Treeconomics

Valuing Solihull's Urban Forest

West Midlands Combined Authority

Solihull Metropolitan Borough Council

Barton Hyett Associates
Arboricultural Consultants

Forest Research

Woodland Trust

Birmingham Tree People

i-Tree

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The study was led by Treeconomics, who were commissioned by WMCA, in partnership with Birmingham Tree People, Barton Hyett Associates and Forest Research. It was made possible through funding received from the Emergency Tree Fund (administered by The Woodland Trust), which draws on Amazon's Right Now Climate Fund. Field survey data was collected by volunteers and surveyors during the summer of 2023.

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Executive Summary

The urban forest within and around Solihull is a vital resource, providing numerous benefits to the people who live, work and visit the borough. The ecosystem services highlighted within this report are just some of the benefits the urban forest provides. This study captures an immediate snapshot of the urban forest at the time the data was collected, in relation to the plots sampled.

The purpose of this report is to provide clear, concise information on the urban forest resource as a means to assist decision making on urban forest management.

Key findings include:

- There are approximately **1.26 million trees** across Solihull - equivalent to **5.8 trees per person and 70 trees per hectare**. Tree cover was estimated at **13.1%** with shrub cover at an estimated **4.7%.**

- **64 species of tree** were recorded across the Solihull study area. The most common tree species are; Ash with an estimated 141,000 trees, English Oak with an estimated 128,000 trees, and Hawthorn with an estimated 123,000 trees.

- Solihull's trees and shrubs have the potential to remove approximately **47 tonnes of air pollution** every year with an associated value of **£2.37 million**. These pollutants include sulphur dioxide (SO_2), particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_2).

- Solihull's trees reduce surface water runoff by over **294,000 m³ per year**. This volume is equivalent to nearly **118 Olympic swimming pools of surface runoff** being averted every single year, a service worth an estimated **£474,000** in avoided water treatment costs.

- In total, the trees store around **365,000 tonnes** of carbon and sequester **12,400 tonnes** of carbon annually, with associated values of approximately **£337 million** and **£11.4 million** respectively.

- The amenity value of the trees was calculated to be **£9.66 billion**, as determined using a CAVAT valuation approach.

- There is a good distribution of both semi-mature and mature trees, however there are very few large senescent (ancient) trees. Managing trees to ensure they reach their full potential, namely in their stature is important, as large trees provide far more benefits than small trees. However, the planting of young trees is also required to replace dying or removed trees and to further enhance the urban forest.

The recommendations from this study include:

- Continue to plant a wide diversity of species (with due consideration to local site factors) to replace the future loss of ash, and reduce the likelihood of severe impact from any given pest or disease outbreak and/or the impacts of climate change.
- Aim to retain large, mature trees wherever possible (as large trees generally provide the most benefits) - make them part of new developments rather than lose them.
- Continue new planting in order to maintain a healthy tree size diversity in Solihull to avoid significant losses in ecosystem service provisions in the future, whilst addressing lack of canopy and unequal distribution of the urban forest.
- Carry out a Tree Planting Opportunity Mapping study to target prioritised areas and optimise resources. This can facilitate additional planting alongside main roads, and join up/fill in gaps within the existing urban forest to enhance wildlife corridors and the connectivity of pathways and cycle lanes through green infrastructure. Tree equity analysis at neighbourhood level can also be incorporated to target areas that lack canopy cover. Particularly in areas with high deprivation and which experience poor air quality, surface flooding, limited existing green space, and heat stress or lack of shade.
- 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.
- Consider developing an Urban Forest Master Plan to follow on from this study providing a vision of what the borough would like to achieve with its urban forest and steps to realise those goals.

Headline Figures

Solihull's Structure and Composition Headline Figures		
Number of Trees (estimate)	1,263,000	
Tree Density (trees/hectare)	70	
Tree Canopy Cover	13.1% (2,335 ha)	
Shrub Cover	4.7%	
Most Common Tree Species	Ash (11.2%), English Oak (10.1%), Hawthorn (9.8%)	
Replacement Cost (CTLA)	£524 million	
Amenity Valuation (CAVAT)	£9.66 billion	
Proportion of Trees in Good or Excellent Condition	86.6%	
Solihull's Ecosystem Services Headline Figures		
Total Carbon Storage	365,000 tonnes	£354 million
Annual Carbon Sequestration	12,400 tonnes	£12,000,000
Annual Pollution Removal	47.2 tonnes	£2,380,000
Annual Avoided Runoff	294,000 m³	£474,000
Total Annual Benefits	£14,854,000	

	West Midlands Total	Birmingham	Coventry
Number of Trees (estimate)	4,918,000	1,129,000	574,000
Canopy cover (ha)	12,996 (14.4%)	4,016 (15%)	1,144 (11.6%)
Total Carbon Storage	1,912,000 tonnes	419,000 tonnes	284,000 tonnes
Annual Carbon Sequestration	57,620 tonnes	12,800 tonnes	7,950 tonnes
Annual Pollution Removal	206 tonnes	80.4 tonnes	16.4 tonnes
Annual Avoided Runoff	1,551,000 m³	481,000 m³	161,000 m³

Table 1: Headline figures for The West Midlands and a comparison of outputs from the component i-Tree Eco studies.

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 therefore should not be added together. There are different methods for estimating tree canopy cover. It is important to note that these different approaches will produce different results. This depends on the methodology, the definition of what constitutes 'cover' (trees, trees and shrubs, trees green-space and shrubs, etc) and the resolution of the data (leaf on vs leaf off, aerial photos vs satellite imagery vs ocular estimates, etc). Therefore, each study must be interpreted in context with consideration for the expected statistical accuracy.

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 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 Energy Security & Net Zero and Department for Business, Energy & Industrial Strategy figures for the non-traded central estimate cost of CO_2. This is currently £265 per metric ton for 2023.

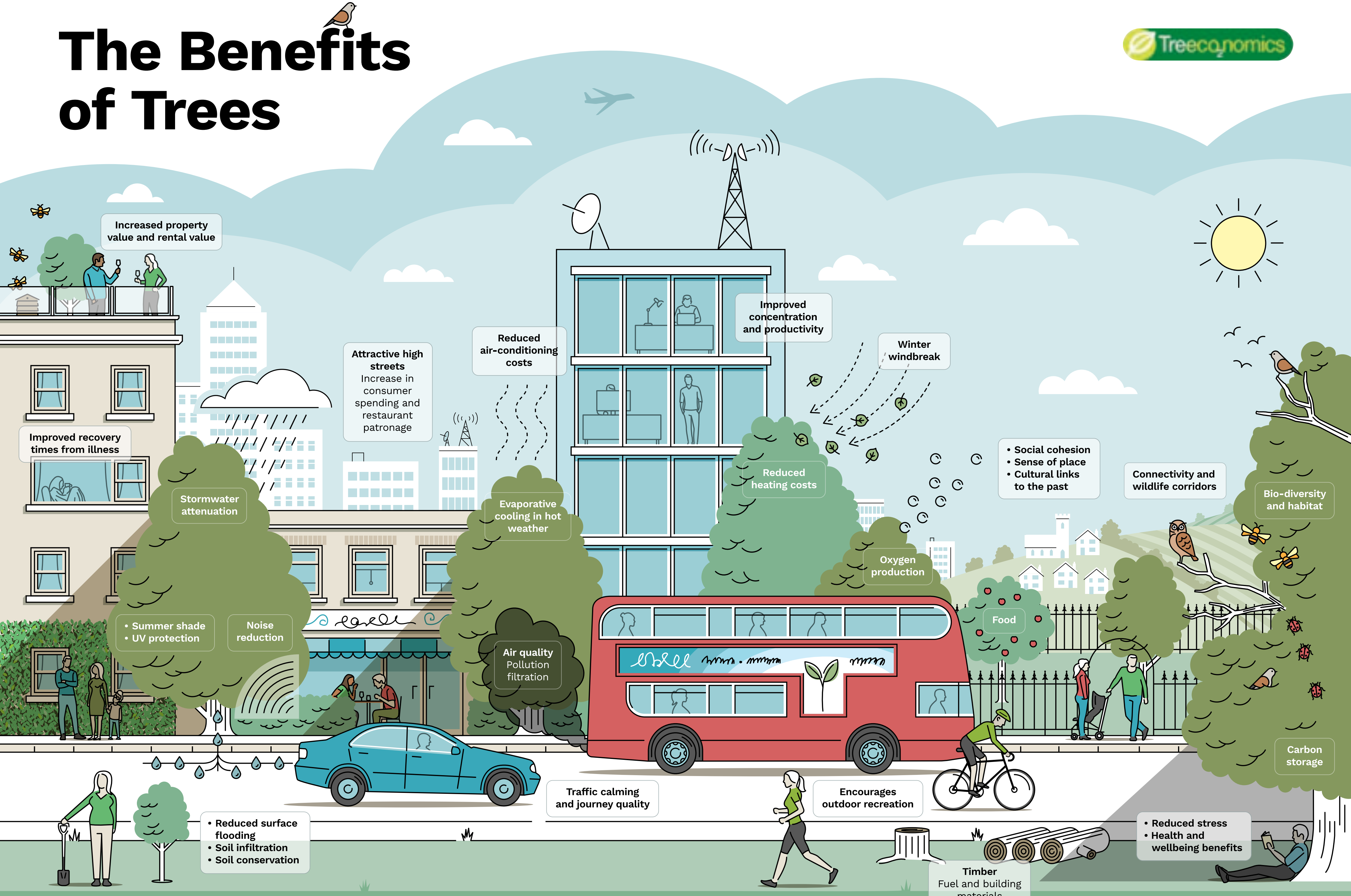
Pollution Removal: This value is calculated based on the 2020 UK social damage costs for 'Road Transport Urban Large'; nitrogen dioxide - £14.633 per kg, sulphur dioxide - £7.064 per kg, particulate matter less than 2.5 microns - £278.213 per kg.

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 £1.6142 per cubic metre and includes the cost of avoided energy and associated greenhouse gas emissions.

Total Annual Benefits: Sum of the annual 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 6.0.32.

The Benefits of Trees



Introduction and Background

Solihull is a metropolitan borough within the West Midlands - a region in central England with a rich industrial history. Solihull's population is 216,000 of 2.9 million people in the West Midlands. Solihull's landscape encompasses a blend of residential, commercial, industrial, recreational and agricultural land, providing a balance between urban life and natural beauty. This report refers to the combined area of Birmingham, Coventry and Solihull which covers an area of 74,473 ha - of which Solihull constitutes 17,828 ha.

This i-Tree Eco study was commissioned by the West Midlands Combined Authority and provides detailed information on the scale of benefits provided by the urban forest in Solihull, expressing the value of some of those benefits in monetary terms. This study shows how the perception of trees, shrubs and green spaces which make up the urban forest can shift from the historic view of a liability to an asset for the council and the local community.

The objectives of the study were to:

- Measure the structure of the urban forest, including the species composition, diversity and condition.
- Calculate the ecosystem service and economic values provided by the urban forest using the i-Tree Eco software.
- Promote the urban forest and emphasise the benefits it provides.
- Conduct a risk analysis of the susceptibility of the trees to pests and diseases.
- Explore the urban forest's potential to influence carbon net-zero balances.
- Forecast possible scenarios based on the current composition of the urban forest and future management strategies.

Report Scope

This study investigates the structure and composition of Solihull'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. By showcasing the economic value of benefits provided by Solihull's urban forest, increased awareness can be used to encourage investment in Solihull's natural capital and wider environment.

The assessment presented in this report is fundamental in understanding factors which are critical to a resilient urban forest including:

- Maintaining and improving the current tree canopy cover in Solihull.
- Identifying areas vulnerable to loss of tree cover (e.g. as a result of pests and diseases, climate change 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 Solihull.
- Those who are interested in local trees for improving their own and others' health, wellbeing and enjoyment across Solihull.

Methodology

To gather a collective representation of Solihull's urban forest across both public and private land, an i-Tree Eco plot-based assessment was undertaken. 300 randomly allocated plots of 0.04ha (400m^2) were surveyed in Solihull. This equates to 1 plot every 59.4ha.

The field data was submitted to the i-Tree server which, combined with local hourly pollution and meteorological data, calculates outputs, some of which are 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. As part of this project Solihull Metropolitan Borough Council's tree management team were provided training in how to use the i-Tree tool and therefore will be able to access all available reports.

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 (£); Carbon storage value (£); Carbon sequestration value (£); Pollution removal value (£).
Additional Information	Potential insect and disease impacts; Oxygen production; Forest food production; UV Screening values.

Table 2: Study outputs

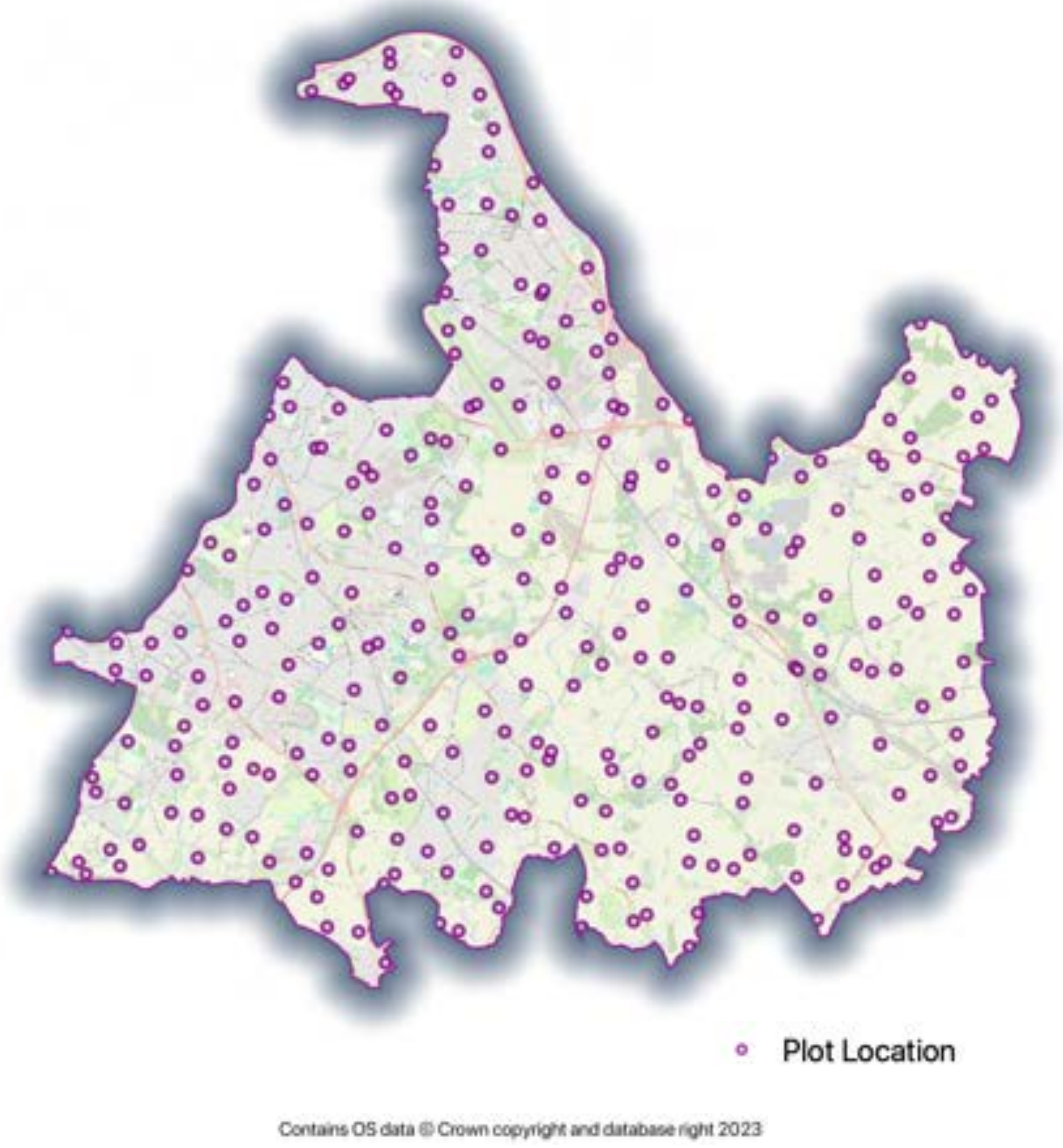


Figure 1: Map of Solihull showing locations of survey plots

Plots were randomly allocated to ensure a statistically significant distribution across Solihull, as such, they fall on both public and private land. While most areas could be accessed with permission, some could not. In the event plots were inaccessible, back-up plots were used. These were randomly allocated within the same grid square as the original.

Data Limitations

While Solihull'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 Solihull's urban forest at the time of measurement. This report is concerned with the trees and shrubs within Solihull. 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.

The Urban Forest - The Structural Resource

Ground Cover

Ground cover refers to the types of surface or vegetation within each plot. Within Solihull the most common ground cover types is grass (19.9%), herbs (17.6%), unmaintained grass (17.5%) and bare soil (11.7%).

Of the surveyed area, 13.1% of Solihull is under tree canopy cover, with 4.7% under shrub cover (note that shrubs are also present under tree cover and so these two figures 'overlap').

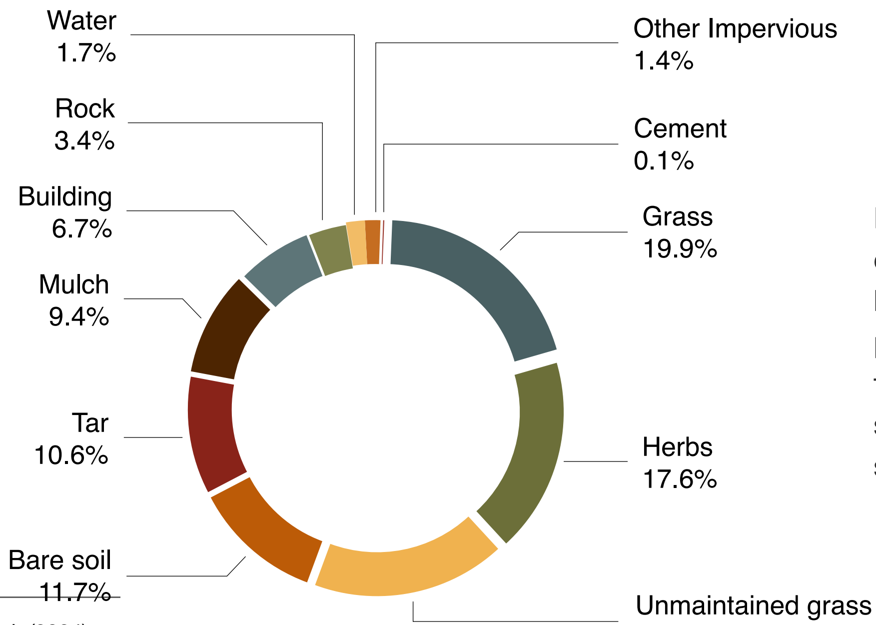


Figure 2: Ground cover types within plots.

Figure 3: Green space throughout Solihull according to Ordnance Survey official categories

For context, the average canopy cover for the UK is 16%[1], though coastal and rural areas are often lower and peri-urban areas are often higher. The survey also showed that a further 6.7% of land within the plots could (in theory) be planted with trees. Utilising available space to increase tree canopy cover can improve the provision of ecosystem services such as reducing air pollution and increasing carbon sequestration

[1] Forest Research (2024)

Land Use

Figure 4 shows the average land cover across Solihull. Surveyed plots indicate that on average Solihull's largest land use is agriculture (42.8%) and residential (18.4%). Parks and forests (combined) account for 9.6% of land cover across Solihull.

2.5% of land in Solihull is vacant (445.8ha). This land could potentially be repurposed for tree planting or the creation of new green spaces. Should the 445.8ha of vacant land be turned over to broadleaved woodland creation, this land could accommodate 713,200 trees (at a spacing of 2.5 x 2.5m/tree). Parkland creation (at a spacing of 25m x 25m/tree) could accommodate 7132 new trees.

Green spaces make up 54.8% of land cover in Solihull; that is significantly higher than the average for Inner London (21%).

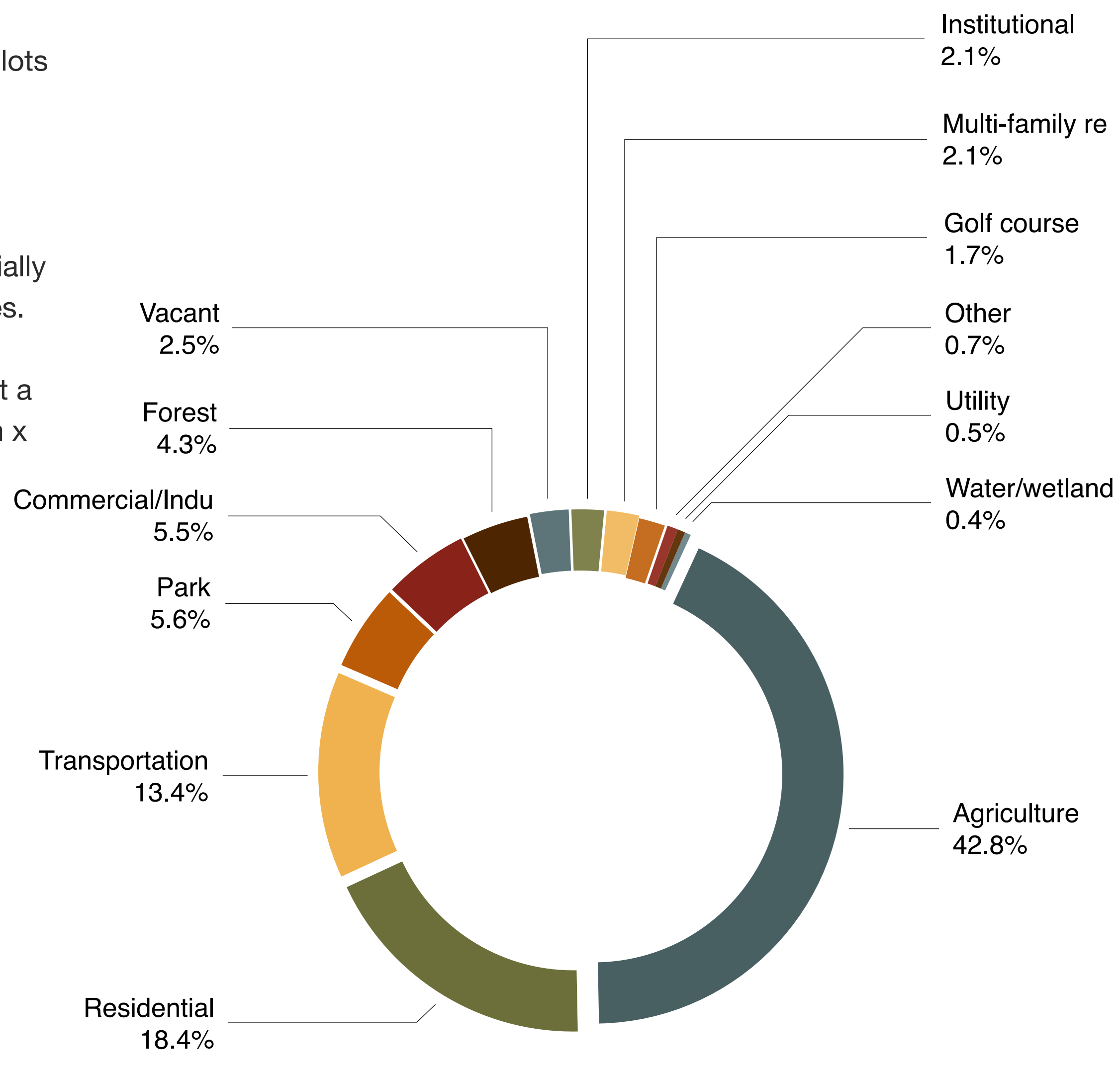


Figure 4: Land use types within plots.

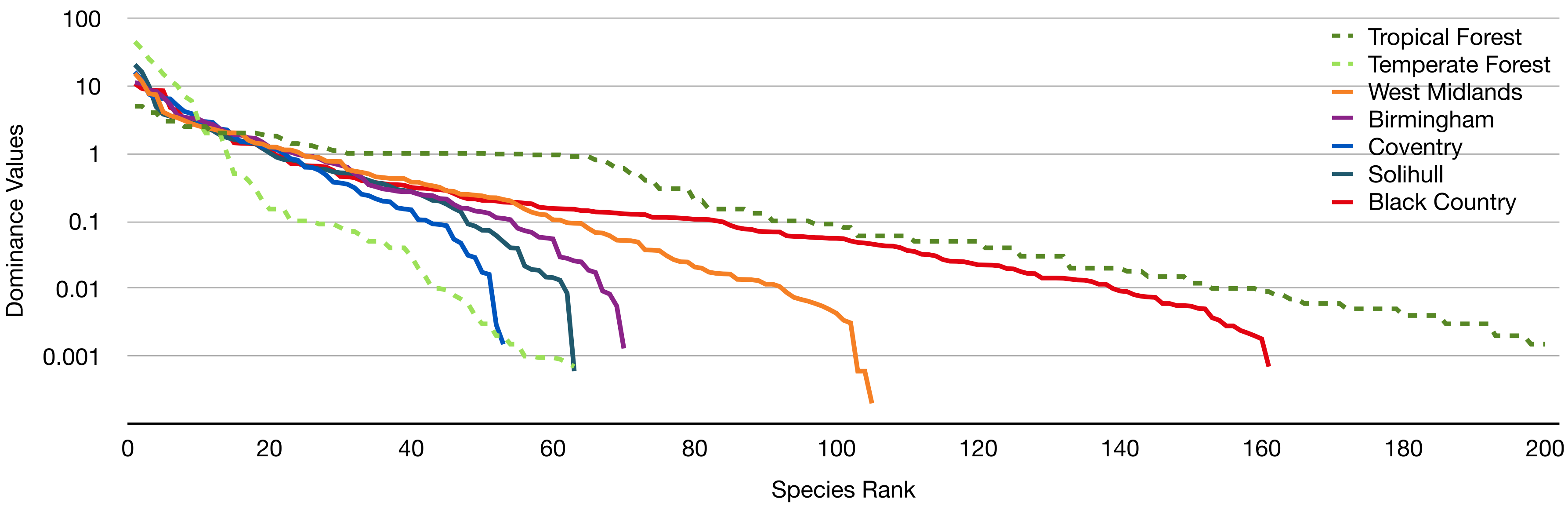


Figure 5: Hubbell's Dominance Diversity Curve showing example forest types and selected UK cities.

Maintaining a species rich urban forest is vital in providing resilience to pests & diseases and climate change. A diverse urban forest can support a range of pollinators and wildlife, whilst enhancing aesthetic value by providing a variety of colours, textures and shapes throughout the year. Overall, promoting diversity in urban forests leads to healthier, more resilient ecosystems that provide a wide range of benefits to both humans and the environment.

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[2]. 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.

Figure 5 shows a dominance diversity curve developed by Hubbell[3]. In this graph, the longer and shallower curves indicate forests with higher diversity and fewer species dominating the population.

[2] Gill et al 2007

[3] Hubbell, 1979 cited in Perry *at al*., 2008

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 Solihull (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.

Species	Species/ ha	SHANNON	MENHINICK	SIMPSON	EVENNESS
64	5.30	3.30	2.30	17.50	0.80

Table 3: Species richness and diversity indexes for Solihull

- **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).[4]
- **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. Menhinick's index is simply the number of species divided by the square-root of the total number of individuals. An index close to 1 or above is considered to be good.
- **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.[5]

According to most metrics, Solihull has a good level of diversity. Whilst Solihull is more diverse than a typical temperate forest, the borough still has potential to improve diversity to the level of some other cities in the UK. It is not uncommon for cities to rank highly in diversity often due to non-native tree species.

In Solihull 72.1% of trees are a native species. These species are important for biodiversity and the ecology of the landscape; however, non-native trees will become increasingly important in a changing climate.

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

[5] i-Tree, 2021

Species Richness

The three most common named species are Ash, English Oak, and Hawthorn (Figure 6). Some trees were identified at genus level only, these have not been included in this species level analysis to avoid mixing metrics, and are instead included in 'All Other'.

The ten most common species account for 64.9% of the total population. In total, 64 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.

Solihull's urban forest has a variety of species present, with only two species exceeding 10% of the total population. With new tree planting, Santamour's 10:20:30 tree population diversity rule[6] would therefore be achievable in the near future, indicating that the urban forest has potential to be more resilient to pests and diseases. The most prominent threats from present pests and diseases in the West Midlands are Ash Dieback with threats to the Oak population such as Acute Oak Decline and Oak Processionary Moth.

The range of tree species diversity in Solihull is good and the area does not rely too heavily on just a few species. Maintaining a broad tree species diversity through planting selection will help ensure the resilience of this urban forest into the future.

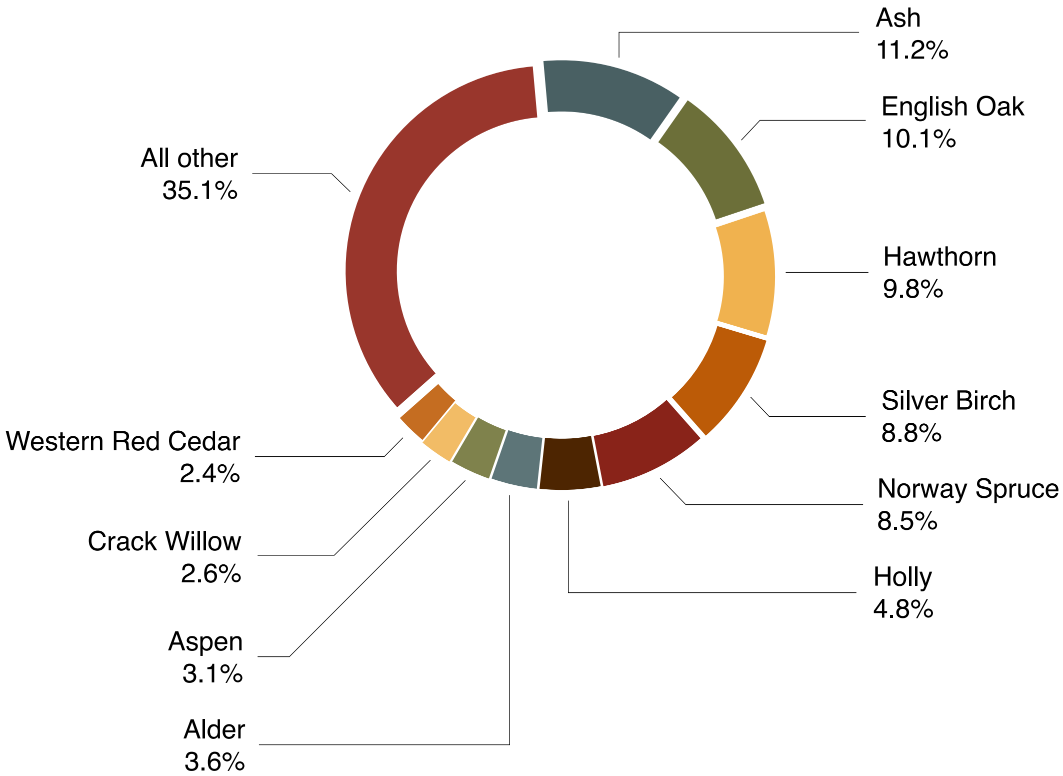


Figure 6: Species composition (most common species).

Santamour's 10-20-30 rule of thumb

This suggests upper limits for a tree population as follows:

- Single species - 10%
- Single genus - 20%
- Single family - 30%

Many old city park and urban tree populations do not adhere to this rule due to historic plantings, but the rule can help inform future plantings.

[6] Santamour, 1990

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 urban forest structure and are therefore the most important in delivering benefits.

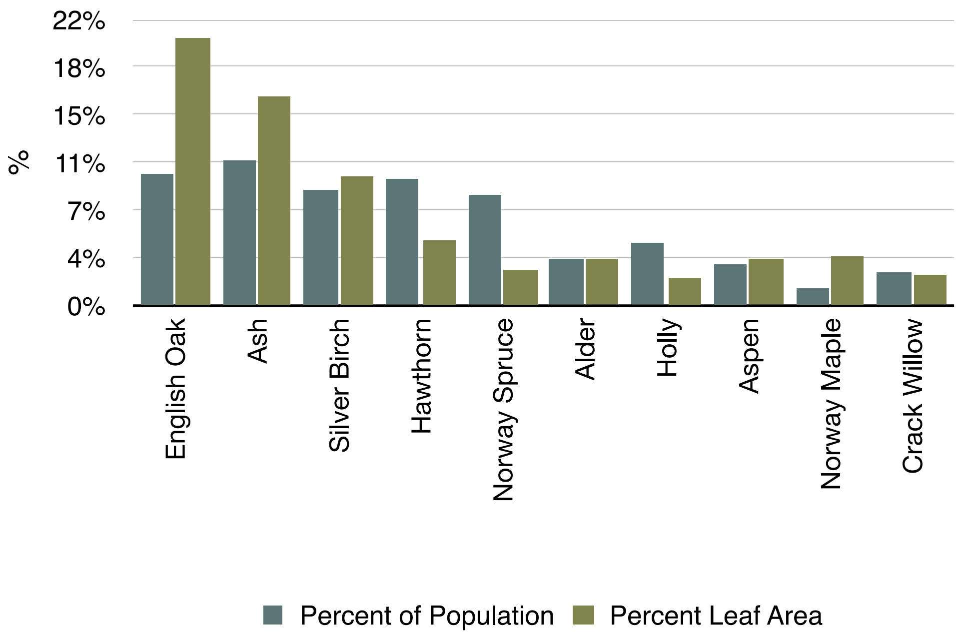


Figure 7: Leaf area and population of Solihull by most dominant tree species.

The Dominance Value is calculated by taking into account the leaf area and relative abundance of the species. In Solihull the most dominant species are Ash, English Oak and Hawthorn due to having a combination of the largest leaf areas and being a common species (Figure 7).

Certain trees have a high dominance value due to their expansive leaf area even though they represent a relatively low proportion of the population - this can be seen in the five most dominant species in Solihull all with similar populations but varying leaf area. The opposite can be true for species with high population but a smaller leaf area - in this example Hawthorn and Holly

Species	Leaf area (ha)	Dominance Value
English Oak	3,808	30.7
Ash	2961	27.2
Silver Birch	1837	18.8
Hawthorn	906	14.7
Norway Spruce	513	11.3
Alder	654	7.1
Holly	403	6.9
Aspen	644	6.6
Norway Maple	705	5.2
Crack Willow	443	5.0

Table 4: List of the ten most dominant tree species in Solihull.
*See appendix II for the full list of tree dominance value ranking in Solihull

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 32.4% percent of the tree population of Solihull'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 8).

> Most regions in England only have 10-20% of trees with a DBH that is greater than 30cm*, but in Solihull it is 21.8%
>
> *Trees in Towns II

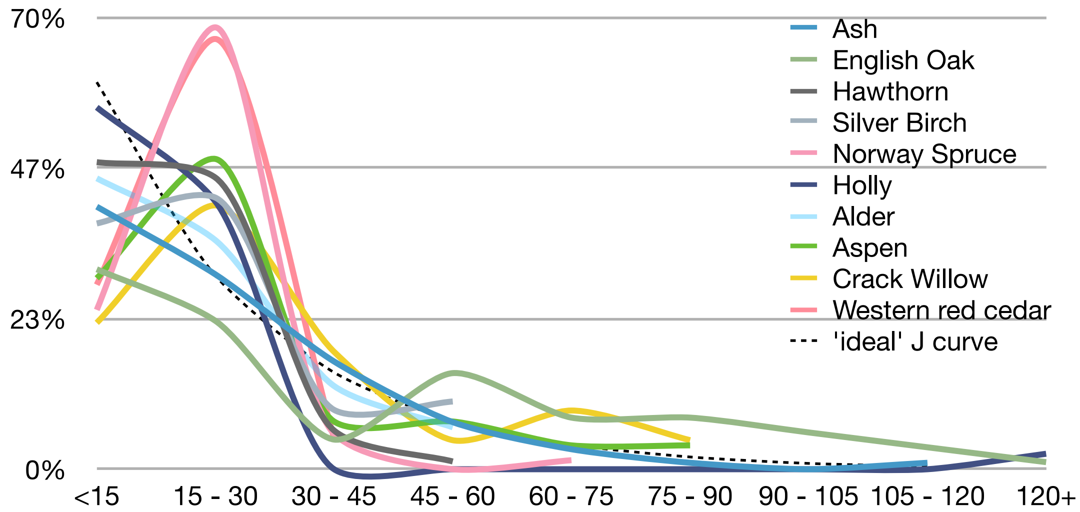


Figure 8: Spread of size classes amongst the top ten species, showing comparison to 'ideal' J-curve
'ideal' J-curve values reduce by half for each increase in DBH class

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 8). Forests are unique and there is no 'one size fits all' target distribution. However, it is noted that Solihull will benefit from a greater proportion of larger trees as the tree stock matures, if correctly managed.

[7] City of Toronto Parks, Forestry and Recreation, 2013

[8] Hand and Doick, 2019

[9] Kimmins, 2004

Biodiversity of the Urban Forest

Biodiversity is important because it provides a wide range of indirect benefits to humans. However, challenges exist in valuing it because it is difficult to identify and measure the passive, non-use values of biodiversity.[10]

The diversity of species within Solihull (both native and non-native) will influence how resilient the tree population will be to future changes, such as minimising the overall impact of exotic pests, diseases and climate change.

A diverse treescape is better able to serve as a habitat for a wide range of creatures, and native trees are important as they are better suited to support other native species.

Unfortunately, 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,[11] therefore non-native species could become increasingly important for the delivery of benefits in Solihull.

Species	Scientific name	Total	Beetles	Flies	True bugs	Wasps & sawflys	Moths & butterflies	Other
Willow (3 spp)	*Salix (3 spp.)*	450	64	34	77	104	162	9
Oak (2 spp)	*Quercus (2 spp.)*	423	67	7	81	70	189	9
Birch (4 spp)	*Betula (4 spp.)*	334	57	5	42	42	179	9
Hawthorn	*Crataegus monogyna*	209	20	5	40	12	124	8
Poplar (3 spp)	*Populus (3 spp.)*	189	32	14	42	29	69	3
Scots Pine	*Pinus sylvestris*	172	87	2	25	11	41	6
Blackthorn	*Prunus spinosa*	153	13	2	29	7	91	11
Common Alder	*Alnus glutinosa*	141	16	3	32	21	60	9
Elm (2 spp)	*Ulmus (2 spp.)*	124	15	4	33	6	55	11
Hazel	*Corylus avellana*	106	18	7	19	8	48	6
Beech	*Fagus sylvatica*	98	34	6	11	2	41	4
Norway Spruce	*Picea abies*	70	11	3	23	10	22	1
Ash	*Fraxinus excelsior*	68	1	9	17	7	25	9
Rowan	*Sorbus aucuparia*	58	8	3	6	6	33	2
Lime (4 spp)	*Tilia (4 spp.)*	57	3	5	14	2	25	8
Field Maple	*Acer campestre*	51	2	5	12	2	24	6
Hornbeam	*Carpinus betulus*	51	5	3	11	2	28	2
Sycamore	*Acer pseudoplatanus*	43	2	3	11	2	20	5
European Larch	*Larix decidua*	38	6	1	9	5	16	1
Holly	*Ilex aquifolium*	10	4	1	2	0	3	0
Horse Chestnut	*Aesculus hippocastanum*	9	0	0	5	0	2	2
Common Walnut	*Juglans regia*	7	0	0	2	0	2	3
Yew	*Taxus baccata*	6	0	1	1	0	3	1
Holm Oak	*Quercus ilex*	5	0	0	1	0	4	0
False acacia	*Robinia pseudoacacia*	2	0	0	1	1	0	0

Table 5: The number of species of insects associated with British trees: a Re-analysis (Kennedy and Southwood)

"The conservation of biodiversity is not just about saving a few species, but about preserving the intricate web of life that sustains us all."

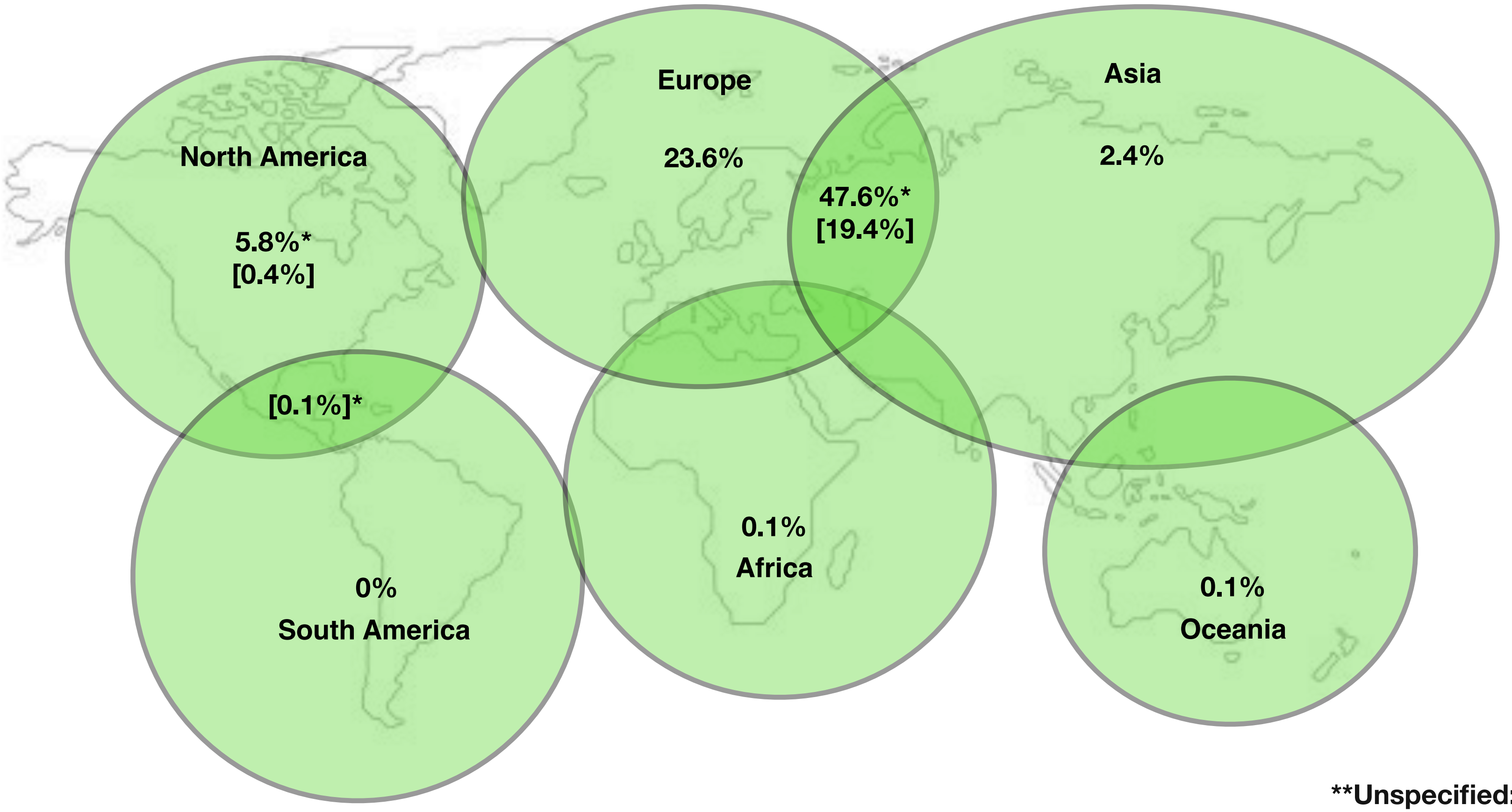
Dr. Thomas Lovejoy

[10] Nunes et al, 2001

[11] Gill et al, 2007

Origin of Tree Species

The map below shows the original continent of origin of the tree species found in Solihull. In total, around 90.6% of the tree population are native to Europe. Of those, it is expected that a smaller percentage are native to the British Isles, although diversity is key to resilience.



****Unspecified: 0.4%**

Figure 9: 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.

**0.4% 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 are produced.

The problems caused by poor air quality are well known, ranging from human health impacts to building damage. Trees significantly contribute 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 $PM_{2.5}$.

12 Nowak et al, 2000.

13 Escobedo and Nowak (2009)

14 DEFRA (2023)

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 VOCs within its algorithms, and the overall effect of Solihull's trees is to reduce ozone through evaporative cooling[12], however this is not valued in this report as there is no UK Social Damage Cost for this pollutant.

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[13]. Furthermore, because filtering capacity is closely linked to leaf area it is generally the trees with larger canopy potential that provide the most benefits.

It is estimated that trees and shrubs combined remove 47.2 metric tonnes of air pollution, including nitrogen dioxide (NO_2), particulate matter less than 2.5 microns ($PM_{2.5}$), and sulphur dioxide (SO_2) per year with an associated value of approximately £2.4 million (based on UK social damage costs published by DEFRA)[14]. Total pollution removal per ha in Solihull is equivalent to 0.003 tonnes per ha per yr.

Pollutant	Tonnes removed by trees per year	Value (approx)
Nitrogen dioxide (NO_2)	39.3	£575,000
Particulates (<$PM_{2.5}$)	6.4	£1,790,000
Sulphur dioxide (SO_2)	1.5	£10,800
Total	47.2	£2,375,800

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

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 risks 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[15].

Within an urban area, the large extent of impervious surfaces increases the amount of run-off. However, trees are effective at reducing this[16]. 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 Solihull help to reduce run-off by an estimated 294,000 cubic metres a year with an associated value of £474,000.

English Oak trees intercept the most water, removing a total of 60,500 m^3 of water per year, a service worth £97,600 (Figure 10). English Oak trees have an expansive canopy to capture/ intercept rainfall and are the second highest proportion of trees within Solihull.

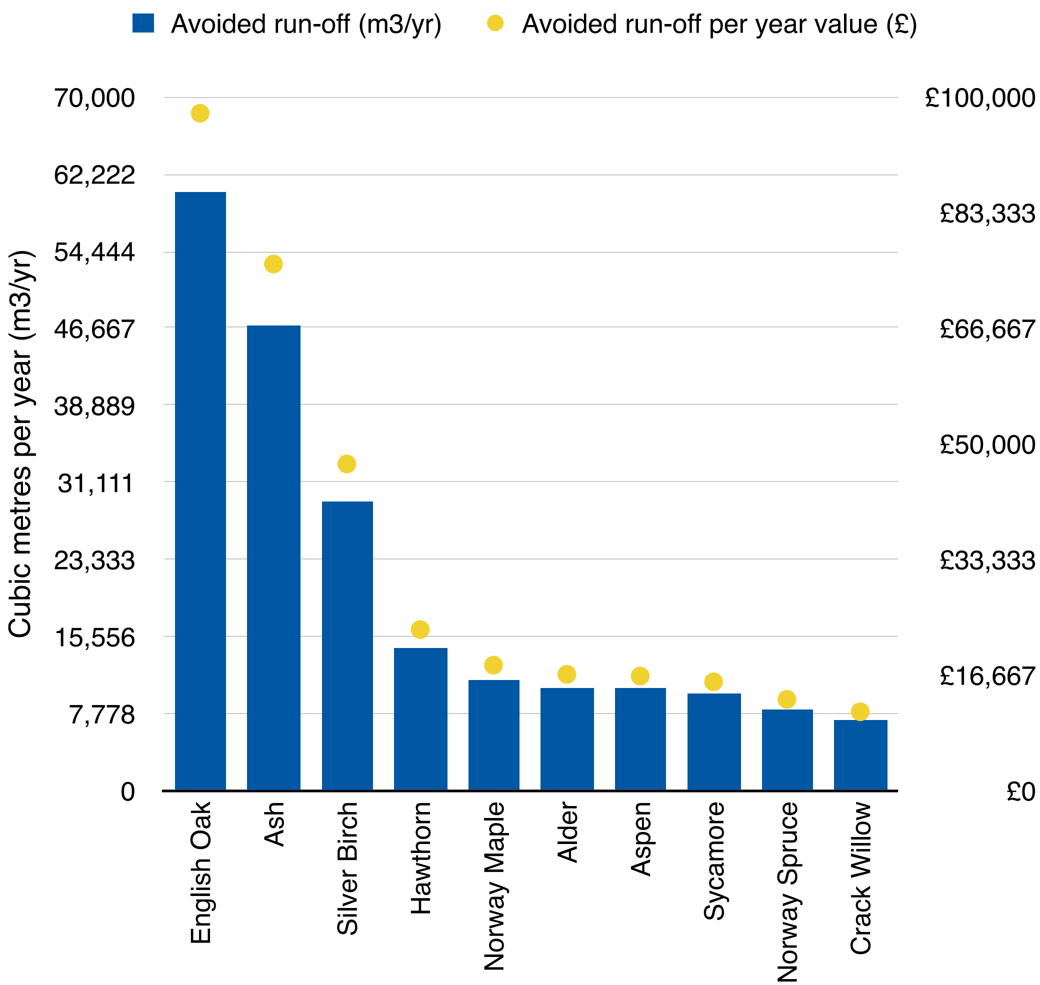


Figure 10: Avoided run-off by the top ten species.

[15] Hirabayashi (2012).

[16] 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[17]. Over the lifetime of a tree, several tonnes of atmospheric carbon dioxide can be absorbed[18].

The gross sequestration of Solihull's trees is approximately 12,400 tonnes of carbon per year (approximately 0.7t/yr/ha). The value of the carbon sequestered annually is estimated at £12 million per year. This value will continue to increase as the trees grow.

Carbon sequestration and storage is a key part of achieving any net-zero target. In 2021, Solihull Borough produced a total of 1,142 kt CO_2e emissions* (equivalent to approximately 311,000 tonnes of carbon), meaning that sequestration by trees account for 4% of the total annual emissions.

*Department for Energy Security and Net Zero, 2023

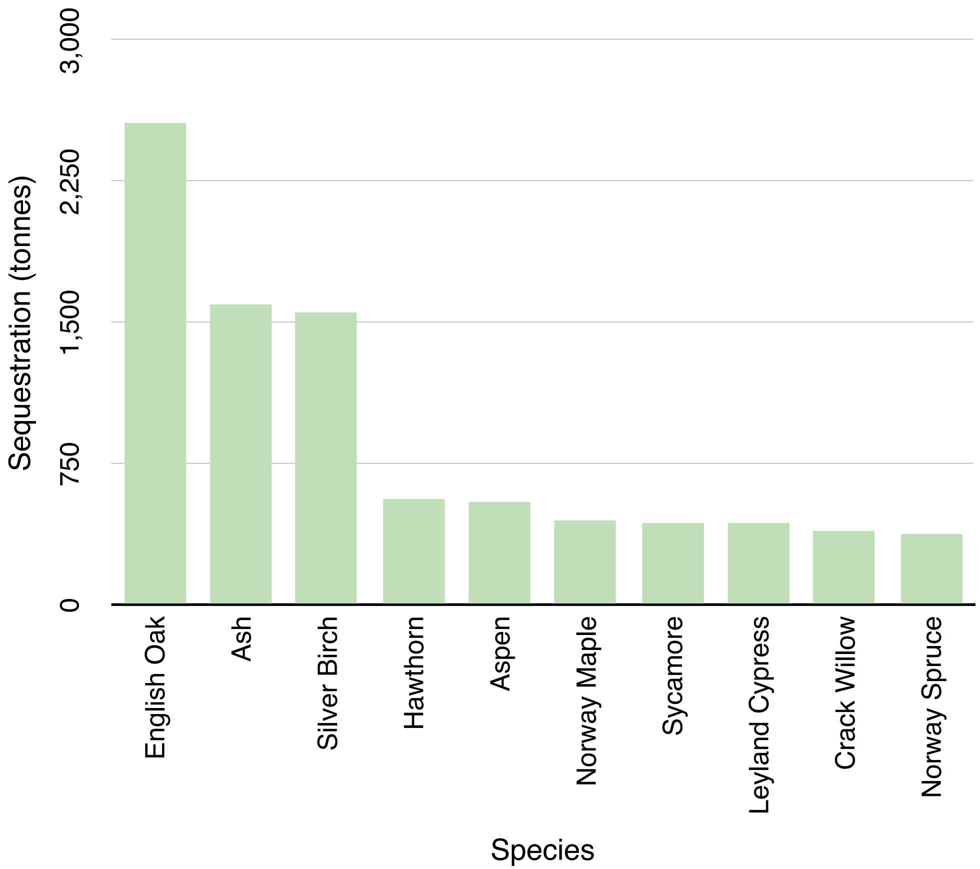


Figure 11: Ten most significant tree species for annual carbon sequestration in Solihull.

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17 Kuhns, 2008

18 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 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 365,000 tonnes (approximately 20.5 tonnes/ha) of carbon is stored in Solihull's trees with an estimated value of over £354 million (based on current carbon figures from the Department for Energy Security & Net Zero and Department for Business, Energy & Industrial Strategy)[19].

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 carbon sinks. Soils are an extremely important reservoir in the carbon cycle because they contain more carbon than the atmosphere and plants combined[20].

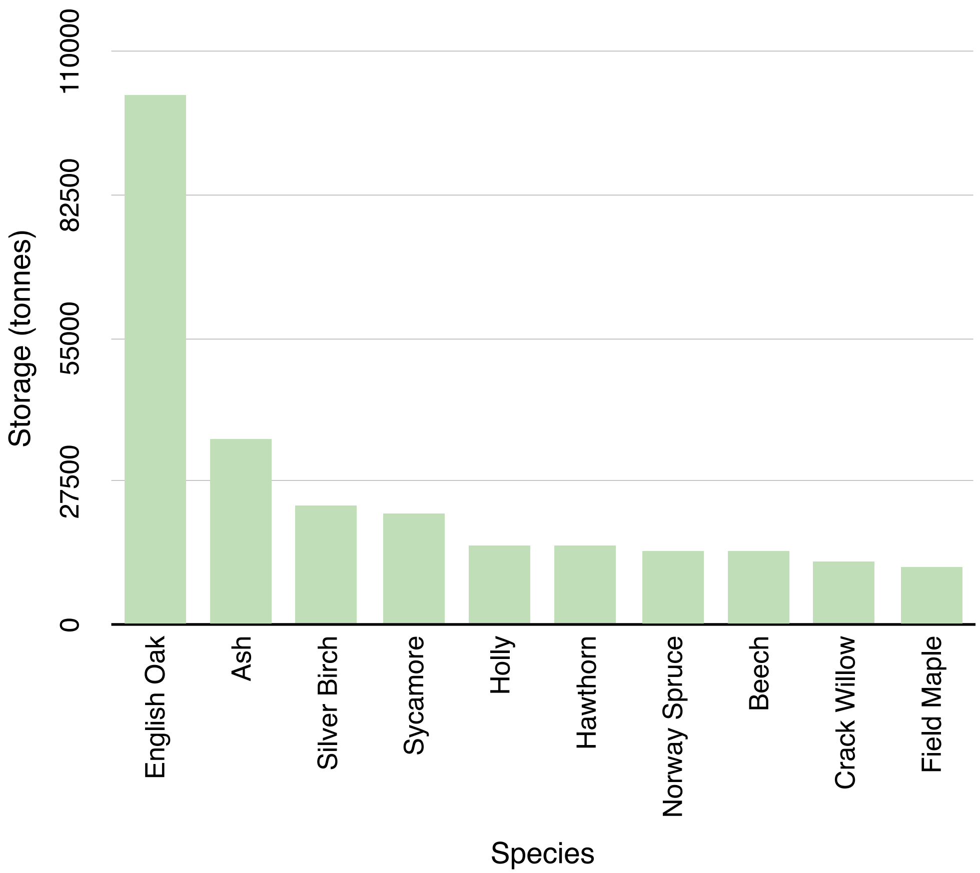


Figure 12: Ten most significant tree species for carbon storage in Solihull.

[19] DBIES (2022)

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

The Carbon Balance

The Climate Change Survey 2020 found 9 out of 10 councils have declared a climate emergency, with approximately 80% setting official targets to become carbon neutral[21]. The West Midlands Combined Authority declared a Climate Emergency in 2019, setting a vision of being carbon neutral by 2041[22].

Solihull Borough's carbon production has been falling quickly over the past few years. However it still produces around 311,000 tonnes of carbon each year (0.85 x the carbon storage and 25.1 x the annual sequestration rate of the trees in Solihull). The carbon emitted equals approximately 1.4 tonnes per person in Solihull. This comes from a range of sources, the highest of which are Transport (44%), Domestic (28%) and Industry (12%)[23].

Carbon offsetting is the process by which an organisation can prove that through action, the carbon which they produce is subsequently captured and stored for a sufficiently long period as to mitigate any environmental damages caused by the initial carbon emission. Invariably urban forestry can only contribute to the carbon balance - to attempt carbon neutrality or 'net-zero' goals through urban forestry alone would be highly unadvisable although it is important to recognise the role it can play in the carbon balance next to other benefits detailed in this report.

Increasing carbon sequestration through urban forestry is a long term solution it is always recommended that carbon emissions should be reduced and other solutions to sequester and store carbon should be sought alongside urban forestry.

Unlike other regions in the West Midlands, Solihull's land use sector has negative emissions, reducing the emissions by approximately 1,340 tonnes of carbon in 2021.

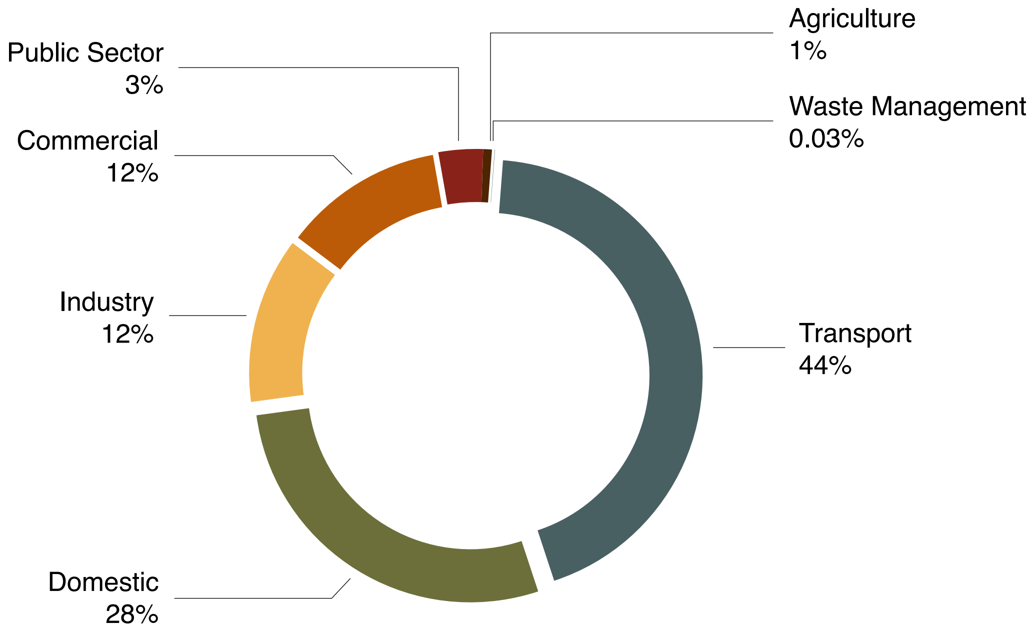


Figure 13: Sources of Solihull's greenhouse gas emission in 2021(excluding land use)

[21] Local Government Association, 2020.

[22] West Midlands Combined Authority, 2023

[23] Department for Energy Security and Net Zero, 2023

The largest trees sequester the most carbon - gaining in sequestration rate and total carbon stored as they grow to maturity. Depending on the growth rates of species, this can take a long time - it is therefore advisable to consider urban forests on timelines that span decades and centuries.

Care and maintenance should be fundamental to any tree planting programme with best practice followed by the present custodians of Solihull’s trees and resources strategically deployed to ensure resources are preserved.

As trees and woodlands age, carbon saturation is reached. This is the point when the rate of carbon sequestration becomes balanced with the rate of carbon released through decomposition of organic matter and respiration. As carbon saturation is reached, carbon sequestration will stabilise or decline. The utilisation of felled timber can lock up carbon, which would otherwise be returned to the atmosphere, whilst new tree planting can ensure sequestration can continue.

Natural Capital Accounting

Natural capital accounting enables the calculation of the monetary value of services provided by assets such as trees, and monitoring of changes in the stocks of those assets and the services they provide. Using Government guidelines for natural capital accounting[24] the present values of three ecosystem services have been calculated: carbon sequestration, air pollution removal and avoided runoff. Natural capital accounting helps provide an understanding of the long-term value of the current urban forest in Coventry, and a baseline for monitoring.

Figure 14 shows the process of applying natural capital accounting principles to a natural asset, to generate annual physical and monetary flows, and a present value. First, the natural assets are identified; in this case woods and trees in the Coventry City Council metropolitan district have been surveyed. Their extent (area in hectares and number of trees) is calculated by i-Tree Eco by extrapolating from survey data. i-Tree Eco uses models of biological function to calculate the delivery of ecosystem services from surveyed trees and extrapolates to give an estimate for the whole urban forest in Coventry. The per annum value of the benefits provided by these services is calculated by multiplying by unit values (see Table 7). Finally, the present value is calculated by estimating the future flows of value over 100 years, to reflect the longevity of renewable natural assets such as trees[25].
Table 7 lists the components of natural capital accounts and their application to this study.

Key Definitions

Carbon dioxide equivalent (CO_2e): The number of tonnes of a greenhouse gas with the same global warming potential as one tonne of CO_2[25]

Discount rate: The rate of decline in the value or price of a service from one year to the next, representing people's preference to receive and pay for a service now rather than in the future

Monetary flow: The flow of value from services provided by a natural asset, typically presented in £ per year

Natural capital: Environmental assets that may provide benefits to humanity[26]

Natural capital accounting: A formal, structured process for classifying, measuring, and recording the condition of environmental assets, and assigning monetary values to the benefits those assets provide[26]

Physical flow: The magnitude of a service provided by a natural asset, such as tonnes of NO_2 removed per year

Present value: The current value of future flows or future stock of monetary value, here summed over 100 years

[24] Defra (2023)

[25] IPCC (2001)

[26] Office for National Statistics (2023)

Unit factor: Rate of provision of a service per unit of asset, such as carbon sequestration per hectare of tree canopy cover
Unit value: Value of a single unit of an ecosystem service, such as £ per tonne of carbon sequestration

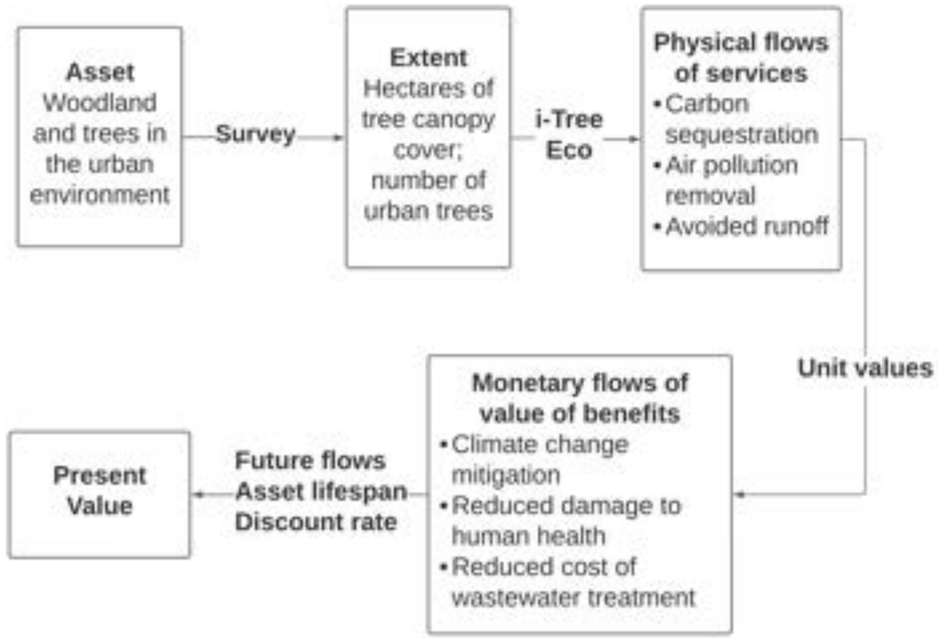


Figure 14: Logic chain applied to natural capital accounting for Solihull.

Type	Account	Description	Application
Physical	Extent	The extent of trees and woods	Calculated by i-Tree Eco from survey data
Physical	Condition	The quality of trees and woods in terms of how well they can provide benefits	Calculated by i-Tree Eco from survey data
Physical	Flow	The magnitude of services provided by trees and woods over one year	Calculated by i-Tree Eco
Monetary	Flow	The flow of value from services over one year	Calculated as physical flow multiplied by the unit value
Monetary	Present value	The present value of the expected future flow of services from trees and woods, typically calculated over 100 years	Calculated over 100 years, with discount rates and uplift applied to future values
Monetary	Maintenance cost	The present cost of expected maintenance of the asset, typically calculated over 100 years	Not calculated

Table 7: Components of natural capital accounts and their application to this study.

Delivery of ecosystem services

In natural capital accounting the value of assets is influenced by their ability to deliver ecosystem services[25]. The ability of any natural capital asset to deliver ecosystem services depends on its 3 factors:

- Quantity
- Quality
- Spatial configuration

Quantity refers to extent, often given as the amount of land the asset covers in hectares, or the number of items in the asset. The quantity of urban trees is calculated by i-Tree Eco from survey data. We calculate the natural capital accounts using ecosystem service provision data for the whole urban forest. We also present indicative per-hectare 100 year present values.

Quality refers to health, biological performance and ecological condition. For example, a degraded peat habitat emits rather than sequesters carbon. Trees with large leaf area and high leaf density are better at retaining particulate matter[27], so trees with reduced leaf area and density owing to disease or poor condition are less able to remove particulate matter and likely other air pollutants from the atmosphere. Interception of rainfall is strongly dependent on leaf area and gaps between leaves[28], so avoided runoff will also be reduced in trees with poor quality or reduced canopies. i-Tree Eco estimates the impact of crown health (dieback) on carbon sequestration; but to date there has been no applicable assessment of how the condition of urban trees impacts their ability to deliver other ecosystem services. Therefore we do not perform additional calculations to represent these reductions. We do, however, present overall information about the condition of urban trees. More detailed tree condition information is given on page 43.

Spatial configuration relates the location of an asset to the services it can provide. For example, trees on flood plains help to reduce downstream flooding by increasing surface roughness, but trees outside the flood plain do not contribute via this mechanism. Spatial configuration also refers to the location of the provision of a service in relation to the beneficiaries. In both cases, the services provided by urban trees are all relevant to the immediate surroundings, and the people benefitting from those services live in close proximity to the trees.

Table 8 summarises the quantity, quality and spatial configuration of trees in the urban forest of Solihull.

[27] Liang, D. and Huang, G. (2023)

[28] Xiao et al, (2000)

Asset	Quantity / estimated number of trees	Quantity / estimated ha of tree canopy cover	Quality	Spatial configuration
Solihull's urban trees	1,263,000	2,336	86.6% of trees in good or excellent condition	Study area is Solihull Borough Council metropolitan district, classified as urban with major conurbation, and predominantly urban*

Table 8: Natural capital assets in Solihull's urban forest
* Office for National Statistics (2023)

Change in services and value over time

People have a preference to receive (and pay for) a service now, rather than in the future. This is known as the social time preference[29], and it means that the value (or price) of a service declines from the present day into the future. The rate of decline is called the social discount rate and is given in HM Treasury Green Book guidance. For most services the discount rate is 3.5% for the first 30 years, declining thereafter; for health-related impacts, the discount rate is 1.5% for the first 30 years, declining thereafter[30].

As a population becomes more wealthy, they may value environmental services more highly. This is reflected in the calculations for air pollution removal and avoided runoff by adjusting the unit values to account for projected income uplift[31].

As a population grows, the number of people receiving a benefit from natural assets increases, and so the value of the asset is said to increase. We reflect this by adjusting the unit values for air pollution removal and avoided runoff to account for projected population changes[32].

It is reasonable to assume that the unit factor (that is, the provision of an ecosystem service per unit of asset) will change over time. Carbon sequestration will change as the age, size and species composition, and condition of the urban forest changes. In our future climate, there are projected to be more frequent and more extreme heavy precipitation events[33]. Rainfall interception is dependent on

[29] HM Treasury (2008)

[30] HM Treasury (2023)

[31] Office for National Statistics (2023)

[32] Office for National Statistics (2022)

[33] Met Office Hadley Centre (2022)

meteorological conditions as well as leaf area, so changes to weather and to the tree population will impact avoided runoff. Air pollution is likely to decline in the UK with the adoption of clean energy and clean transport technologies; absorption of air pollutants by trees depends on atmospheric concentrations, and along with structural and composition changes to the urban forest, so the unit factors for air pollution removal will change. We cannot currently predict these changes so we hold the unit factors constant for the 100 years.

Finally, the value of benefits flowing from each ecosystem service is likely to change. Reduction in air pollution concentrations means that the value of air pollution removal will decline, while predicted increasing frequency and intensity of precipitation events indicates that avoided runoff will become more valuable. We do not have projections for these changes, so we hold the unit values for air pollution removal and avoided runoff constant and adjust them using population and income projections. For carbon sequestration, however, we use projected values to 2122 following Green Book guidance[34].

Table 9 summarises the details of calculations for each ecosystem service.

Ecosystem service	Future unit factors	Unit values	Discount rates	Income uplift	Population uplift
Carbon sequestration	Held constant (calculated by i-Tree Eco)	£265 per tonne in 2023 to £398 per tonne in 2050, then 1.5% annual growth rate***	3.5% for 30 years, then declining*	Not applicable	Not applicable
Air pollution removal	Held constant (calculated by i-Tree Eco)	Held constant at latest UK social damage costs applicable to each urban area****: £14,408 per tonne of NO_2 £104,833 per tonne of $PM_{2.5}$ £16,616 per tonne of SO_2	1.5% for 30 years, then declining*	1.00% for 30 years, then declining*****	0.35% in 2024, then declining**
Avoided runoff	Held constant (calculated by i-Tree Eco)	Held constant at local volumetric wastewater treatment cost******: £1.6142 per m^3	3.5% for 30 years, then declining*	1.00% for 30 years, then declining***	0.35% in 2024, then declining**

Table 9: Details of calculations for each ecosystem service
*HM Treasury (2008)
**HM Treasury (2023)
***BEIS (2021)
****Defra (2023)
*****Office for National Statistics (2023)
****** Severn Trent Water (2022)

[34] Department for Energy Security and Net Zero (2023)

Results

Figure 15 shows the contribution of gross carbon sequestration, air pollution removal and avoided runoff to the present values of the urban forests in Solihull. Of these three ecosystem services, carbon sequestration makes the greatest contribution. The overall present value for the urban forest in Solihull is £695 million.

English Oak contributes the largest amount to the Present Value of carbon sequestration, at £119 million (20.6% of the total value of carbon sequestration). English Oak makes the largest contribution to both air pollution removal (£20.3 million; 20.6%) and avoided runoff (£3.77 million; 20.6%). These data show that English Oak is currently important for long-term value of the urban forest, and that for the projected 100-year value to be realised, it is important to maintain that population. However, the data does not necessarily imply that more of this species should be planted. A species-diverse urban forest is more resilient to pests and diseases, helping to ensure the longevity of benefit provision.

The £695 million Present Value reflects just a fraction of the total value of the urban forest. It is estimated from only three of the many ecosystem services that urban forests can provide, and of those three, carbon sequestration makes the greatest contribution. However, when planning and managing an urban forest it is important to consider all the benefits that urban trees can provide, including those not considered in this report such as provision of shade, reduction of noise and social and cultural values.

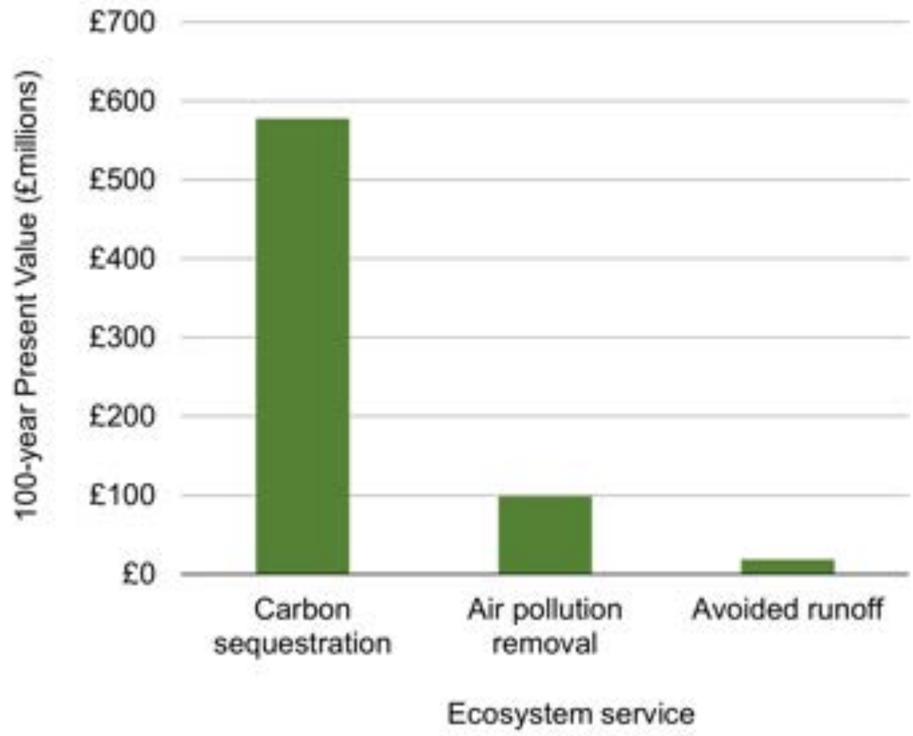


Figure 15. Contributions of carbon sequestration, air pollution removal, and avoided runoff to the 100-year present value of the urban forest in Solihull.

The Present Values presented herein assume no change in the urban forest over the next 100 years, which is unrealistic. Future benefit provision in Solihull will depend on the demand for services from those who live in, work in and visit the area, and on how the urban forest changes. Growing urban populations will increase the number of people benefitting from existing and future urban trees, while an increase in urbanisation could reduce urban forest extent and the benefits it provides. How the urban forest is cared for now and in the future will affect benefit provision through tree planting, removal, and management, the impacts of pests and diseases and which species are planted and where.

The natural capital value is a useful monitoring metric. Future changes in urban forest extent or the number of trees at maturity (when their ecosystem service provision is expected to be greatest) will lead to a greater natural capital value. Periodic review of Solihull's urban forest natural capital value as part of a rolling programme of natural asset monitoring and evaluation can help to ensure benefit delivery into the future.

Capital Asset Value for Amenity Trees (CAVAT)

The urban forest of Solihull has an estimated public amenity asset value of £9.66 billion according to the CAVAT Adjusted Quick Method valuation, which takes into account the size, accessibility and health of trees as well as any species-specific attributes contributing to public amenity value. English Oak had the highest amenity value of any single species in Solihull, contributing 40.3% of the urban forest's amenity value. The next largest contributors were Ash, followed by Silver Birch. Combined, these three species represent 56.2% of the total amenity value for Solihull. It is not particularly surprising that the most common and largest stature tree species have higher CAVAT value. A combination of greater size, condition, and longevity in species leads to higher CAVAT values.

The single most valuable tree encountered in the study was a 22m high, 1.15m DBH English Oak in excellent condition growing in a park; it was estimated to have an amenity value of £235,000.

The land use type containing the highest amenity value of trees was 'Park', with 31% of the total value of the trees, and an estimated value of £1.55 billion when extrapolated for the whole of Solihull. 'Residential' and 'Agricultural' were the next most important land-uses, contributing 22% and 17% 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 (%)
English Oak	2.62 million	£3.9 billion	40.3%
Ash	£573,000	£852 million	8.8%
Silver Birch	£459,000	£681 million	7.1%
Norway Spruce	£381,000	£566 million	5.9%
Aspen	£304,000	£452 million	4.7%
Sycamore	£180,000	£268 million	2.8%
Crack Willow	£152,000	£225 million	2.3%
Holly	£111,000	£165 million	1.7%
Common Lime	£111,000	£164 million	1.7%
Silver Maple	£103,000	£153 million	1.6%

Table 10: CAVAT amenity value for the top ten most valuable tree species.

Land use	Value of measured trees per land use (£)	Value per land use extrapolated across the area (£)	Proportion of total value (%)
Park	£1.05 million	£1.55 billion	31.1%
Residential	£731,000	£1.09 billion	21.7%
Agriculture	£581,000	£864 million	17.3%
Transportation	£560,000	£832 million	16.6%
Vacant	£202,000	£301 million	6.0%
Commercial/ Industrial	£116,000	£173 million	3.5%
Multi-Family Residential	£114,000	£170 million	3.4%
Institutional	£11,700	£17.4 million	0.3%

Table 11: CAVAT amenity value for each land use.

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

Replacement Cost

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.

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[35].

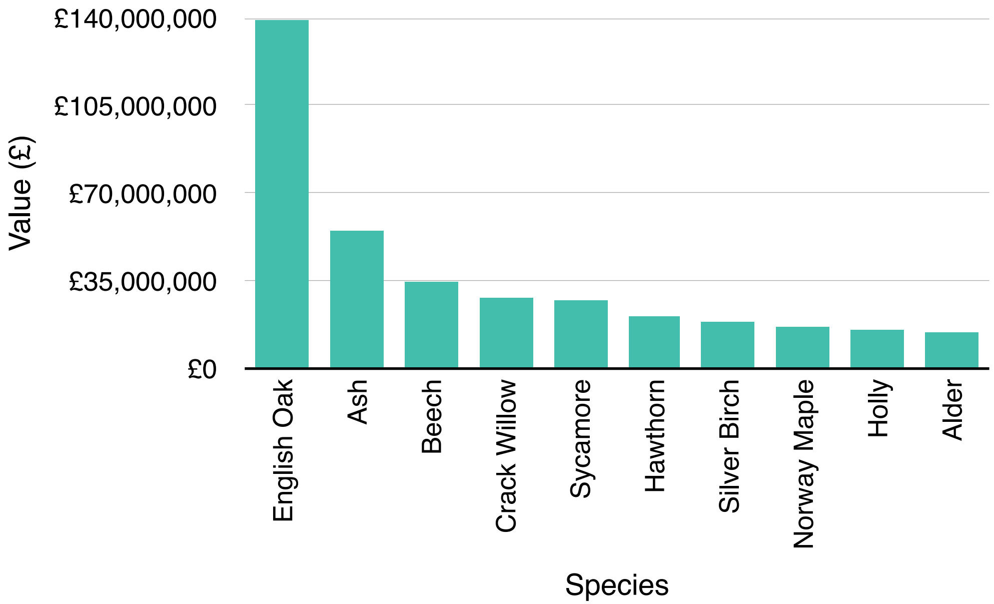
The formula allows for tree suitability in the landscape and nursery prices. This explains why the value given for Ash is comparably low even though it is the most common species, on account of the decreased suitability due to Ash Dieback - a pathogen which is discussed later.

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 16.

[35] Hollis (2007)

The total replacement cost of all trees in Solihull currently stands at £524 million, English oak trees are currently the species with the highest replacement value, on account of both their size and population, followed by Ash and Beech. These three species of tree account for £228 million (43.5%) of the total replacement cost of the trees in Solihull. A full list of trees with the associated replacement cost is given in appendix III.

Figure 16: Replacement Cost of the 10 most valuable tree species



in Solihull.

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[36]. It is likely that climate change will result in the introduction of pests and diseases not yet present in the UK[37]. 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[38]. Further temperature changes are likely to affect the geographical range, development rate and seasonal timing of life-cycle events of insects, and will have an impact on their host plants and predators.

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 West Midlands, based on whether it affected a single tree genus shown in Table 12, or multiple genera in Table 13.

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

Table 12: Risk matrix used for the probability of a pest or disease, which affects a single tree genus, becoming prevalent in the West Midlands.

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

Table 13: Risk matrix used for the probability of a pest or disease, which affects multiple tree genera, becoming prevalent in the West Midlands.

36 Kew Royal Botanical Garden (2017)

37 Wainhouse and Inward (2016)

38 Federickson-Matika and Riddell (2021)

This informed Table 14 which gives an overview of the existing and emerging risks to Solihull'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.
The UK plant risk register 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[39]. Here, emphasis has been given to a subset of pests and pathogens which severely impact trees or pose human health risks. The matrix emphasises causative agents, which are damaging, would affect >0.01% of the area's trees.

The pest which could potentially have the greatest estimated impact across Solihull's urban forest is the Asian longhorn beetle (though this is not currently present in the UK), which could affect 48% of its trees - worth £248 million. The greatest risk, which is already present in the UK, is threats to the Oak and Ash population from Acute Oak Decline, Oak Processionary Moth and Ash Dieback: each threaten 11% of the total tree population - the Oak and Ash population are valued at £143 million and 54.7 million respectively.

Some pests and diseases only affect a small proportion of the population, for example Dothistroma Needle Blight only threatens 3% of the species in Solihull. However, these seemingly low risk pests and diseases can be widespread and are therefore one of the greater threats. The population at risk from Dothistroma Needle Blight is valued at £11.8 million.

Figure 17: Symptoms of Acute Oak Decline (Source: Forest Research)

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[39] DEFRA 2022; Forest Research, 2022

Pest/Pathogen	Major tree hosts affected	Prevalence in UK	Replacement cost of trees	Tree Population at risk (%)
Acute Oak Decline	Oak species	Central and SE England, Welsh borders and SE Wales	£143,000,000	11%
Asian Longhorn Beetle	Many broadleaf species	None (previous outbreaks contained)	£248,000,000	48%
Beech Leaf Disease	Mainly American beech species but also others	None	£34,100,000	1%
Bronze Birch Borer	All birch species	None	£20,300,000	9%
Ash Dieback	Many ash species	Occurs in most parts of the UK	£54,700,000	11%
Citrus Longhorn Beetle	Many broadleaf species	None	£191,000,000	35%
Dothistroma Needle Blight	Many pine species	Widespread	£11,800,000	3%
Elm Zigzag Saw Fly	Some elm species	Present in SE England and East Midlands	£3,350,000	2%
Emerald Ash Borer	Common ash and narrow-leaved ash	None	£54,700,000	11%
Great Spruce Bark Beetle	Spruce species	Present	£11,500,000	8%
Horse Chestnut Leaf Miner	Horse Chestnut	Present in all parts of GB	£2,940	0%
Mountain Ash Ringspot	Rowan	Widespread through Scotland and the North. Likely present across the whole UK.	£17,600	1%
Oak Lace Bug	Oak species	None	£143,000,000	11%
Oak Processionary Moth	Oak species	Established in Greater London and some surrounding counties	£143,000,000	11%
Oriental Chestnut Gall Wasp	Sweet Chestnut	Around London and the South East	£0	0%
Phytopthora austrocedri	*Juniperus spp, Chamaecyparis lawsonia, Chamaecyparis nootkkatensis*	Scotland and England only	£7,290,000	2%

Table 14. The significance of a range of existing and emerging pests and diseases to Solihull's urban forest.

Pest/Pathogen	Major tree hosts affected	Prevalence in UK	Replacement cost of trees	Tree Population at risk (%)
Phytophthora lateralis	*Chamaecyparis formosensis, Chamaecyparis lawsoniana, Chamaecyparis obtuse, Chamaecyparis pisifera, Rhododendron spp., Thuja plicata, Thuja occidentalis, Pseudotsuga menziesii, Taxus brevifolia*	Occurs across the whole of the UK	£13,500,000	4%
Pine Processionary Moth	*Pinus nigra, Pinus sylvestris, Pinus pinea, Pinus halepensis, Pinus pinaster, Pinus contorta, Pinus radiata, Pinus canariensis, Cedrus atlantica, Larix decidua, Pseudotsuga menziesii*	None	£16,500,000	3%
Plane Lace Bug	Plane species	None	£0	0%
Plane Wilt	Plane species	None	£0	0%
Rednecked Long-horn Beetle	Cherry species	None	£12,900,000	6%
Sirococcus tsugae	Cedar and Hemlock species	Yes	£5,290,000	0%
Sweet chestnut blight	Chestnut species	Yes but uncommon	£0	0%

Table 14. The significance of a range of existing and emerging pests and diseases to Solihull's urban forest.

Ash Dieback

Ash Dieback is a vascular wilt fungus which causes the dieback and death of Ash trees. It has had a major impact upon the Ash population across Europe. Since Ash Dieback was first recorded in the UK in 2012, the rate of infection has increased at a steady rate and is now considered endemic, causing significant damage across the country.

Whilst initially occurring predominantly in Ash populations that had been recently planted, by the summer of 2014 infected trees were being found within established trees in the wider environment.

Ash is the most populous tree species in Solihull and provides 16% of the total leaf area. Therefore the implications of losing Ash trees cannot be understated. The effects of Ash Dieback in the UK have already been significant, with many woodlands, hedgerows and landscapes losing a significant proportion of their Ash trees, which compromises social wellbeing and environmental health.

To address the impact of Ash Dieback in England and Wales, the Ash Dieback Action Plan Toolkit was developed. The Toolkit is an evolving document being updated with best practice for local authorities in tackling Ash Dieback[40]. Using this toolkit, local authorities can produce their own tailored Action Plans with aims to mitigate the effects of the disease on both the natural environment and the local economy. Support is a provided by a range of organisations, including the Tree Council, the Forestry Commission, Natural England, the Woodland Trust and local authorities.

[40] The Tree Council. 2023

Figure 18: Ash Dieback causing the wilting of leaves (Source: Joe Bates, Woodland Trust)

Tree condition

One of the most important factors when dealing with any potential pest or disease impact is to consider the health of the tree. Tree condition was measured as part of the survey and Figure 19 shows the health of the ten most common trees in Solihull. Overall, tree health in Solihull is very positive with 78.1% rated as excellent condition and a further 12.1% rated good or fair. 9.7% of trees were rated as poor or worse. Approximately 7.5% are dying or already dead.

81.3% of Ash trees in Solihull are in an excellent or good condition. However, Ash is the second most common species in the West Midlands and the resulting loss from an increased impact of Ash Dieback, as seen in other parts of the country, remains a high risk.

Improving the diversity of species, particularly the evenness of species across the population, will increase the resilience of the urban forest as a whole.

It will be important to tackle Ash Dieback and prepare to replace the trees which will inevitably be lost. Selecting species which are suitable replacements for Ash is key to replacing the lost canopy cover and replacement species should have roughly the same potential for ecosystem service provision as those which are lost.

A few species are of concern, such as Scots Pine, Elm and Grey Alder. These species have low population sizes and were also recorded as being in poor or worse condition

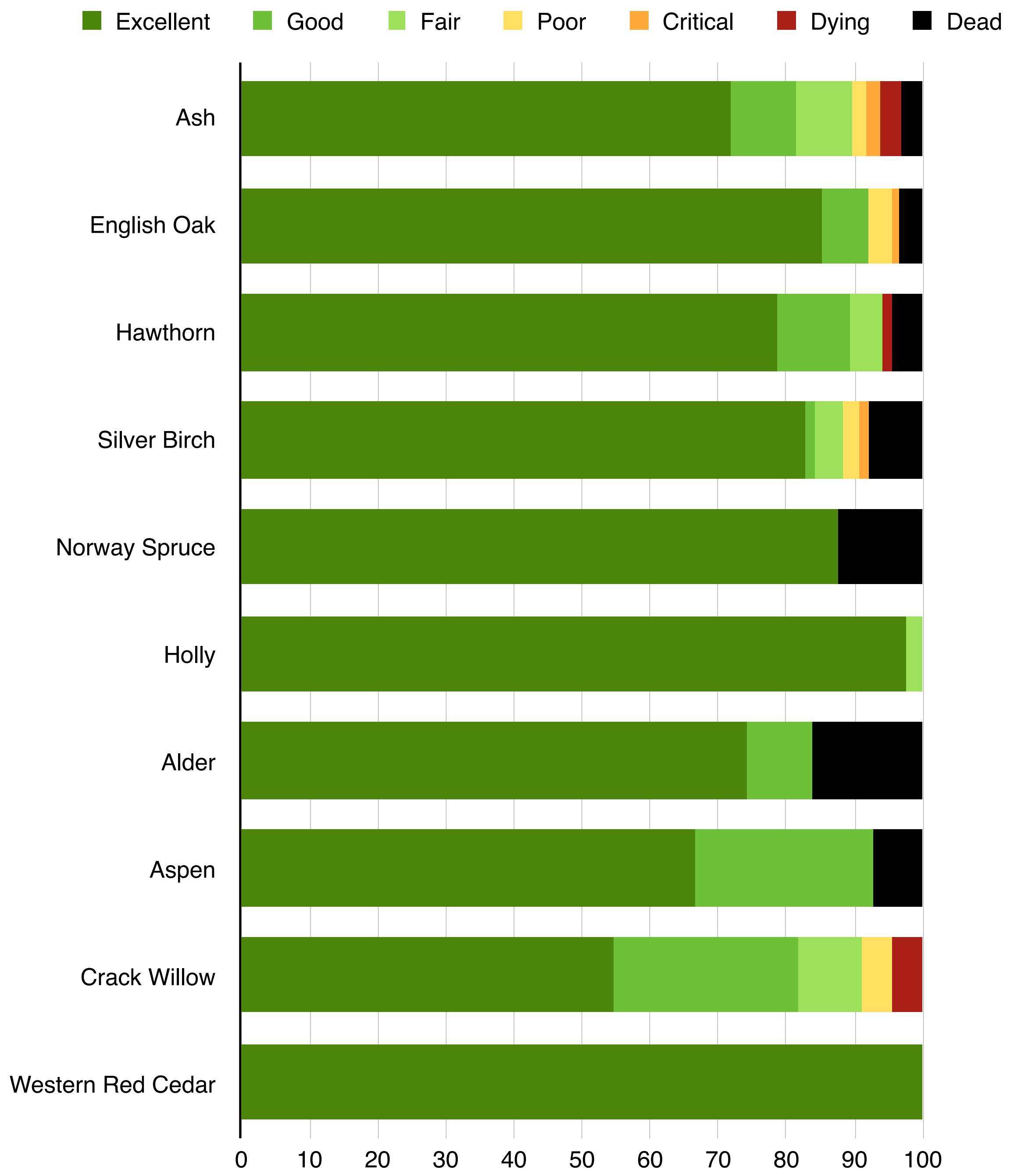

Figure 19: Condition of the 10 most common tree species in Solihull

Conclusions and Recommendations

Trees confer many 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 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.

- Carry out a cost benefit analysis using this data and influence management strategies and operational documents and synchronise reviews of urban forest management documents with further i-Tree Eco studies to ensure continuous monitoring.
- Combine this data with other potential data sources to help target new tree planting and to inform species choice, eg:
  - To address localised flooding and drainage issues to identify and assess potential opportunities to enhance the water management benefits.
  - To address local air pollution and assess potential opportunities to enhance air pollution mitigation benefits.
- Use data to support bids for funding and to develop and drive both small and large scale community projects, educational resources and public information.

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 larger canopies through appropriate management, species selection and planting location. This can also allow biodiversity value to increase, maintenance costs to be reduced and a less stressed tree stock of generally better quality, 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 Tree Strategy and a Tree Planting Opportunity Mapping exercise 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 recommendations:

- Continue to plant a wide diversity of species (with due consideration to local site factors) to replace the future loss of ash, and reduce the likelihood of severe impact from any given pest or disease outbreak.
- Produce a Tree Planting Strategy: see the TDAG species selection guide for further information (Tree Species Selection for Green Infrastructure: A Guide for Specifiers).
- Continue new planting within Solihull to avoid significant losses in ecosystem service provisions in the future and to address lack of canopy and unequal distribution of the urban forest.

- Aim to retain large, mature trees wherever possible, as large trees provide the most benefits - make them part of developments rather than lose them. Use CAVAT to highlight amenity values of threatened trees to developers and communities, and to leverage compensation or sufficient replacement planting for amenity trees that are removed by developers. TDAG's guide to delivering trees in planning and development contains recommendations for ensuring that the value of trees is recognised and reflected in new developments (Trees in Hard Landscapes: A Guide for Delivery).
- Carry out a Tree Planting Opportunity Mapping study to target prioritised areas and optimise resources. This can facilitate additional planting alongside main roads, and joining up/filling in gaps within the existing urban forest to enhance wildlife corridors and the connectivity of pathways and cycle lanes through green infrastructure. Tree equity analysis at neighbourhood level can be incorporated to target areas that lack canopy cover, particularly areas with high deprivation and which experience high pollution, surface flooding, limited green space or lack of shade.
- 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.
- Promote Solihull's urban forest to all, and emphasise the benefits it provides through educational resources and public information.
- Establish values that can be used in cost-benefit analysis to better inform asset and risk management.
- Consider developing an Urban Forest Master Plan to follow on from this study providing a vision of what the Borough would like to achieve with its urban forest and step to realise those goals.

Appendix I. Relative Tree Effects

The urban forest in Solihull 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.

Carbon storage is equivalent to:
- Annual carbon (C) emissions from 284,000 family cars
- Annual C emissions from 117,000 single-family houses

Nitrogen dioxide removal is equivalent to:
- Annual nitrogen dioxide emissions from 6,200 family cars
- Annual nitrogen dioxide emissions from 2,790 single-family houses

Sulphur dioxide removal is equivalent to:
- Annual sulphur dioxide emissions from 18,200 family cars
- Annual sulphur dioxide emissions from 48 single-family houses

Annual carbon sequestration is equivalent to:
- Annual C emissions from 9,700 family cars
- Annual C emissions from 4,000 single-family houses

Average family car emissions per mile were based on dividing total 2021 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 2021 by passenger cars (National Travel Survey https://www.gov.uk/government/statistical-data-sets/nts09-vehicle-mileage-and-occupancy). The CO and Nitrogen dioxide figures were converted from mg of pollution per km into kg of pollution that an average car in a year will produce using UK averages updated in 2022 (https://carfueldata.vehicle-certification-agency.gov.uk).

Average CO2 emissions per car mile in the UK were based on Department for Transport for the UK in 2020 (https:// www.nimblefins.co.uk/average-co2-emissions-car-uk) and were converted into equivalent Carbon emissions per average car per year.

Appendix II. Species Dominance Ranking List

Scientific Name	Common Name	% Population	% Leaf Area	Dominance value
Quercus robur	English Oak	10.1%	20.6%	30.7
Fraxinus excelsior	Common Ash	11.2%	16.0%	27.2
Betula pendula	Silver Birch	8.8%	9.9%	18.8
Crataegus monogyna	Hawthorn	9.8%	4.9%	14.7
Picea abies	Norway Spruce	8.5%	2.8%	11.3
Alnus glutinosa	Common Alder	3.6%	3.5%	7.1
Ilex aquifolium	Holly	4.8%	2.2%	6.9
Populus tremula	Aspen	3.1%	3.5%	6.6
Acer platanoides	Norway Maple	1.4%	3.8%	5.2
Salix fragilis	Crack Willow	2.6%	2.4%	5.0
Acer pseudoplatanus	Sycamore	1.3%	3.3%	4.6
Pinus sylvestris	Scots Pine	2.2%	1.9%	4.1
Prunus avium	Wild Cherry	2.2%	1.5%	3.7
Thuja plicata	Western Red Cedar	2.4%	0.9%	3.3
Salix caprea	Goat Willow	1.5%	1.6%	3.1
Acer campestre	Field Maple	1.5%	1.4%	3.0
Prunus spinosa	Blackthorn	2.3%	0.5%	2.8
Fagus sylvatica	Common Beech	0.7%	1.7%	2.4
x Hesperotropsis leylandii	Leyland Cypress	1.2%	1.2%	2.4
Tilia x europaea	Common Lime	0.2%	2.0%	2.3
Ulmus glabra	Wych Elm	0.7%	1.4%	2.1
Corylus avellana	Hazel	1.5%	0.6%	2.1
Sorbus aucuparia	Rowan	1.4%	0.7%	2.0
Chamaecyparis lawsoniana	Lawson Cypress	1.3%	0.8%	2.0
Sambucus nigra	Elder	1.6%	0.4%	2.0
Alnus incana	Grey Alder	1.0%	0.8%	1.9
Ulmus procera	English Elm	1.5%	0.3%	1.8
Malus domestica	Apple	1.4%	0.4%	1.8

Scientific Name	Common Name	% Population	% Leaf Area	Dominance value
Tilia cordata	Small Leaved Lime	0.7%	0.8%	1.5
Sorbus intermedia	Swedish Whitebeam	0.9%	0.4%	1.4
Prunus domestica	Plum	0.8%	0.5%	1.3
Taxus baccata	Common Yew	0.6%	0.6%	1.2
Acer saccharinum	Silver Maple	0.1%	1.0%	1.1
Quercus petraea	Sessile Oak	0.6%	0.5%	1.1
Populus nigra v. italica	Lombardy Poplar	0.5%	0.6%	1.1
Populus alba	White Poplar	0.2%	0.8%	1.0
Betula pubescens	Downy Birch	0.5%	0.5%	1.0
Pinus nigra	Austrian Pine	0.5%	0.3%	0.8
Tilia platyphyllos	Large Leaved Lime	0.5%	0.2%	0.7
Cotoneaster	Cotoneaster	0.3%	0.2%	0.6
Prunus cerasifera	Cherry Plum	0.3%	0.2%	0.5
Quercus cerris	Turkey Oak	0.1%	0.4%	0.5
Magnolia	Magnolia	0.3%	0.2%	0.5

Scientific Name	Common Name	% Population	% Leaf Area	Dominance value
Cedrus deodara	Deodar Cedar	0.1%	0.3%	0.4
Prunus laurocerasus	Cherry Laurel	0.2%	0.2%	0.4
Cedrus atlantica v. glauca	Atlas Cedar	0.1%	0.3%	0.4
Chamaecyparis pisifera	Sawara Cypress	0.2%	0.1%	0.4
Pseudotsuga menziesii	Douglas Fir	0.1%	0.3%	0.4
Larix kaempferi	Japanese Larch	0.2%	0.1%	0.3
Pyracantha	Firethorn	0.2%	0.0%	0.3
Amelanchier x lamarckii	Juneberry	0.2%	0.0%	0.3
Aesculus hippocastanum	Horse Chestnut	0.2%	0.0%	0.3
Robinia pseudoacacia	False Acacia	0.1%	0.1%	0.2
Euonymus europaeus	European Spindle	0.1%	0.1%	0.2
Acer palmatum	Palmate Maple	0.1%	0.1%	0.2
Morus nigra	Black Mulberry	0.1%	0.1%	0.2
Crataegus laevigata	Midland Hawthorn	0.1%	0.0%	0.2
Olea europaea	Olive	0.1%	0.0%	0.2

Scientific Name	Common Name	% Population	% Leaf Area	Dominance value
Juniperus communis	Common Juniper	0.1%	0.0%	0.2
Carpinus betulus	Common Hornbeam	0.1%	0.0%	0.1
Elaeagnus	Silverberry	0.1%	0.0%	0.1
Laburnum anagyroic	Common Laburnum	0.1%	0.0%	0.1
Eucalyptus gunnii	Cider Gum	0.1%	0.0%	0.1
Prunus serrula	Tibetan Cherry	0.1%	0.0%	0.1

Appendix III. Tree values by species

Species	Common Name	Estimated No. of Trees	Carbon Stored (tonnes)	Net Seq (tonnes/yr)	Avoided Runoff (m³/yr)	Replacement Cost (£)
Fraxinus excelsior	Common Ash	140,984	35,637	1,601	47,018	£54,651,939
Quercus robur	English Oak	127,767	101,820	2,558	60,479	£139,687,296
Crataegus monogyna	Hawthorn	123,361	15,175	558	14,382	£21,102,815
Betula pendula	Silver Birch	111,613	23,004	1,555	29,167	£18,508,745
Picea abies	Norway Spruce	107,207	14,195	380	8,146	£11,531,904
Ilex aquifolium	Holly	60,212	15,293	203	6,407	£14,800,719
Alnus glutinosa	Common Alder	45,526	5,144	272	10,382	£14,393,851
Populus tremula	Aspen	39,652	9,919	545	10,228	£4,898,505
Salix fragilis	Crack Willow	32,309	11,950	395	7,042	£27,769,803
Thuja plicata	Western Red Cedar	30,840	418	14	2,578	£4,918,226
Prunus spinosa	Blackthorn	29,372	2,014	158	1,515	£1,352,990
Pinus sylvestris	Scots Pine	27,903	3,851	167	5,523	£8,342,309
Prunus avium	Wild Cherry	27,903	5,385	308	4,484	£7,818,376
Sambucus nigra	Elder	20,560	933	41	1,080	£1,794,906
Salix caprea	Goat Willow	19,092	3,217	71	4,716	£9,423,316
Acer campestre	Field Maple	19,092	11,179	74	4,235	£7,517,599
Corylus avellana	Hazel	19,092	1,780	60	1,695	£2,955,655
Ulmus procera	English Elm	19,092	818	43	829	£473,567
Acer platanoides	Norway Maple	17,623	8,361	448	11,199	£16,775,268
Malus domestica	Apple	17,623	2,214	157	1,044	£4,666,642
Sorbus aucuparia	Rowan	17,623	1,213	100	1,916	£1,009,254
Acer pseudoplatanus	Sycamore	16,154	21,579	433	9,714	£26,579,487
Chamaecyparis lawsoniana	Lawson Cypress	16,154	2,454	118	2,249	£6,115,922
x Hesperotropsis leylandii	Leyland Cypress	14,686	8,347	429	3,501	£9,496,398
Alnus incana	Grey Alder	13,217	1,272	45	2,362	£3,255,971
Sorbus intermedia	Swedish Whitebeam	11,749	1,064	82	1,274	£1,077,561
Prunus domestica	Plum	10,280	2,044	156	1,502	£2,226,398
Fagus sylvatica	Common Beech	8,812	13,928	92	5,034	£34,118,994
Ulmus glabra	Wych Elm	8,812	1,892	117	4,104	£2,877,101
Tilia cordata	Small Leaved Lime	8,812	368	46	2,317	£942,948
Taxus baccata	Common Yew	7,343	3,484	72	1,813	£12,863,628
Quercus petraea	Sessile Oak	7,343	732	28	1,478	£1,247,016
Populus nigra v. italica	Lombardy Poplar	5,874	6,219	184	1,732	£7,559,756

Species	Common Name	Estimated No. of Trees	Carbon Stored (tonnes)	Net Seq (tonnes/yr)	Avoided Runoff (m^3/yr)	Replacement Cost (£)
Pinus nigra	Austrian Pine	5,874	927	50	857	£3,409,608
Betula pubescens	Downy Birch	5,874	1,055	71	1,570	£1,840,336
Tilia platyphyllos	Large Leaved Lime	5,874	318	23	580	£474,341
Magnolia	Magnolia	4,406	252	35	451	£443,770
Cotoneaster	Cotoneaster	4,406	271	35	669	£343,948
Prunus cerasifera	Cherry Plum	4,406	300	47	519	£266,226
Tilia x europaea	Common Lime	2,937	3,522	102	5,977	£11,550,232
Populus alba	White Poplar	2,937	1,921	56	2,386	£2,564,053
Prunus laurocerasus	Cherry Laurel	2,937	1,120	32	593	£1,252,428
Chamaecyparis pisifera	Sawara Cypress	2,937	323	16	402	£762,455
Larix kaempferi	Japanese Larch	2,937	188	8	265	£512,391
Pyracantha	Firethorn	2,937	102	12	64	£165,524
Amelanchier x lamarckii	Juneberry	2,937	55	15	56	£134,301
Aesculus hippocastanum	Horse Chestnut	2,937	11,147	13	55	£5,547
Acer saccharinum	Silver Maple	1,469	1,749	68	2,999	£6,376,102
Cedrus atlantica v. glauca	Atlas Cedar	1,469	984	39	798	£3,023,413
Cedrus deodara	Deodar Cedar	1,469	773	45	955	£2,261,846
Quercus cerris	Turkey Oak	1,469	1,122	65	1,172	£1,972,513
Pseudotsuga menziesii	Douglas Fir	1,469	217	6	742	£1,702,415
Morus nigra	Black Mulberry	1,469	205	30	179	£473,516
Robinia pseudoacacia	False Acacia	1,469	320	18	247	£438,053
Juniperus communis	Common Juniper	1,469	223	9	116	£414,946
Acer palmatum	Palmate Maple	1,469	100	5	213	£143,229
Laburnum anagyroides	Common Laburnum	1,469	125	12	39	£108,170
Euonymus europaeus	European Spindle	1,469	235	18	214	£60,888
Elaeagnus	Silverberry	1,469	30	7	43	£60,846
Carpinus betulus	Common Hornbeam	1,469	22	6	43	£59,336
Olea europaea	Olive	1,469	32	5	118	£52,170
Crataegus laevigata	Midland Hawthorn	1,469	36	9	145	£47,013
Eucalyptus gunnii	Cider Gum	1,469	46	15	25	£39,508
Prunus serrula	Tibetan Cherry	1,469	21	12	2	£30,565

Appendix IV. 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 and a variety of threats to oak populations.

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, 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[41]. 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[42].
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.

41 Nowak 1994

21 Nowak et al (2007)

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[43]. 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[44] [45] that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50% resuspension rate of particles back to the atmosphere[46].

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[47] [48].

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 (the health and completeness of the crown of the tree),
- an assessment of Life Expectancy.

43 Baldocchi (1987), (1988)

44 Bidwell and Fraser (1972)

45 Lovett (1994)

46 Zinke (1967)

47 Hollis (2007)

48 Rogers et al (2012)

The Unit Value is determined by the CAVAT steering group and published online. The Unit Value for 2023 is £24.59.

DBH is taken directly from the field measurements.

The CTI rating is determined from the London Tree Officers Association approved list and is calculated on an area by area 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.

Appendix V. Volunteers

The West Midlands Combined Authority, Barton Hyett Associates and Treeconomics would like to thank the team of volunteer surveyors who made this project possible:

Amy Barradas-Lingard
Paul Cardall
Manuel Barradas (Manny)
John Murphy
Sonja Kuster
Isaac Westlake
Hassana Gul
Gratas Grubys
Jude Norris
Qori Ocean
Komkiew Pinpimai
Valerie Edkins
Mick Dainty
Ayah Al-athwari
Krish Kumar
Sara Griffiths
Dee
Kate Renshaw
Raghav Kumar
Narahari Aryal
Rachel Brackwell
Jessica Mansell
Amritpal Singh
Emily Kendall
Laura
Rosie Walsh
Lara Charalambides
Chang Ho Choi
Anantharam Venkatachalam
Rayyan Rameezuddin
Hamza Khawaja
Julianne Statham
Tom Barradas-Lingard
Aziz Naji
Tom Hansen
Deborah Blount
Miranda Kingston
John Kingston
Emma Wilson
Aqila Alam
Khadija Haque
Abdelrahman Mohammad (Abdo)
Helen Murie
Lisa Mignanelli
Sam
Adria Rus
Linda Green
Manuel (Manny) Alejandro Barradas
Gig Payne
Deb Cashmore
Julianne Statham
Alex Virdi
Adam Stanley
Luke Stanley
Kirandip Kaur
Cameron Bailey (Cam)
Maddy Whapples
Claudia Zopon Harris
Abdelrahman Mohammad
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Bibliography

Albrecht, M., Schmid, B., Hautier, Y. and Müller, C.B., (2012). Diverse pollinator communities enhance plant reproductive success. *Proceedings of the Royal Society B: Biological Sciences*, *279*(1748), pp.4845-4852.

Baldocchi, D (1988). A multi layer model for estimating sulfur dioxide deposition to a deciduous oak forest canopy. Atmospheric Environment 22, 869-884.

Baldocchi, D., Hicks, B., Camara, P (1987). A canopy stomatal resistance model for gaseous deposition to vegetated surfaces. Atmospheric Environment. 21, 91-100.

Baritz, R., Seufert, G., Montanarella, L., Ranst, E (2010). Carbon concentrations and stocks in forest soils of Europe. Forest Ecology and Land Management 260, 262-277.

BEIS (2021). Valuation of greenhouse gas emissions: for policy appraisal and evaluation. Available at: https://www.gov.uk/government/publications/valuing-greenhouse-gas-emissions-in-policy-appraisal/valuation-of-greenhouse-gas-emissions-for-policy-appraisal-and-evaluation

Bendel, C.R., Kral-O'Brien, K.C., Hovick, T.J., Limb, R.F. and Harmon, J.P., (2019). Plant–pollinator networks in grassland working landscapes reveal seasonal shifts in network structure and composition. Ecosphere, 10(1), p.e02569.

Bidwell, R., Fraser, D (1972). Carbon monoxide uptake and metabolism by leaves. Canadian Journal of Botany 50, 1435-1439.

Bradley, R.I., Milne, R., Bell, J., Lilly, A., Jordan, C., Higgins, A., 2005. A soil carbon and land use database for the United Kingdom. Soil Use and Management 21, 363–369.

Britt, C., Johnston, M (2008). Trees in Towns II - A new survey of urban trees in England and their condition and management. Department for Communities and Local Government, London.

Broadmeadow, M., Ray, D., Samuel, C (2005). Climate Change and the future for broadleaved tree species in Britain. Forestry 78, 145.

Cackowski, J., Nasar, J. (2003). The Restorative effects of roadside vegetation: implications for automobile driver anger and frustration. Environment and Behavior 35, 736-751.

Carey, P.D., Wallis, S., Chamberlain, P.M., Cooper, A., Emmett, B.A., Maskell, L.C., McCann, T., Murphy, J., Norton, L.R., Reynolds, B., Scott, W.A., Simpson, I.C., Smart, S.M., Ullyett, J.M., (2008). Countryside Survey: UK Results from 2007. NERC/Centre for Ecology & Hydrology, 105 pp.

City of Toronto, Parks, Forestry and Recreation. (2013). Every Tree Counts: A Portrait of Toronto's Urban Forest. Toronto, Ontario. Urban Forestry. https://www.toronto.ca/wp-content/uploads/2017/12/92de-every-tree-counts-portrait-of-torontos-urban-forest.pdf

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R., Paruelo, J., Raskin, R., Sutton, P., van den Belt, M., (1997). The Value of the worlds ecosystem services and natural capital. Nature 15, 253-260.

Countryside Survey, (2007). Accounting for nature: assessing habitats in the UK countryside. [online] Available at: http://www.countrysidesurvey.org.uk/reports2007.html.

Chapparro and Terradas (2009). Ecological Services Of Urban Forest in Barcelona [Online] Available at: http://itreetools.org/resources/reports/Barcelona%20Ecosystem%20Analysis.pdf [Accessed 4th May 2022].

Dawson, J.J.C., Smith, P., 2007. Carbon losses from soil and its consequences for land use management. Science of the Total Environment 382 (2–3), 165–190.

DEFRA (2007). The air quality strategy for England, Scotland, Wales and Northern Ireland. DEFRA. London.

DEFRA (2022) UK Plant Health Risk Register. Available at: https://secure.fera.defra.gov.uk/phiw/riskRegister/index.cfm.

Defra (2023). Enabling a Natural Capital Approach. Available at: https://www.gov.uk/government/publications/enabling-a-natural-capital-approach-enca-guidance

Defra (2023). Air quality appraisal: damage cost guidance. Available at: https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-damage-cost-guidance

DEFRA (2023) Dept for Business, Energy & Industrial Strategy. Green Book supplementary guidance: valuation of energy use and green gas emissions for appraisal. Supplementary guidance to Treasury's Green Book providing government analysts with rules for valuing energy usage and greenhouse gas emissions [online] Available at: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse- gas-emissions-for-appraisal Last Updated: 23.01.2023

Department for Energy Security and Net Zero. (2023). UK local authority and regional greenhouse gas emissions national statistics, 2005 to 2021. Accessed: Dec 2023. Available online: https://www.gov.uk/government/statistics/uk-local-authority-and-regional-greenhouse-gas-emissions-national-statistics-2005-to-2021

Department for Energy Security and Net Zero (2023). Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal. Data Table 3. Available at: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

De Groot, R., Alkemade, R., Braat, L., Hein, L., Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity 7, 260-270.

De Vries, W., Reinds, G.J., Posch, M., Sanz, M., Krause, G., Calatyud, V., Dupouey, J., Sterba, H., Gundersen, P., Voogd, J., Vel, E., 2003. Intensive Monitoring of Forest Ecosystems in Europe. Tech. Rep., EC. UN/ECE, Brussels

Doick, K., Neilan, C., Jones, G., Allison, A., McDermott, I., Tipping A., Haw, R., (2018) CAVAT (Capital Asset Value for Amenity Trees): valuing amenity trees as public assets, Arboricultural Journal, 40:2, 67-91.

Emmett, B.A., Reynolds, B., Chamberlain, P.M., Rowe, E., Spurgeon, D., Brittain, S.A., Frogbrook, Z., Hughes, S., Lawlor, A.J., Poskitt, J. and Potter, E., 2010. Countryside survey: soils report from 2007

Escobedo, F., Nowak, D (2009). Spatial heterogeneity and air pollution removal by an urban forest. Landscape and Urban Planning, 2009 Vol. 90 (3-4) pp. 102-110.

European Environment Agency (2019). Soil and climate change [Online] Available at: https://www.eea.europa.eu/signals/signals-2019-content-list/articles/soil-land-and-climate-change [Accessed: Jan12 2020].

Forest Research (2022) Pest and disease resources. Available online at: https://www.forestresearch.gov.uk/tools-and-resources/fthr/pest-and-disease-resources/.

Forest Research (2024). Tree canopy cover leaflet. Tools and Resources. Last accessed:Feb 2024. Available online: https://www.forestresearch.gov.uk/tools-and-resources/fthr/tree-canopy-cover-leaflet/#:~:text=Background,over 283 towns and cities.

Frederickson-Matika, D., Riddell, C. (2021). Climate change and tree diseases. Climate change factsheet-How are root pathogens likely to be influenced by climate change? Forest Research, Farnham. Available at:

https://cdn.forestresearch.gov.uk/2021/06/21_0004_leaflet_cc_factsheet_root_pathogens_wip07_acc.pdf

Gazis, R., Chaverri, P. (2010) Diversity of fungal endophytes in leaves and stems of wild rubber trees (Hevea brasiliensis) in Peru. Fungal Ecology, 3 (3), 240-254

Gill, S., Handley, A., Ennos, A., Paulett, S (2007). Adapting cities for climate change: the role of green infrastructure. Built Environment 33 (1), 115-133.

gov.uk (2012) Green Book supplementary guidance: valuation of energy use and green gas emissions for appraisal. Supplementary guidance to Treasury's Green Book providing government analysts with rules for valuing energy usage and greenhouse gas emissions [online] Available at: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal Last Updated: 10.12.2021

Gupta, R.K., Rao, D.L.N., 1994. Potential of wastelands for sequestering carbon by reforestation. Current Science 66 (5), 378–380.

Hand, K.L., Doick, K.J. (2019). Understanding the role of urban tree management on ecosystem services. Forestry Commission Research Note 39. Forestry Commission, Edinburgh. 10pp. https://www.forestresearch.gov.uk/research/understanding-role-urban-tree-management-ecosystem-services/

Hanley, N., Splash, C (1993). Cost benefit analysis and the environment. E Elgar, England

Hirabayashi, S. 2012. i-Tree Eco Precipitation Interception Model Descriptions, http://www.itreetools.org/eco/resources/iTree_Eco_Precipitation_Interception_Model_Descript ions_V1_2.pdf

HM Treasury (2008). Intergenerational wealth transfers and social discounting: Supplementary Green Book guidance. Available at: https://assets.publishing.service.gov.uk/media/5a7a05d540f0b66a2fbff54e/

HM Treasury (2023). The Green Book (2022). Available at: https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government/the-green-book-2020#a6-discounting

Hollis, A. (2007) Depreciated replacement cost in amenity tree valuation. UKI-RPAC guidance note 1.

Holzinger, O (2011). The Value of Green Infrastructure in Birmingham and the Black Country. CEEP, Birmingham.

Hubbell (1979) cited in Perry, D., Oren, R. and Hart, S. (2008). Forest Ecosystems 2nd Edition, John Hopkins University Press Maryland.

i-Tree. (2021) 'i-Tree software suite v6' [Online] Available at: https://www.itreetools.org/documents/275/EcoV6_UsersManual.2021.09.22.pdf [Accessed: 4th May 2022].

i-Tree. (2023). I-Tree Eco: Application Overview. I-Tree. [Accessed: September 2023]. https://www.itreetools.org/tools/i-tree-eco/i-tree-eco-overview

IPCC (2001). Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Integovernmental Panel on Climate Change. IPCC, Cambridge, UK and New York, USA, pp. 398.

Jandl, R., Lindner, M., Vesterdal, L., Bauwens, B., Baritz, R., Hagedorn, F., Johnson, D.W., Minkkinen, K., Byrne, K.A., 2007. How strongly can forest management influence soil carbon sequestration? Geoderma 137, 253–268.
Jones, T. (2022). How 'green' is your city centre? The best and worst in Britain ranked. Sky News - Climate. Last accessed: 7/7/2023. Available online: https://news.sky.com/story/how-green-is-your-city-centre-the-best-and-worst-in-britain-ranked-12753904

Kew Royal Botanic Gardens (2017) State of the world's plants 2017, State of the world's plants 2017. Kew. Available at: https://stateoftheworldsplants.org/2017/report/SOTWP_2017.pdf.

Kniver, M. (2011) Urban plants' role as carbon sinks 'underestimated' BBC. [Online] Available at: http://www.bbc.co.uk/news/science-environment-14121360 [Accessed: 4th May 2022].

Kuhns, M (2008). Landscape trees and global warming. [Online] Available at:http://www.actrees.org/files/Research/Landscape%20Trees%20and%20Global%20Warming%20-%20Utah%20State%20University%20Forestry%20Extension.pdf [Accessed: 4th May 2022]

Lal, R., (2003). Global potential of soil carbon sequestration to mitigate the greenhouse effect. Critical Reviews in Plant Sciences 22, 151–184.

Lawton Report (2010). Making space for nature [Online] Available at: https://webarchive.nationalarchives.gov.uk/ukgwa/20130402151656/http://archive.defra.gov.uk/environment/biodiversity/documents/201009space-for-nature.pdf [Accessed: 4th May 2022].

Liang, D. and Huang, G. (2023). Influence of urban tree traits on their ecosystem services: A literature review. Land, 12(9), https://doi.org/10.3390/land12091699.

Local Government Association. (2020). Climate Change Survey, February 2020. Available at: https://www.local.gov.uk/publications/climate-change-survey-february-2020 [Accessed: September 2023].

Lovett, G (1994). Atmospheric deposition of nutrients and pollutants in North America: an ecological perspective. Ecological Applications 4, 629-650.

McPherson, G. (2000). Expenditures associated with conflicts between street tree roots growth and hardscape in California. Journal of Arboriculture 6, 289-297.

McPherson, B., Sundquist, E (2009). Carbon sequestration and its role in the global carbon cycle. American Geophysical Union 183.

The Natural Choice (2011). Securing the value of nature [Online] Available at:https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/228842/8082.pdf [Accessed: May 2022].

The Natural Capital Committee's third State of Natural Capital (2015). Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/516725/ncc-state-natural-capital-third-report.pdf [Accessed: May 2022].

Neilan, C. (2011) Capital Asset Valuation for Amenity Trees. Arboricultural Association - Tree Valuation Methods in the UK.

Nowak, D. (1994) Atmospheric carbon dioxide reduction by Chicago's urban forest. In,
McPherson, E., Nowak, D., Rowntree, R., (Eds). Chicago's urban forest ecosystem: Results of the Chicago Urban Forest Climate Project. USDA Forest Service, Radnor, PA.

Nowak, D., Civerolo, K., Rao, S., Sistla, G,. Luley, C., Crane, D. (2000). A modeling study of the impact of urban trees on ozone. Atmospheric Environment 34, 1601-1613.

Nowak, David J., Hoehn, R., and Crane, D. 2007. Oxygen production by urban trees in the United States. Arboriculture & Urban Forestry 33(3):220-226.

Nowak, D., Hoehn, R., Crane, D., Stevens, J., Leblanc F. (2010). Assessing urban forest effects and values, Chicago's urban forest. Resource bulletin NRS-37. USDA Forest Service, Radnor, PA.

Nowak, D., Crane, D., (2002) Carbon storage and sequestration by urban trees in the USA. Environmental Pollution 116, 381-389.

Nunes, P., and van de Bergh, J (2001). Economic valuation of biodiversity: sense or nonsense? Ecological Economics 39, 203-222.

Office for National Statistics (2022). Population and migration principal projection – UK summary. 2020-based interim edition of this dataset. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/tablea11principalprojectionuksummary

Office for National Statistics (2023). Principles of UK natural capital accounting: 2023. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/principlesofuknaturalcapitalaccounting2023

Office for National Statistics (2023). Rural Urban Classification (2011) of Local Authority Districts in England. Available at: https://geoportal.statistics.gov.uk/datasets/rural-urban-classification-2011-of-local-authority-districts-in-england-1/about

Office for National Statistics (2023). England natural capital accounts methodology: 2023. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/englandnaturalcapitalaccountsmethodology2023

Orford, K.A., Murray, P.J., Vaughan, I.P. and Memmott, J., 2016. Modest enhancements to conventional grassland diversity improve the provision of pollination services. Journal of Applied Ecology, 53(3), pp.906-915.

Ostle N,. Levy, P., Evans, C., Smith, D (2011) UK land use and soil carbon sequestration. Land Use Policy 26, 274-283.

Rogers, K,. Hansford, D., Sunderland, T., Brunt, A., Coish, N., (2012) Measuring the ecosystem services of the Black Country's trees: The the Black Country i-Tree Eco pilot project. Proceedings of the ICF - Urban Tree Research Conference. Birmingham, April 13-14.

Rogers, K,. Evans, G., (2015) Valuing the Natural Capital of Area 1: A pilot study Available at: https://www.treeconomics.co.uk/wp-content/uploads/2018/08/Area-1-i-Tree-Report.pdf [Last accessed: 10 Dec 2020]

Sales, K., Chambers-Ostler, A., Walker, H., Handley, P., Sparrow, K., Hill, D., and Doick, K.J. (2022). Valuing Derby's Urban Trees; A report to Derby City Council. Forest Research, Farnham. 122 pp.

Santamour, F.S. (1990) Trees for urban planting: Diversity, uniformity and common sense, in: Proceedings of the Conference Metropolitan Tree Improvement Alliance (METRIA). pp. 57–65.

Severn Trent Water (2022). Metered volumetric water supply charge for 2022-23. Available at: https://www.stwater.co.uk/content/dam/stw/my-account/our-charges/2022/st-hh-scheme-of-charges-22-23.pdf

Stewart, S., Owen, S., Donovan, R., MacKensie, R., Hewitt, N., Skilba, U., Fowlar, D (2003). Trees and sustainable urban air quality: using trees to improve air quality in cities. Lancaster University, Lancaster.

Tiwary, A., Sinnet, D., Peachey, C., Chalabi, Z,. Vardoulakis, S., Fletcher, T., Leonardi, G., Grundy, C., Azapagic, A., T, Hutchings. (2009). An integrated tool to assess the role of new planting in PM_{10} capture and the human health benefits: A case study in London. Environmental Pollution 157, 2645-2653.

TEEB (2010) The Economics of Ecosystems and Biodiversity. Available at: http://www.teebweb.org/our-publications/teeb-study-reports/synthesis-report/ [Accessed: 2 Feb 2015]

The Tree Council. (2023). Ash Dieback: Action Plan Toolkit for England and Wales. Accessed: Dec 2023. Available online: https://treecouncil.org.uk/guidance-resources/ash-dieback-action-plan-toolkit-for-england-and-wales/

Trees Design Action Group (2014). Trees in Hard Landscapes - A guide for delivery. [Online] available at: www.tdag.org.uk/trees-in-hard-landscapes.html.

Troy. A., Bagstad, K (2009). Estimation of Ecosystem service values for Southern Ontario. Spatial Informatics Group. Ontario Ministry of Natural Resources.

UFORE (2010). Methods [Online] Available at: http://www.ufore.org/methods.html [Last Accessed 22 Feb 2011].

UK National Ecosystem Assessment (2011). [Online] Available at: http://uknea.unep-wcmc.org/ [Accessed: May 2022].

Wainhouse, D. and Inward, D.J., 2016. The influence of climate change on forest insect pests in Britain. Forestry Commission.

Ward, S.E., Smart, S.M., Quirk, H., Tallowin, J.R., Mortimer, S.R., Shiel, R.S., Wilby, A. and Bardgett, R.D., 2016. Legacy effects of grassland management on soil carbon to depth. Global change biology, 22(8), pp.2929-2938.

West Midlands Combined Authority. 2023. Environment and Energy. Last Accessed: Dec, 2023 Available online: https://www.wmca.org.uk/what-we-do/environment-and-energy/

Xiao, Q., McPherson, E. G., Ustin, S. L., and Grismer, M. E. (2000). A new approach to modeling tree rainfall interception. Journal of Geophysical Research (Atmospheres), 105, 29173-29188, https://doi.org/10.1029/2000JD900343.

Zinke, P (1967). Forest interception studies in the United States. In Sopper, W., Lull, H., eds. Forest hydrology. Oxford, UK: Pergamon Press 137-161.