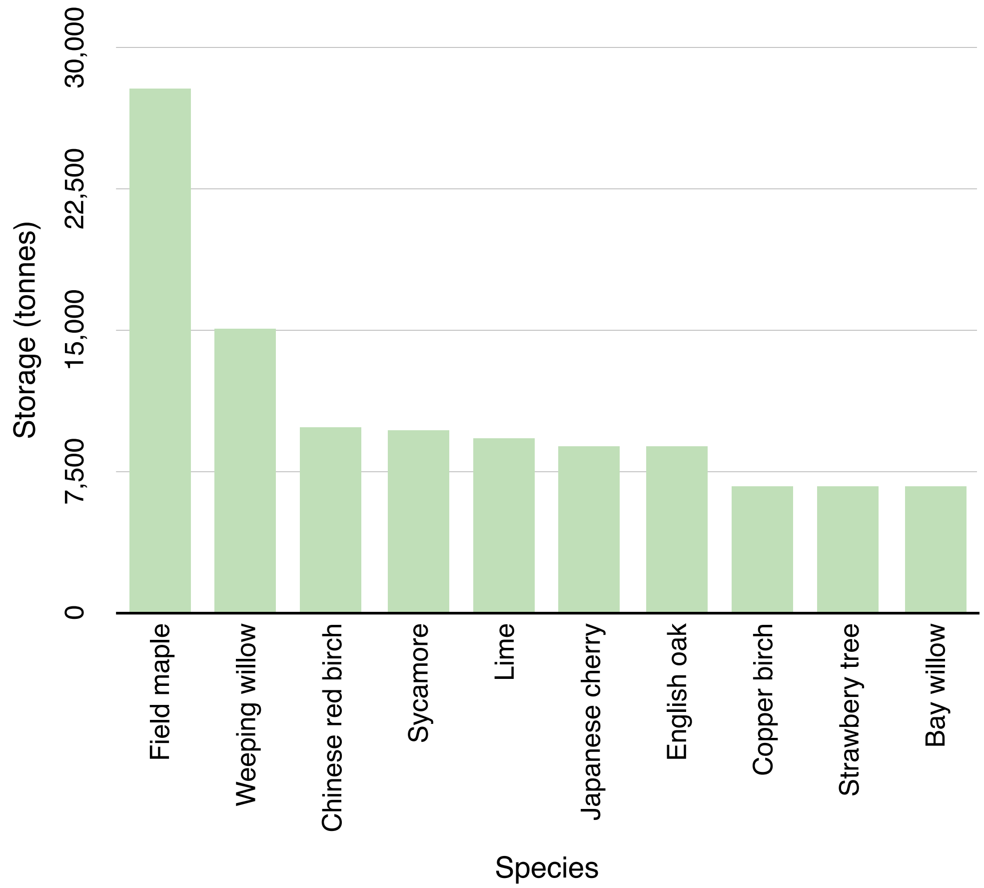


Figure 10: Ten most significant tree species for carbon storage in Sandwell.

[16] DBIES (2022)

[17] Ostle *et al.*, (2011)

Capital Asset Value for Amenity Trees (CAVAT)

This is a valuation of the amenity services provided by trees. The Adjusted Quick Method valuation takes into account the size, accessibility, and health of trees as well as any species specific attributes contributing to public amenity value.

The urban forest of Sandwell has an estimated public amenity asset value of £ 9,437 million.

Field maple had the highest amenity value of any single species in Sandwell, contributing 8% of the urban forest's amenity value. The next largest contributors were English oak, followed closely by sycamore. Combined, these three species represent 15% of the total amenity value for Sandwell. The amenity value of field maple, English oak, and sycamore was surprisingly low; considering they constitute 17% of the total population. This is likely due to a combination of smaller size, worse condition, and lower longevity in these species.

The land use type containing the highest amenity value of trees was 'park', with 25% of the total value of the trees, and an estimated value of £5,748 million when extrapolated for the whole of Sandwell. 'Residential' and 'forest' were the next most important land-uses, contributing 22% and 12% to the total amenity value, respectively.

CAVAT is a vital metric for valuing trees; it gives an indication of the whole value of the tree, not just the cost of purchase, planting, or management. It is a very different value than replacement cost as it shows how much trees mean to the people and communities who interact with them.

Species	Value of measured trees (£)	Value extrapolated across the area (£)	Proportion of total value (%)
Field maple	802,938	722 million	7.6
English oak	427,994	385 million	4.1
Sycamore	323,337	291 million	3.1
Dawn redwood	259,639	233 million	2.5
Weeping willow	231,339	208 million	2.2
Occidental plane	208,854	188 million	2.0
Lombardy poplar	206,499	186 million	2.0
Lime	205,335	185 million	2.0
Strawberry tree	193,998	174 million	1.8
Norway maple	169,499	152 million	1.6
All other species	7.5 million	6.7 billion	71.1

Table 7. CAVAT amenity value for the top ten most valuable tree species in Sandwell.

Land use	Value of measured trees per land use (£)	Value per land use extrapolated across the area (£)	Proportion of total value (%)
Park	3,119,022	2.8 billion	29.7
Residential	2,234,118	2.0 billion	21.3
Utility	1,276,863	1.1 billion	12.2
Forest	896,578	806 million	8.5
Golf course	705,444	634 million	6.7
Institutional	517,842	465 million	4.9
Vacant	455,042	409 million	4.3
Transportation	355,560	3120 million	3.4
Commercial/ Industrial	325,130	292 million	3.1
Multi-family residential	224,582	202 million	2.1
Other	222,443	200 million	2.1
Cemetery	109,208	98 million	1.0
Agriculture	58,604	53 million	0.6

Table 8. CAVAT amenity value for each land use in Sandwell.

Further details on the CAVAT methodology are included in Appendix V.

Trees and woodlands have a structural value which is based on the depreciated replacement cost of the actual tree.

Large, healthy long lived trees provide the greatest structural and functional value.

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 is calculated means that it does not constitute a benefit provided by the trees, nor is it a true reflection of the value of the trees. The valuation is a depreciated replacement cost, based on the Council of Tree and Landscape Appraisers (CTLA) formulae[18].

The formula allows for tree suitability in the landscape and nursery prices. This explains why the value given for Ash is comparably low, on account of the decreased suitability due to Ash Dieback, a pathogen which is discussed later.

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 Figure 13.

The total replacement cost of all trees in the study area currently stands at £684 million. Field maple trees are currently the species with the highest replacement value, on account of both their size and population, followed by sycamore and English oak. These three species of tree account for £153 million (22%) of the total replacement cost of the trees in Sandwell. A full list of trees with the associated replacement cost is given in appendix III.

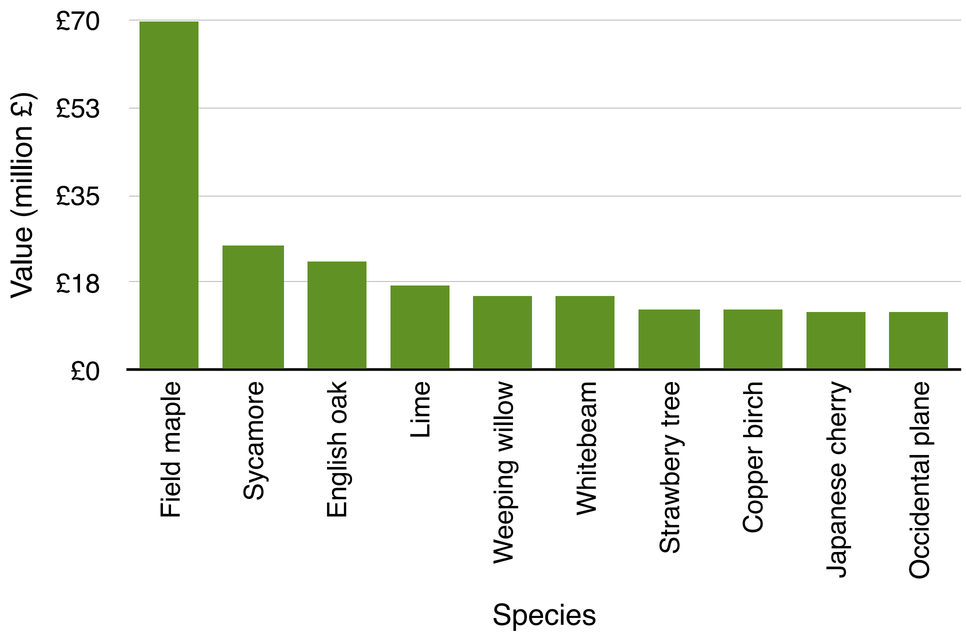


Figure 13: Replacement cost of the 10 most valuable tree species in Sandwell.

[18] Hollis (2007)

Potential Pest and Disease Impacts

Animal pests and microbial pathogens are a serious threat to urban forests and society, causing direct economic costs from damage, and impacting on ecosystem service provision[19]. It is likely that climate change will result in the introduction of pests and diseases not yet present in the UK[20]. The changing climate of the UK is predicted to increase growth or spore release of root pathogens, and to make trees more susceptible to infection[21].

The potential damage from pests and diseases varies according to a wide variety of factors such as tree health, local tree management, and the weather. In addition, a tree community that is dominated by a few species is more vulnerable to a significant impact from a particular disease than a population which has a wider variety of tree species present.

Risk matrices were devised for determining the potential impact of a pest or pathogen, should it become established within the Black Country, based on whether it affected a single treen genus shown in Table 9, or multiple genera in Table 10.

Prevalence	% of Community at Risk		
	0-25	26-50	>50
Not in UK			
Present in UK			
Present in Midlands			

Table 9. Risk matrix used for the probability of a pest or disease, which affects a single tree genus, becoming prevalent in the Black Country.

Prevalence	% of Community at Risk		
	0-5	6-10	>10
Not in UK			
Present in UK			
Present in Midlands			

Table 10. Risk matrix used for the probability of a pest or disease, which affects multiple tree genera, becoming prevalent in the Black Country.

This informed Table 11, which gives an overview of the existing and emerging risks to Sandwell's urban forest, including the predicted proportion of the tree community that would be affected, and the associated amenity value of those trees across the study area.

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[19] Kew Royal Botanical Garden (2017)

[20] Wainhouse and Inward (2016)

[21] Federickson-Matika and Riddell (2021)

The UK plant risk register 2021 contains 1,240 entries, and is multifaceted, considering the current extent of a disease, the likelihood of its spread, the severity of its damage, and the ability to mitigate it[22]. The matrix emphasises causative agents which are damaging, and would affect >0.01% of the area's trees (for the full disease list considered see the full Black Country Natural Capital Valuation report, page 29).

Further information such as how to identify each disease, reduce the likelihood of its arrival, and limit the impact of outbreaks can be found on the UK Plant Health Risk Register, and Forest Research pest and disease webpages[23].

The pest which could potentially have the greatest estimated impact across Sandwell's urban forest is the Asian Longhorn beetle (though this is not currently present in the UK), which could affect nearly 60% of its trees. However, the greatest risks already present in the Midlands are two species of *Phytophthora* water moulds.

Relative to the whole of the Black Country, Sandwell has a higher risk from Asian longhorn beetles and diseases affecting broadleaf trees, especially oaks. However, it has a relatively low risk of spruce bark beetles and pine processionary moths.

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[22] DEFRA (2022)

[23] Forest Research (2022)

Pest/Pathogen	Major tree hosts affected	Prevalence in England	Imminent Risk to Midlands	CAVAT value of trees (millions £)*	Tree Population at risk (%)
Alder bleeding canker (*Phytophthora alni*)	Alnus spp. including A. cordata, glutinosa	Widespread in riparian area, especially in South	High – already present	351	5.7
Acute oak decline	Quercus spp. including Q. ilex, petraea, robur	Present, in Centre and South East	High – already present	975	11.1
Asian longhorn beetle (*Anoplophora glabripennis*)	Many broadleaf species (see Appendix III (Sales et al. 2022))	Absent, a contained outbreak in the South East	Medium –climate change, trade	5,093	58.7
Bacterial leaf scorch (*Xylella fastidiosa*)	Many broadleaf species (see Appendix III (Sales et al. 2022))	Absent	Medium – climate change, generalist	1,712	29.2
Bronze birch borer (*Agrilus anxius*)	Betula spp. including B. pendula, utilis	Absent	Medium – climate change, trade	580	10.7
Ash dieback (*Hymenoscyphus fraxineus*)	Fraxinus spp.	Present, widespread, especially in South, East and North West	High – already present	548	8.4
Dothistroma Needle Blight (*Dothistroma septosporum*)	Larix decidua Pinus spp. Pseudotsuga menziesii	Present, localised throughout	High – already present	42	0.3
Emerald ash borer (*Agrilus planipennis*)	Fraxinus spp. including F. americana, excelsior	Absent	High – suitable climate, trade	548	8.4
Elm zigzag saw fly (*Aproceros leucopoda*)	Ulmus spp.	Present, localised to Greater London and East.	Medium – climate change	28	1.3
Oak Lace bug (*Corythucha arcuata*)	Primarily Castanea spp. and Oak spp. Rarely Acer, Fagus, Betula Tilia, Sorbus, Prunus	Absent	Medium – climate change, generalism	1,000	11.7

Pest/Pathogen	Major tree hosts affected	Prevalence in England	Imminent Risk to Midlands	CAVAT value of trees (millions £)*	Tree Population at risk (%)
Oak processionary moth (*Thaumetopoea processionea*)	Quercus spp. including Q. petraea, robur	Present, Greater London and locally in South East	High – already present	975	11.1
Phytophthora austrocedri	Chamaecyparis lawsoniana and C. nootkatensis Juniperus communis	Present, especially North and South East	High – already present	104	0.7
Phytophthora kernoviae	Many broadleaf species (see Appendix III (Sales et al. 2022))	Present, primarily in South West	High – already present	1,002	15.1
Ramorum disease (*Phytophthora ramorum*)	Over 150 plants (see Appendix III (Sales et al. 2022))	Present, widespread in West, especially South and North	High – already present	2,947	34.9
Rednecked Long-horn Beetle (Aromia bungii)	Prunus spp. in Europe, but several other unconfirmed hosts	Absent, one interception in the South East	Medium – climate change, trade	307	6.4
Sirococcus Blight (*Sirococcus tsugae*)	Cedrus spp. and Tsuga spp.	Present, locally in Centre and West	High – already present	128	0.3
Sweet chestnut blight (*Cryphonectria parasitica*)	Castanea spp.	Present, locally, especially in South West	High – already present	24	0.7
Two-lined chestnut borer (*Agrilus bilineatus*)	Castanea dentata Quercus spp. including Q. robur	Absent	Medium – climate change, trade	1,000	11.7

Table 11. The significance of a range of existing and emerging pests and diseases to Sandwell's urban forest. * Rounded to the nearest million.

Conclusions and Recommendations

The results and data from previous i-Tree Eco studies have been used in a variety of ways to better manage trees and inform decision making. With better information we can make better decisions regarding trees and this is one of the key benefits of undertaking a project such as this. This is a preliminary report, designed to provide the relevant data to facilitate future reports, strategies, and policies.

In relation to the benefits assessed by i-Tree, the trees that offer the greatest benefits are those that are larger and therefore have a greater canopy cover. Trees are more likely to achieve a larger canopy through appropriate thinning and management, species selection, and planting location. This can also allow biodiversity value to increase, maintenance costs to be reduced, and the tree stock is of generally better quality and are less stressed, which in turn reduces the susceptibility of trees to pests and diseases. Woodland compartments that are not managed are much less likely to achieve these objectives.

The production of a district level tree strategy would be a means to prioritise these and the following ideas and actions and to set key performance indicators with measurable outcomes. In particular, the authors would like to draw attention to the following:

- Continue to plant a wide diversity of species (with due consideration to local site factors) to replace the future loss of ash, to reduce the likelihood of severe impact from any given pest or disease outbreak and consider producing a tree planting strategy; see the TDAG species selection guide for further information (Tree Species Selection for Green Infrastructure: A Guide for Specifiers).
- Continue to retain large, mature trees wherever possible, as large trees provide the most benefits. Make them part of developments rather than lose them.
- Increase new planting to maintain a healthy size diversity within Sandwell to avoid significant losses in ES provisions in the future.
- The trees of Sandwell store a vast amount of carbon considering the total number of trees. This implies that the trees typically have a large structure, but are reaching maturity with small canopies. Ensuring that new and existing trees are given the space to reach their full potential is key.
- Consider the equity of how trees and the benefits they provide are distributed; increase planting and management in areas that lack canopy cover, particularly areas with high deprivation and which experience high pollution, surface flooding, limited green space, or lack of shade, as well as looking at additional planting alongside main roads, and joining up/filling in gaps within the existing urban forest to enhance wildlife corridors and connect pathways through green infrastructure. Neighbourhood level analysis of the urban forest would be beneficial.
- Use CAVAT to highlight the amenity value of trees to developers and communities, and to leverage compensation or sufficient replacement planting for amenity trees that are removed.
- Set up community tree care schemes to encourage engagement by local people and help to ensure the good health of young trees, particularly new plantings as they are at the most risk from external factors such as drought, disease and even vandalism.

Further uses for the data

- Carry out a cost benefit analysis using this data, which can then be used to inform the benefits side of the calculations, thereby assisting with decision making.
- Use data to influence urban forest management when preparing strategies or operational documents and to schedule the review of urban forest management documents together with the commissioning of future i-Tree Eco studies to ensure findings can rapidly be fed in to optimise operation.
- Combine this data with other potential data sources to help target new tree planting and to inform species choice, eg:
    - Use data on localised flooding and drainage issues to identify and assess potential opportunities to enhance the water management benefits.
    - Use Protected Landscape data (ie National Park, AONB boundaries, etc.)to to help prioritise potential opportunities to enhance the biodiversity benefits.
    - Use local air pollution data to identify and assess potential opportunities to enhance the air pollution mitigation benefits.
- Use the i-Tree data to produce educational and public information around Sandwell's trees.
- Use data to support bids for funding and to develop and drive both small and large scale community projects.

Appendix I. Relative Tree Effects

The urban forest in Sandwell provides benefits that include carbon storage and sequestration and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average carbon emissions and average passenger automobile emissions. These figures should be treated as a guideline only as they are largely based on US values (see footnotes).

Carbon storage is equivalent to:

- Annual carbon (C) emissions from 281,000 automobiles
- Annual C emissions from 115,000 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 1,800 automobiles
- Annual nitrogen dioxide emissions from 809 single-family houses

Sulphur dioxide removal is equivalent to:

- Annual sulphur dioxide emissions from 10,200 automobiles
- Annual sulphur dioxide emissions from 27 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Sandwell in 1.4 days
- Annual C emissions from 4,300 automobiles
- Annual C emissions from 1,800 single-family houses

Average passenger automobile emissions per mile were based on dividing total 2002 pollutant emissions from light-duty gas vehicles (National Emission Trends http://www.epa.gov/ttn/chief/trends/index.html) divided by total miles driven in 2002 by passenger cars (National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/2004/).

Average annual passenger automobile emissions per vehicle were based on dividing total 2002 pollutant emissions from light-duty gas vehicles by total number of passenger cars in 2002 (National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/2004/).

Carbon dioxide emissions from automobile assumed six pounds of carbon per gallon of gasoline if energy costs of refinement and transportation are included (Graham, R.L., Wright, L.L., and Turhollow, A.F. 1992. The potential for short-rotation woody crops to reduce U.S. CO2 Emissions. Climatic Change 22:223-238).

Appendix II. Species Lookup Tables

Top 40 most common trees in Sandwell and their scientific names

Common Name	Scientific Name
Birch spp	*Betula*
Ash spp	*Fraxinus*
Field maple	*Acer campestre*
English oak	*Quercus robur*
Bird cherry	*Prunus padus*
Beech spp	*Fagus*
Sycamore	*Acer pseudoplatanus*
Alder spp	*Alnus*
Lime	*Tilia x europaea*
Smooth alder	*Alnus serrulata*
Sour cherry	*Prunus cerasus*
Whitebeam	*Sorbus aria*
London plane	*Platanus occidentalis*
American pussy willow	*Salix discolor*
Korean thuja	*Thuja koraiensis*
Norway maple	*Acer platanoides*
Chinese red-barked birch	*Betula albosinensis*
Ash	*Fraxinus excelsior*
Ashe's Blackjack Oak	*Quercus marilandica var. ashei*
Chinese weeping willow	*Salix babylonica*

Common Name	Scientific Name
Rowan	*Sorbus aucuparia*
Japanese rowan	*Sorbus commixta*
Sydney golden wattle	*Acacia longifolia ssp. longifolia*
Red maple	*Acer rubrum 'Columnare'*
Horse chestnut	*Aesculus hippocastanum*
Hybrid buckeye	*Aesculus x hybrida*
Alder	*Alnus x fallacina*
Sweet Chestnut	*Castanea sativa*
Engelmann hawthorn	*Crataegus engelmannii*
Hawthorn	*Crataegus rosei*
American beech	*Fagus grandifolia*
Holly	*Ilex aquifolium*
American holly	*Ilex opaca*
Juniper	*Juniperus communis*
Black Walnut	*Juglans nigra*
Wild privet	*Ligustrum vulgare*
Dawn redwood	*Metasequoia glyptostroboides*
Plane	*Platanus*
Black poplar	*Populus nigra*
Lombardy poplar	*Populus nigra v. italica*

Appendix III. Species Dominance Ranking List

Scientific Name	% Population	% Leaf Area	Dominance Value
Fraxinus	7.4	11.4	18.8
Quercus robur	6.7	9.9	16.7
Acer campestre	6.7	7.9	14.6
Betula	9.4	4.8	14.2
Tilia x europaea	2.3	4.6	6.9
Fagus	3.4	3.5	6.8
Acer pseudoplatanus	3.0	3.4	6.4
Alnus	3.0	3.3	6.3
Prunus padus	3.7	0.9	4.6
Fagus sylvatica 'Purpurea'	0.3	3.8	4.2
Cupressus	0.3	3.3	3.7
Platanus occidentalis	1.3	2.3	3.6
Aesculus hippocastanum	0.7	2.4	3.1
Acer platanoides	1.0	1.9	2.9
Populus nigra v. italica	0.7	1.9	2.6
Fraxinus excelsior	1.0	1.5	2.5
Quercus x ashei	1.0	1.4	2.5
Betula albosinensis	1.0	1.4	2.4
Quercus x atlantica	0.7	1.6	2.3
Prunus cerasus	1.7	0.6	2.3
Alnus serrulata	2.0	0.2	2.3
Sorbus aria	1.7	0.6	2.2
Salix discolor	1.3	0.8	2.1
Arbutus unedo	0.3	1.7	2.1
Metasequoia glyptostroboides	0.7	1.4	2.1
Salix babylonica	1.0	0.9	1.9
Acer rubrum 'Columnare'	0.7	1.0	1.7

Scientific Name	% Population	% Leaf Area	Dominance Value
Thuja koraiensis	1.3	0.3	1.6
Juniperus communis	0.7	0.8	1.5
Populus nigra	0.7	0.8	1.5
Aesculus x hybrida	0.7	0.7	1.4
Platanus	0.7	0.7	1.4
Sorbus aucuparia	1.0	0.4	1.4
Acacia mearnsii	0.3	1.0	1.3
Alnus x fallacina	0.7	0.6	1.3
Tsuga	0.3	0.9	1.2
Juglans nigra	0.7	0.5	1.2
Salix myricoides	0.3	0.7	1.0
Ilex opaca	0.7	0.4	1.0
Sorbus commixta	1.0	0.0	1.0
Schizomeria ovata	0.7	0.3	1.0
Crataegus engelmannii	0.7	0.3	1.0
Prunus serrulata	0.67	0.3	1.0
Quercus variabilis	0.3	0.6	1.0
Quercus myrsinifolia	0.3	0.6	1.0
Tilia americana	0.7	0.3	1.0
Acacia longifolia ssp. longifolia	0.7	0.3	0.9
Quercus grisea	0.3	0.6	0.9
Sapium caribaeum	0.3	0.5	0.8
Callitris baileyi	0.3	0.5	0.8
Chamaecyparis obtusa	0.3	0.5	0.8
Robinia pseudoacacia	0.7	0.2	0.8
Acer macrophyllum	0.3	0.46	0.8
Castanea sativa	0.7	0.1	0.8
Acer	0.3	0.4	0.8

Scientific Name	% Population	% Leaf Area	Dominance Value
Ligustrum vulgare	0.7	0.1	0.8
Cupressus macrocarpa	0.3	0.4	0.8
Sorbus commixta 'Embley'	0.7	0.1	0.8
Crataegus rosei	0.7	0.1	0.7
Fagus grandifolia	0.7	0.1	0.7
Ilex aquifolium	0.7	0.0	0.7
Sambucus canadensis	0.7	0.0	0.7
Salix	0.3	0.4	0.7
Ulmus americana	0.7	0.0	0.7
Salix arizonica	0.7	0.0	0.7
Pseudotsuga	0.3	0.3	0.7
Crataeva	0.3	0.3	0.7
Quercus douglasii	0.3	0.3	0.7
Acer rubrum 'Brandywine'	0.3	0.3	0.6
Pterocarya pterocarpa	0.3	0.3	0.6
Catalpa bignonioides	0.3	0.3	0.6
Quercus arkansana	0.34	0.3	0.6
Crataegus furtiva	0.3	0.3	0.6
Pyrus	0.3	0.3	0.6
Salix serissima	0.3	0.26	0.6
Corylus	0.3	0.25	0.6
Quercus cerris	0.3	0.2	0.6
Abies	0.3	0.2	0.6
Juniperus californica	0.3	0.23	0.6
Quercus prinus	0.3	0.2	0.6
Populus grandidentata	0.3	0.2	0.5
Salix petrophila	0.3	0.2	0.5
Prunus cerasifera	0.3	0.2	0.5

Scientific Name	% Population	% Leaf Area	Dominance Value
Chamaecyparis thyoides	0.3	0.2	0.5
Quercus sinuata	0.3	0.2	0.5
Ulmus crassifolia	0.3	0.1	0.5
Populus balsamifera	0.3	0.1	0.5
Crataegus laevigata	0.3	0.1	0.4
Platycladus	0.34	0.1	0.4
Buxus	0.3	0.1	0.4
Acer opalus	0.3	0.09	0.4
Ulmus pumila	0.3	0.08	0.4
Betula pendula	0.3	0.1	0.4
Xylocarpus moluccensis	0.3	0.1	0.4
Carpinus	0.3	0.1	0.4
Pyrus pyrifolia	0.3	0.1	0.4
Euonymus	0.3	0.0	0.4
Platanus x hispanica	0.3	0.0	0.4
Salix triandra	0.3	0.0	0.4
Crataegus	0.3	0.0	0.4
Taxus baccata	0.3	0.0	0.4
Celtis australis	0.3	0.0	0.4
Crataegus x anomala	0.3	0.0	0.4
Quercus suber	0.3	0.02	0.4
Crataegus monogyna	0.3	0.0	0.4
Viburnum opulus v. americanu	0.34	0.0	0.3
Borassus aethiopum	0.34	0.0	0.3
Crataegus douglasii	0.34	0.0	0.3

Appendix IV. Tree values by species

Species	Number of trees	Carbon stored (tonnes)	Net Seq (tonnes/yr)	Avoided runoff (m3)	Replacement Cost (£)
Betula	24,925	29,800	638	6,281	£42,403,791
Fraxinus	19,584	28,387	498	14,767	£36,558,895
Acer campestre	17,803	27,745	15	10,240	£69,601,290
Quercus robur	17,803	8,822	318	12,896	£21,613,169
Prunus padus	9,792	4,822	94	1,132	£10,243,862
Fagus	8,902	24,460	294	4,530	£41,315,546
Acer pseudoplatanus	8,011	9,689	253	4,441	£25,171,613
Alnus	8,011	5,101	74	4,261	£18,512,626
Tilia x europaea	6,231	9,283	333	5,942	£17,094,314
Alnus serrulata	5,341	743	16	321	£3,255,756
Prunus cerasus	4,451	2,563	72	762	£5,044,813
Sorbus aria	4,451	6,315	21	715	£14,576,942
Platanus occidentalis	3,561	2,419	90	2,945	£11,376,404
Salix discolor	3,561	2,151	84	986	£2,262,923
Thuja koraiensis	3,561	3,402	15	370	£5,104,698
Acer platanoides	2,670	4,061	93	2,483	£7,922,302
Betula albosinensis	2,670	9,797	97	1,785	£9,905,907
Fraxinus excelsior	2,670	473	42	1,956	£1,277,117
Quercus x ashei	2,670	2,480	70	1,873	£7,686,214
Salix babylonica	2,670	15,020	115	1,180	£14,847,756
Sorbus aucuparia	2,670	832	64	482	£2,582,521
Sorbus commixta	2,670	608	27	29	£908,944
Acacia longifolia ssp. longifolia	1,780	1,661	2	341	£7,902,470
Acer rubrum 'Columnare'	1,780	6,330	123	1,349	£9,623,516
Aesculus hippocastanum	1,780	4,732	48	3,090	£7,366,497
Aesculus x hybrida	1,780	2,393	76	945	£952,332
Alnus x fallacina	1,780	985	20	812	£5,816,679
Castanea sativa	1,780	1,027	30	150	£4,565,497
Crataegus engelmannii	1,780	491	18	421	£425,990
Crataegus rosei	1,780	978	4	88	£499,861
Fagus grandifolia	1,780	172	7	87	£284,080
Ilex aquifolium	1,780	36	3	64	£44,508
Ilex opaca	1,780	1,083	22	468	£4,486,435
Juniperus communis	1,780	2,444	2	1,036	£6,008,632

Species	Number of trees	Carbon stored (tonnes)	Net Seq (tonnes/yr)	Avoided runoff (m3)	Replacement Cost (£)
Juglans nigra	1,780	2,160	51	697	£8,716,887
Ligustrum vulgare	1,780	492	38	121	£1,403,475
Metasequoia glyptostroboides	1,780	2,249	39	1,819	£7,088,038
Platanus	1,780	5,609	24	941	£1,195,718
Populus nigra	1,780	2,460	91	1,013	£9,448,635
Populus nigra v. italica	1,780	4,966	177	2,502	£8,700,197
Prunus serrulata	1,780	8,843	8	409	£11,642,743
Quercus x atlantica	1,780	2,323	62	2,119	£8,099,246
Robinia pseudoacacia	1,780	312	20	209	£1,551,726
Salix arizonica	1,780	457	66	47	£467,834
Sambucus canadensis	1,780	152	7	61	£627,148
Schizomeria ovata	1,780	5,602	123	431	£10,710,630
Sorbus commixta 'Embley'	1,780	920	33	108	£1,518,909
Tilia americana	1,780	1,227	43	364	£6,862,782
Ulmus americana	1,780	20	6	56	£36,719
Abies	890	5,646	14	302	£1,097,616
Acer	890	1,133	35	581	£2,135,101
Acer macrophyllum	890	2,400	42	595	£2,380,878
Acacia mearnsii	890	482	5	1,308	£5,305,614
Acer opalus	890	303	27	120	£671,697
Acer rubrum 'Brandywine'	890	2,415	52	385	£1,215,697
Arbutus unedo	890	6,676	1	2,269	£12,153,506
Betula pendula	890	817	53	89	£3,380,010
Borassus aethiopum	890	67	3	11	£975,261
Buxus	890	74	6	133	£67,086
Carpinus	890	1,590	1	77	£4,558,863
Callitris baileyi	890	5,400	3	651	£9,258,263
Catalpa bignonioides	890	652	15	354	£3,318,090
Celtis australis	890	28	3	34	£383,030
Chamaecyparis obtusa	890	1,714	30	649	£4,907,175
Chamaecyparis thyoides	890	470	12	217	£1,428,638
Corylus	890	988	30	321	£1,260,671
Crataegus	890	61	4	45	£110,898
Crataeva	890	845	30	427	£446,345
Crataegus x anomala	890	231	5	34	£309,474
Crataegus douglasii	890	139	0	0	£0

Species	Number of trees	Carbon stored (tonnes)	Net Seq (tonnes/yr)	Avoided runoff (m3)	Replacement Cost (£)
Crataegus furtiva	890	538	1	347	£1,236,894
Crataegus laevigata	890	235	12	146	£365,031
Crataegus monogyna	890	194	12	20	£478,082
Cupressus	890	6,676	7	4,302	£12,550,770
Cupressus macrocarpa	890	1,023	1	548	£3,094,723
Euonymus	890	2,127	1	58	£722,649
Fagus sylvatica 'Purpurea'	890	6,676	7	4,951	£12,001,475
Juniperus californica	890	1,910	50	296	£2,025,547
Platycladus	890	530	22	145	£573,845
Platanus x hispanica	890	596	17	49	£1,916,606
Populus balsamifera	890	229	11	156	£1,150,226
Populus grandidentata	890	333	27	270	£2,135,101
Prunus cerasifera	890	128	14	224	£269,623
Pseudotsuga	890	2,584	17	429	£1,038,548
Pterocarya pterocarpa	890	725	18	362	£1,654,555
Pyrus	890	2,521	2	340	£6,894,260
Pyrus pyrifolia	890	230	19	71	£781,258
Quercus arkansana	890	2,103	11	348	£7,352,572
Quercus cerris	890	1,480	30	315	£2,778,274
Quercus douglasii	890	560	22	422	£2,082,061
Quercus grisea	890	2,026	50	774	£7,047,897
Quercus myrsinifolia	890	1,671	1	803	£5,794,522
Quercus prinus	890	141	6	280	£269,067
Quercus sinuata	890	2,119	12	198	£3,820,630
Quercus suber	890	721	13	31	£1,891,006
Quercus variabilis	890	1,794	49	837	£5,794,522
Salix	890	6,676	1	493	£13,624,440
Sapium caribaeum	890	4,266	22	666	£6,504,084
Salix myricoides	890	6,676	1	917	£10,227,505
Salix petrophila	890	1,516	61	260	£1,388,041
Salix serissima	890	1,090	8	336	£1,888,974
Salix triandra	890	1,624	2	46	£2,704,008
Taxus baccata	890	23	2	45	£22,254
Tsuga	890	4,980	53	1,137	£6,011,362
Ulmus crassifolia	890	397	32	187	£766,672
Ulmus pumila	890	725	33	103	£826,561

Species	Number of trees	Carbon stored (tonnes)	Net Seq (tonnes/yr)	Avoided runoff (m3)	Replacement Cost (£)
Viburnum opulus v. americanum	890	42	4	12	£44,114
Xylocarpus moluccensis	890	1,618	64	78	£3,934,905

Appendix V. Notes on 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).
- Total carbon stored and net carbon annually sequestered by trees.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power plants.
- 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 Ash Dieback, Asian longhorned beetle, Ramorum disease and Phytophthora kernoviae.

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

Once the data has been uploaded to i-Tree, the software is able to determine current carbon storage, biomass for each tree which 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[24]. 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 were 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[25].

24 Nowak 1994

21 Nowak et al (2007)

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[26]. 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[27] [28] that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere[29].

Annual avoided surface run-off is calculated based on rainfall interception by vegetation, specifically the difference between annual run-off with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface run-off, only the precipitation intercepted by leaves is accounted for in this analysis. The value of avoided run-off 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 is reported.

Replacement Costs were based on valuation procedures of the Council of Tree and Landscape Appraisers which uses tree species, diameter, condition and location information[30] [31].

An amended CAVAT quick method was chosen to assess the trees in this study, in conjunction with the CAVAT steering group (as done with previous i-Tree Eco studies in the UK). In calculating CAVAT the following data sets are used:

- the current Unit Value, representing the fiscal value of the tree, by cross-sectional area,
- Diameter at Breast Height (DBH),
- Community Tree Index (CTI) rating, reflecting local population density,
- an assessment of accessibility,
- an assessment of overall functionality, (that is the health and completeness of the crown of the tree);
- an assessment of Life Expectancy.

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26 Baldocchi (1987), (1988)

27 Bidwell and Fraser (1972)

28 Lovett (1994)

29 Zinke (1967)

30 Hollis (2007)

31 Rogers et al (2012)

The Unit Value is determined by the CAVAT steering group and published online. The Unit Value for 2021/22 (the year of the study) is £16.26.

DBH is taken directly from the field measurements.

The CTI rating is determined from the LTOA approved list and is calculated on a borough by borough basis.

Functionality was calculated directly from the amount of canopy remaining from field observations.

For the purposes of this report trees with data entered only at genus level were not represented in the figures so as to more accurately represent species level results.

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