Treeconomics

Valuing Birmingham, Coventry and Solihull's Urban Forest

West Midlands Combined Authority

Barton Hyett Associates
Arboricultural Consultants

Forest Research

WOODLAND TRUST

BIRMINGHAM TREE PEOPLE

i-Tree

The Authors

Ben Coles - Treeconomics
Harry Munt - Treeconomics
Rosie Webb - Treeconomics
Hannah Walker - Forest Research

Reviewed by:

Kenton Rogers - Treeconomics
Catherine Vaughan-Johncey - Treeconomics

Proof read by:

Charlotte Wilkinson

Acknowledgements

Our thanks to the many people that made this project possible.

We would like to say a huge thank you for the time and support from our wonderful team of volunteers (named in appendix v) and surveyors who completed the all important field work for this study. This project would not have been possible without your commitment.

A special thanks go to Barton Hyett Associates and Birmingham Tree People for assistance with field work and to Forest Research for their contribution to the work on the natural capital accounts chapters.

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

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.

Table of Contents

Executive Summary

The urban forest within and around Birmingham, Coventry and Solihull is a vital resource, providing numerous benefits to the people who live, work and visit the region. 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 **2,966,000 trees** across Birmingham, Coventry and Solihull - equivalent to **1.7 trees per person and 54.5 trees per hectare.** Tree cover was estimated at **13.8%** with shrub cover at an estimated **8.75%**.

- **105 species of tree** were recorded across the Birmingham, Coventry and Solihull study areas. The most common tree species are Silver Birch, with an estimated 261,000 trees, Ash, with an estimated 255,000 trees and English Oak with an estimated 255,000 trees.

- Birmingham, Coventry and Solihull's trees and shrubs have the potential to remove approximately **144 tonnes of air pollution** every year, with an associated value of **£11 million**. These pollutants include sulphur dioxide (SO_2), particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_2).

- Birmingham, Coventry and Solihull's trees reduce surface water runoff by over **936,000 m³ per year.** This volume is equivalent to over **374 Olympic swimming pools** of surface runoff being averted every single year, a service worth an estimated **£1.51 million** in avoided water treatment costs.

- In total, the trees store around **1,068,000 tonnes** of carbon and sequester **33,200 tonnes** of carbon annually, with associated values of approximately **£1.037 billion** and **£32.22 million** respectively.

- The amenity value of the trees was calculated to be **£46.5 billion**, as determined using a CAVAT valuation approach.

- There is a good age class 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 generally provide far more benefits than small trees.

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 to maintain a healthy tree size diversity across the region 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 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 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 such as Birmingham Tree People 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 as Birmingham have done to follow on from this study, providing a vision of what the region would like to achieve with its urban forest and steps to realise those goals.

Headline Figures

Birmingham, Coventry and Solihull's Urban Forest Structure and Composition Headline Figures		
Number of Trees (estimate)	2,966,000	
Tree Density (trees/hectare)	54.5	
Tree Canopy Cover	13.8% (7,496 ha)	
Shrub Cover	8.75% (4767 ha)	
Most Common Tree Species	Silver Birch (8.8%), Ash (8.6%) & English Oak (8.6%)	
Replacement Cost (CTLA)	£1.85 billion	
Amenity Valuation (CAVAT)	£46.5 billion	
Proportion of Trees in Good or Excellent Condition	82.5%	
Birmingham, Coventry and Solihull's Urban Forest Ecosystem Services Headline Figures		
Total Carbon Storage	1,068,000 tonnes	£1.037 billion
Annual Carbon Sequestration	33,200 tonnes	£32,220,000
Annual Pollution Removal	144 tonnes	£11,010,000
Annual Avoided Runoff	936,000 m³	£1,510,000
Total Annual Benefits	£44,740,000	

	Birmingham	Coventry	Solihull
Number of Trees (estimate)	1,129,000	574,000	1,260,000
Canopy cover (ha)	4,016 (15%)	1,144 (11.6%)	2,336 (13.1%)
Total Carbon Storage	419,000 tonnes	284,000 tonnes	365,000 tonnes
Annual Carbon Sequestration	12,800 tonnes	7,950 tonnes	12,400 tonnes
Annual Pollution Removal	80 tonnes	16 tonnes	47 tonnes
Annual Avoided Runoff	481,000 m³	161,000 m³	294,000 m³

Table 1: Headline figures for Birmingham, Coventry and Solihull 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 trees of over 7cm DBH within 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.

Local Authority	Pollution Category	NO_2 (per kg)	SO_2 (per kg)	PM2.5 (per kg)
Birmingham & Coventry	Road Transport Inner Conurbation	£24.781	£7.064	£473.577
Solihull	Road Transport Urban Large	£14.633	£7.064	£278.213

Table 2: UK social damage costs for Local Authorities

Pollution Removal: This value is calculated based on the 2023 UK social damage costs Birmingham, Coventry and Solihull.

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 £1.61 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
Treeconomics
Increased property value and rental value
Improved recovery times from illness
Stormwater attenuation
Attractive high streets Increase in consumer spending and restaurant patronage
Reduced air-conditioning costs
Evaporative cooling in hot weather
Improved concentration and productivity
Winter windbreak
Reduced heating costs
Oxygen production
• Social cohesion
• Sense of place
• Cultural links to the past
Connectivity and wildlife corridors
Bio-diversity and habitat
Food
• Summer shade
• UV protection
Noise reduction
Air quality Pollution filtration
Carbon storage
Traffic calming and journey quality
Encourages outdoor recreation
• Reduced surface flooding
• Soil infiltration
• Soil conservation
Timber Fuel and building materials
• Reduced stress
• Health and wellbeing benefits
© Treeconomics 2023. Version 2. www.treeconomics.co.uk

Introduction and Background

The West Midlands is a region in central England with a rich industrial history. With a combined population of 1.73 million people Birmingham, Coventry and Solihull hosts some of the most built up areas in the country, however, the area also boasts picturesque countryside, providing a balance between urban life and natural beauty. The combined area of Birmingham, Coventry and Solihull covers an area of 74,473 ha.

This series of i-Tree Eco studies was commissioned by the West Midlands Combined Authority to provide detailed information on the scale of benefits provided by the urban forest in Birmingham, Coventry and Solihull, expressing the value of some of those benefits in monetary terms. This report demonstrates how the perception of trees, shrubs and green spaces which make up the urban forest can shift from the historic view of liability to an asset for the WMCA 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 Birmingham, Coventry and 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 Birmingham, Coventry and Solihull's urban forest, increased awareness can be used to encourage investment in their 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 Birmingham, Coventry and 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 the West Midlands.
- Those who are interested in local trees for improving their own and others' health, wellbeing and enjoyment across the West Midlands.

Methodology

To gather a collective representation of Birmingham, Coventry and Solihull's urban forest across both public and private land, a series of i-Tree Eco plot-based assessments was undertaken. 1,000 randomly allocated plots of 0.04ha (400m^2) were surveyed (450 in Birmingham, 250 in Coventry and 300 in Solihull) which equates to 1 plot every 54.5 ha.

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 3 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 the West Midlands Combined Authority's constituent Council's tree management teams 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 3: Study outputs

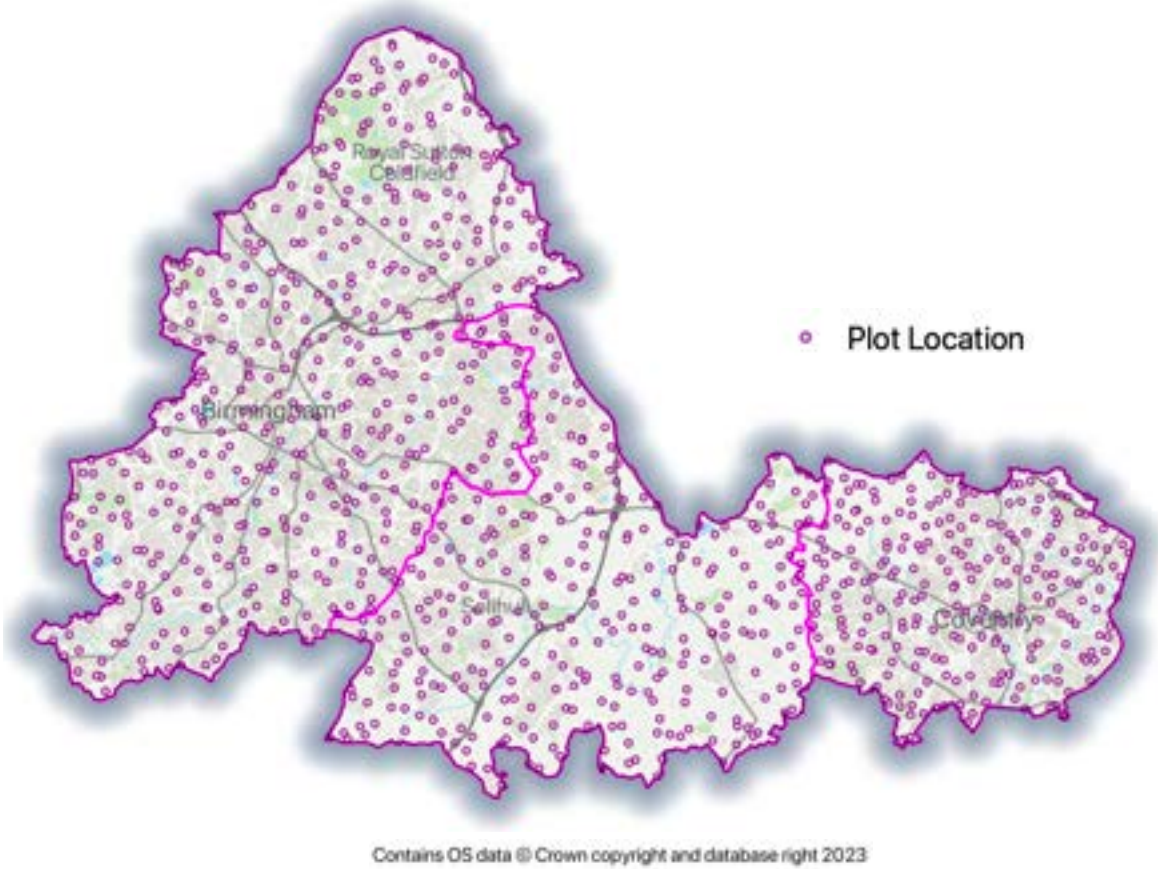

Figure 1: Map of Birmingham, Coventry and Solihull showing Local Authority boundaries and locations of survey plots

Plots were randomly allocated to ensure a statistically significant distribution across Birmingham, Coventry and Solihull; 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. Full methodology can be found within the appendix.

Data Limitations

While Birmingham, Coventry and 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 Birmingham, Coventry and Solihull's urban forest at the time of measurement. This report is concerned with the trees and shrubs within Birmingham, Coventry and 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 Birmingham, Coventry and Solihull the most common ground cover types are maintained grasses (24.1%), buildings (14.1%), tar (13.9%) and herbs (13.3%).

Of the surveyed area, 13.8% of Birmingham, Coventry and Solihull is under tree canopy cover, with 8.75% under shrub cover (note that shrubs are also present under tree cover and so these two figures 'overlap').

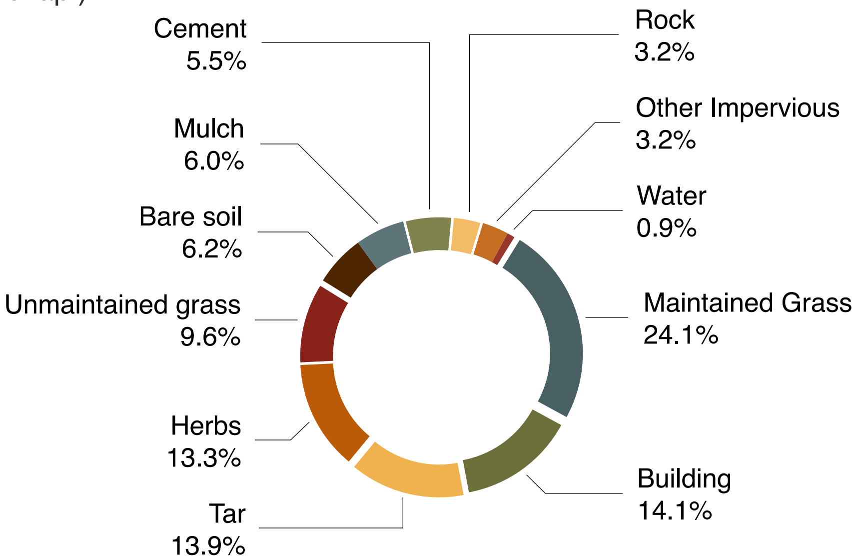

Figure 2: Ground cover types within plots.

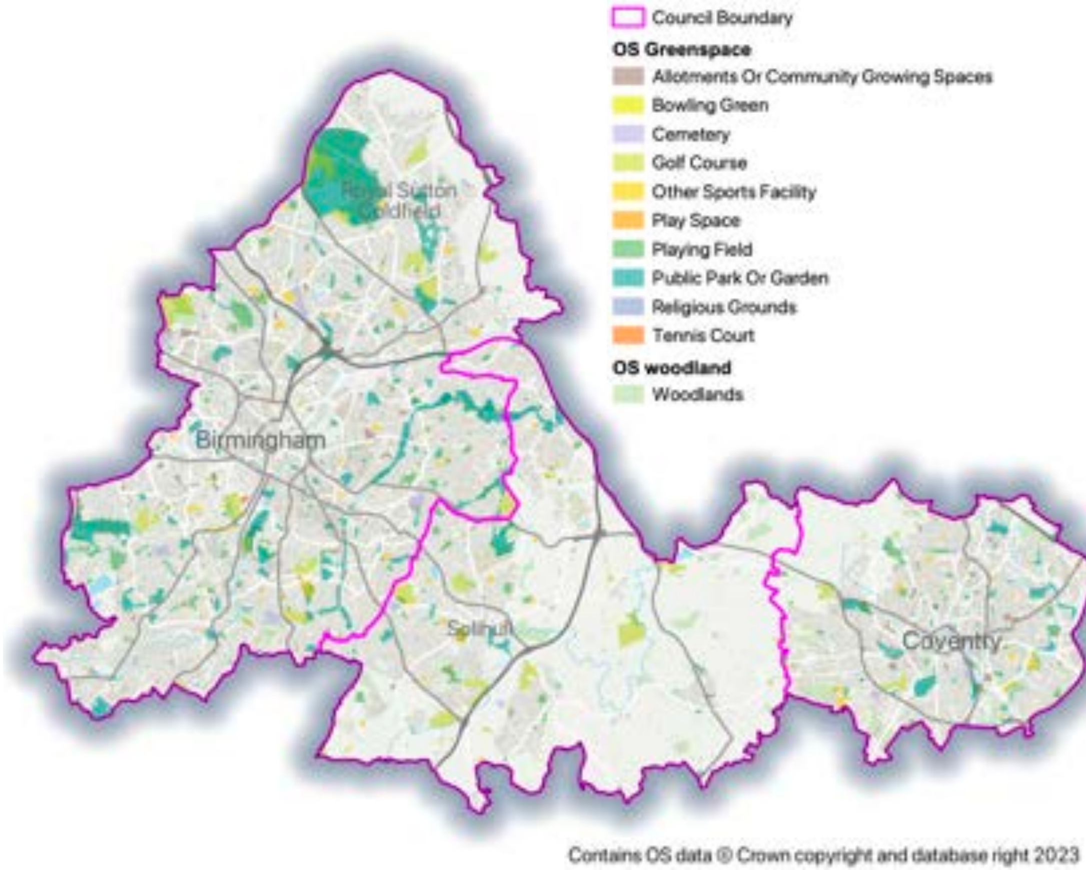

Figure 3: Green space throughout Birmingham, Coventry and Solihull according to Ordnance Survey official categories

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 14.2% 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 Birmingham, Coventry and Solihull. Surveyed plots indicate that on average Birmingham, Coventry and Solihull's largest land use is residential (30.2%) and agriculture (20.1%). Parks account for 8.9% of land cover across Birmingham, Coventry and Solihull.

2.2% of land in Birmingham, Coventry and Solihull is vacant (1,200 ha). This land could potentially be repurposed for tree planting or the creation of new green spaces. Should the 1,200 ha of vacant land be turned over to broadleaved woodland creation, this land could accommodate 1.92 million trees (at a spacing of 2.5 x 2.5m/tree). Parkland creation (at a spacing of 25m x 25m/tree) could accommodate 19,200 new trees.

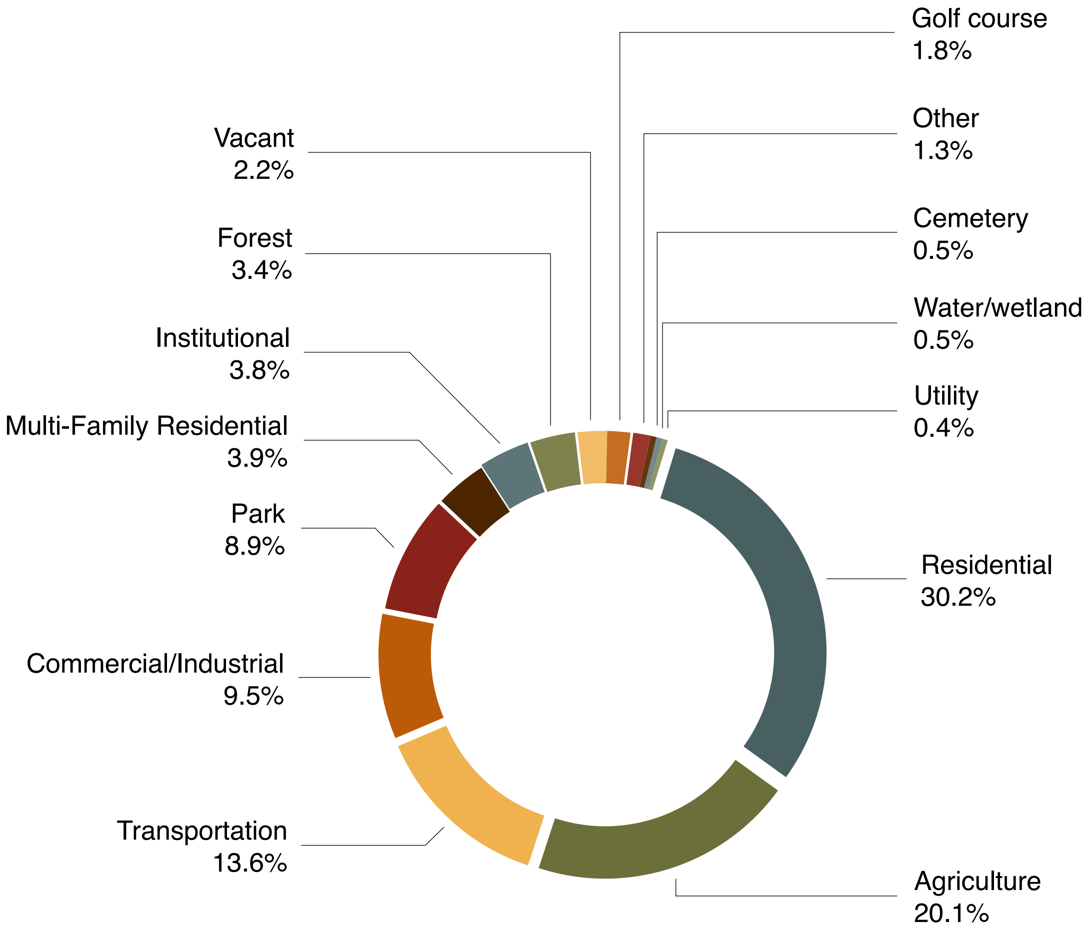

Figure 4: Ground cover types within plots.

Green spaces make up 35.1% of land cover in Birmingham, Coventry and Solihull; that is significantly higher than the average for Inner London (21%).

Tree Species Dominance and Diversity

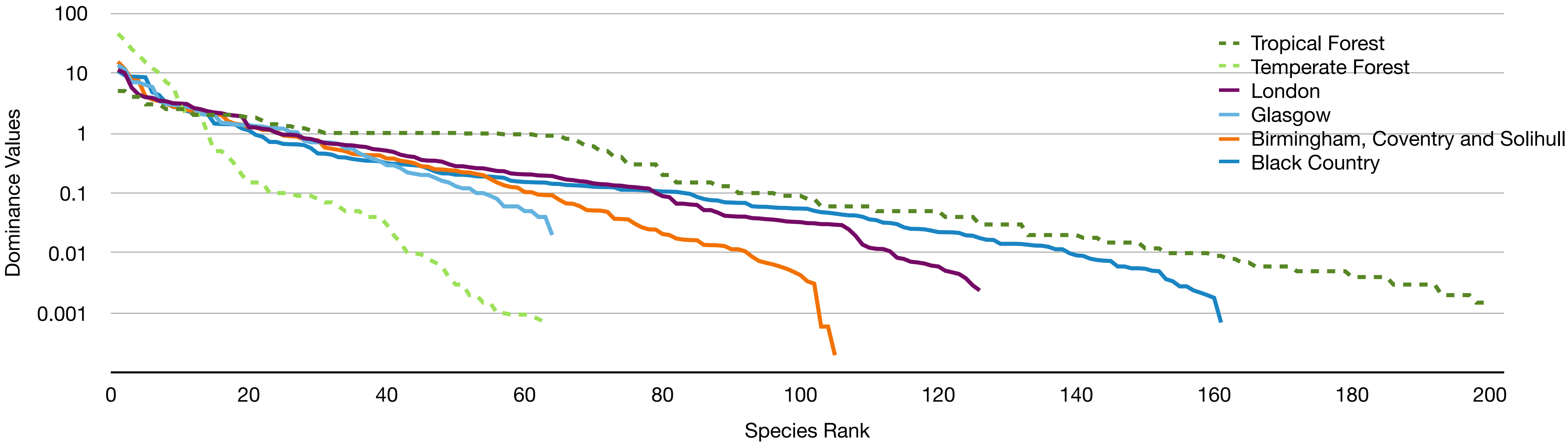

Figure 5: Hubbell's Dominance Diversity Curve showing example forest types and selected UK cities.

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 Birmingham, Coventry and 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 4.

Species	Species/ha	SHANNON
97	10.30	3.51

Table 4: Species richness and diversity indexes for Birmingham, Coventry and 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]

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

In Birmingham, Coventry and Solihull 69% 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

Species Richness

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

The ten most common species account for 59.9% of the total population. In total, 97 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.

Birmingham, Coventry and Solihull's urban forest has a variety of species present, with no species exceeding 10% of the total population. Santamour's 10:20:30 tree population diversity rule[5] is achieved across Birmingham, Coventry and Solihull and, with strategic new tree planting, would be maintainable giving the urban forest more resilience to pests and diseases. The most prominent threats from present pests and diseases in Birmingham, Coventry and Solihull are Ash Dieback and threats to the Oak population such as Acute Oak Decline and Oak Processionary Moth.

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

[5] Santamour, 1990

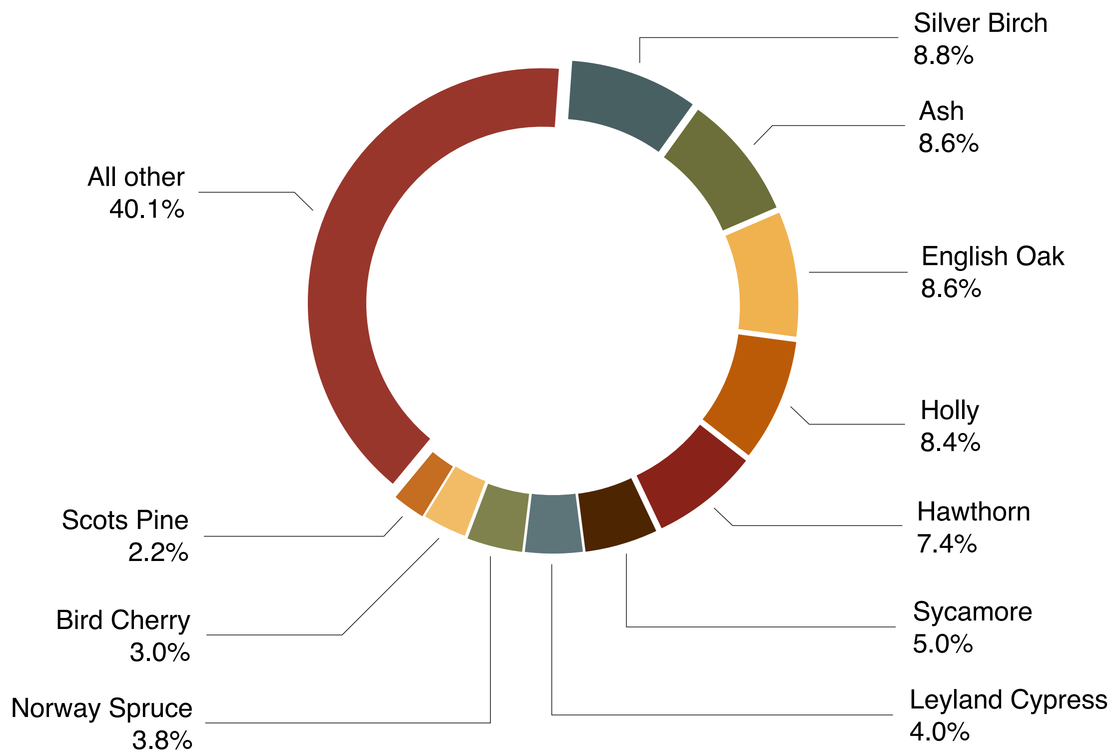

Figure 6: Species composition (most common species).

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.

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.

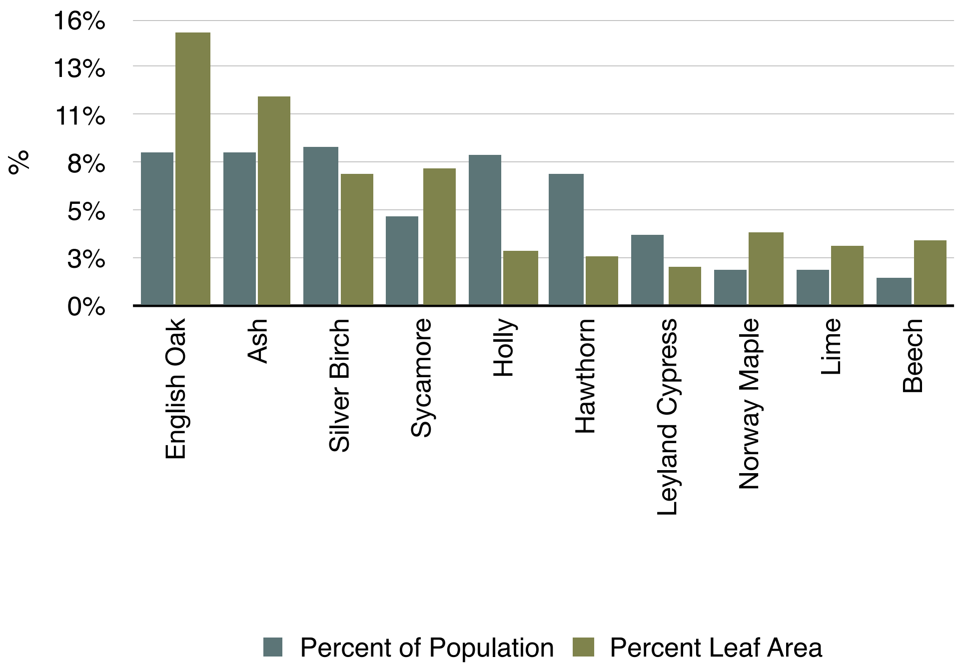

Figure 7: Leaf area and population of Birmingham, Coventry and Solihull by most dominant tree species.

The Dominance Value is calculated by taking into account the leaf area and relative abundance of the species. In Birmingham, Coventry and Solihull the most dominant species are English Oak, Ash and Silver Birch - 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 English Oak, Ash and Silver Birch 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 Holly and Hawthorn.

Species	Leaf area (ha)	Dominance Value
English Oak	8,293	23.9
Ash	6,335	20.3
Silver Birch	4,006	16.2
Sycamore	4,146	12.7
Holly	1,661	11.5
Hawthorn	1,498	10.2
Leyland Cypress	1,164	6.1
Norway Maple	2,221	6.1
Lime	1,834	5.3
Beech	1,965	5.2

Table 5: The ten most dominant tree species in Birmingham, Coventry and Solihull.

*See appendix II for the full list of tree dominance value ranking in Birmingham, Coventry and 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 30.3% percent of the tree population of Birmingham, Coventry and 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[6] 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[7].

Size class distribution (or diversity) 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 Birmingham, Coventry and Solihull it is 29.2%
>
> *Trees in Towns II

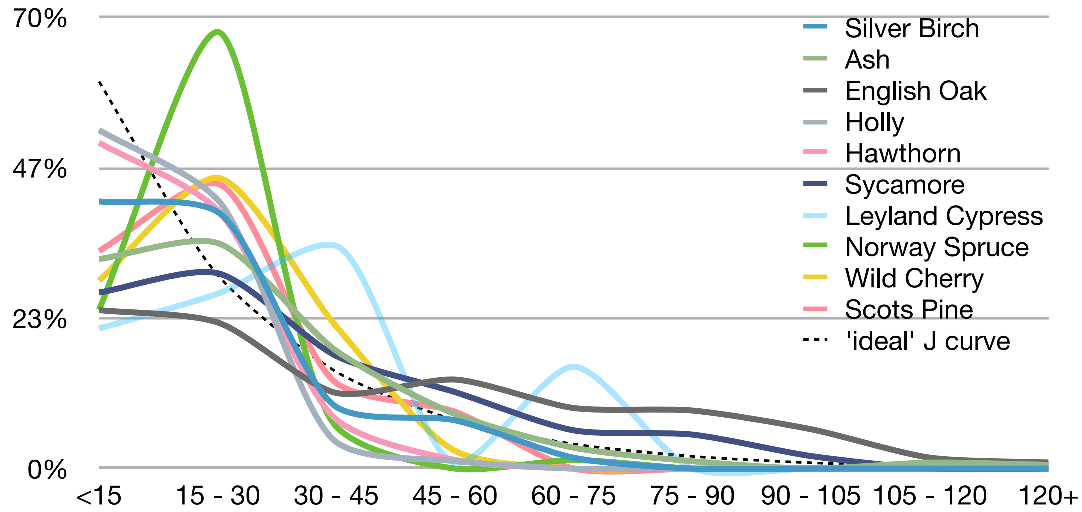

Figure 8: Spread of size classes amongst the top ten species, showing comparison to 'ideal' J-curve
'ideal' J-curve values reduce by half for each increase in DBH class

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

---

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

[7] Hand and Doick, 2019

[8] 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.[9]

The diversity of species within Birmingham, Coventry and 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. 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,[10] therefore non-native species could become increasingly important for the delivery of benefits in Birmingham, Coventry and 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 6: 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

[9] Nunes et al, 2001

[10] Gill et al, 2007

Origin of Tree Species

The map below shows the original continent of origin of the tree species found in Birmingham, Coventry and Solihull. In total, around 86.1% of the tree population are native to Europe. Of those, it is expected that a smaller percentage are native to the British Isles, however diversity is key to resilience.

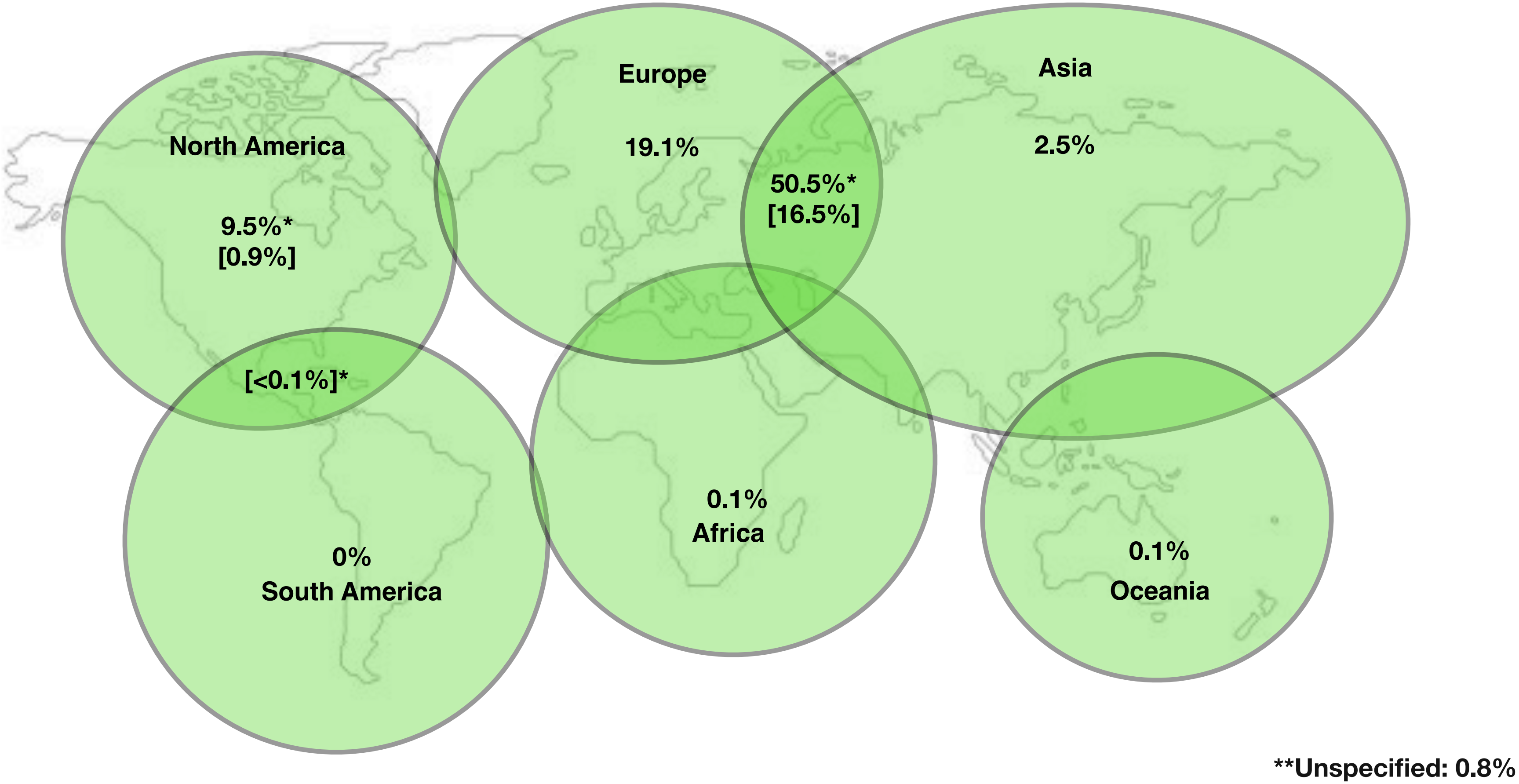

Figure 9: Origin of Tree Species; the share of trees native to different geographical regions. Overlaps indicate origins within both continents

*In these cases, where only genus is available, the proportion in brackets may include additional regions.

**0.8% 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 $PM_{2.5}$.

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 Birmingham, Coventry and Solihull's trees is to reduce ozone through evaporative cooling[11], 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[12]. 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 144.3 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 £11,00,000 (based on UK social damage costs published by DEFRA)[13]. Total pollution removal per ha in Birmingham, Coventry and Solihull is equivalent to 0.003 tonnes per ha per yr.

Pollutant	Tonnes removed by trees per year	Value (approx)
Nitrogen dioxide (NO_2)	119	£2,550,000
Particulates (<$PM_{2.5}$)	4.9	£34,700
Sulphur dioxide (SO_2)	20.4	£8,420,000
Total	144	£11,004,700

Table 7: Quantity and value of the pollutants removed per-annum within Birmingham, Coventry and Solihull. Valuation methods used are UK social damage cost (UKSDC).

11 Nowak et al, 2000.

12 Escobedo and Nowak (2009)

13 DEFRA (2023)

Avoided Run-Off

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

During precipitation events, a portion of the precipitation will be intercepted by vegetation (trees and shrubs) while a further portion reaches the ground. Precipitation that reaches the ground and does not infiltrate into the soil becomes surface run-off[14].

Within an urban area, the large extent of impervious surfaces increases the amount of run-off. However, trees are effective at reducing this[15]. 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 Birmingham, Coventry and Solihull help to reduce run-off by an estimated 936,000 cubic metres a year with an associated value of £1,510,000. English Oak trees intercept the most water, removing a total of 140,000 m^3 of water per year, a service worth £225,000 (Figure 10). English Oak trees have an expansive canopy to capture/ intercept rainfall and represent a high proportion of trees within Birmingham, Coventry and Solihull.

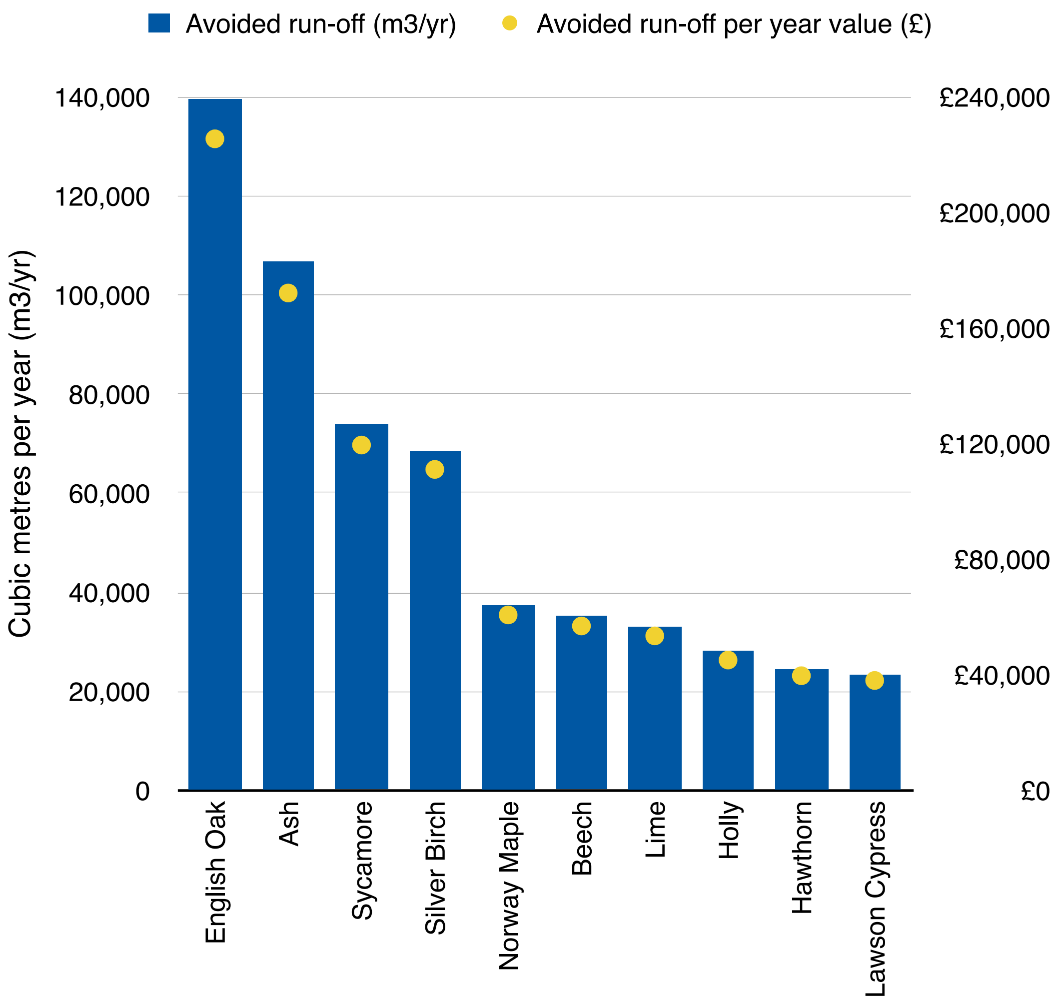

Figure 10: Avoided run-off by the top ten species.

[14] Hirabayashi (2012).

[15] 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[16]. Over the lifetime of a tree, several tonnes of atmospheric carbon dioxide can be absorbed[17].

The gross sequestration of Birmingham, Coventry and Solihull's trees is approximately 33,200 tonnes of carbon per year (approximately 0.6t/yr/ha). The value of the carbon sequestered annually is estimated at £32.2 million per year. This value will continue to increase as the trees grow.

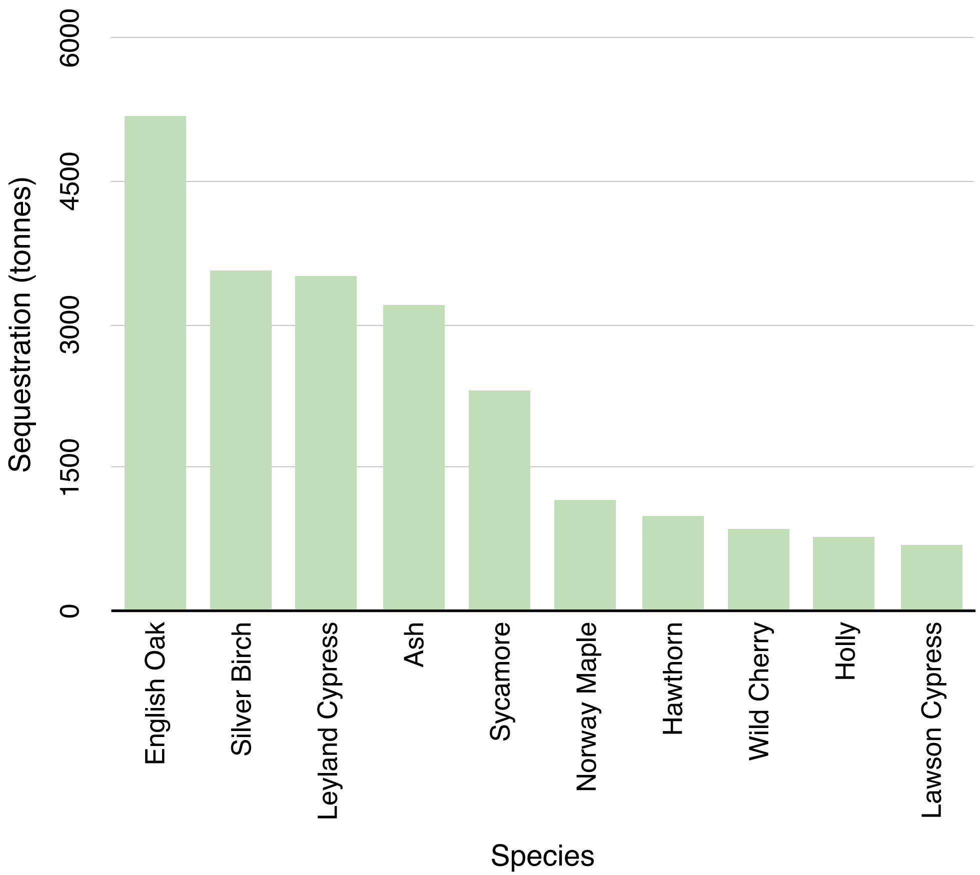

Figure 11: Ten most significant tree species for annual carbon sequestration in Birmingham, Coventry and Solihull.

Carbon sequestration and storage is a key part of achieving any net-zero target. In 2021, Birmingham, Coventry and Solihull produced a total of 6,203 kt CO_2e emissions* (equivalent to approximately 1,690,000 tonnes of carbon), meaning that sequestration by trees account for 2% of the total annual emissions.

*Department for Energy Security and Net Zero 2023

16 Kuhns, 2008

17 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 1,068,000 tonnes (approximately 19.6 t/ha) of carbon is stored in Birmingham, Coventry and Solihull's trees with an estimated value of over £1.037 million (based on current carbon figures from the Department for Energy Security & Net Zero and Department for Business, Energy & Industrial Strategy)[18].

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[19].

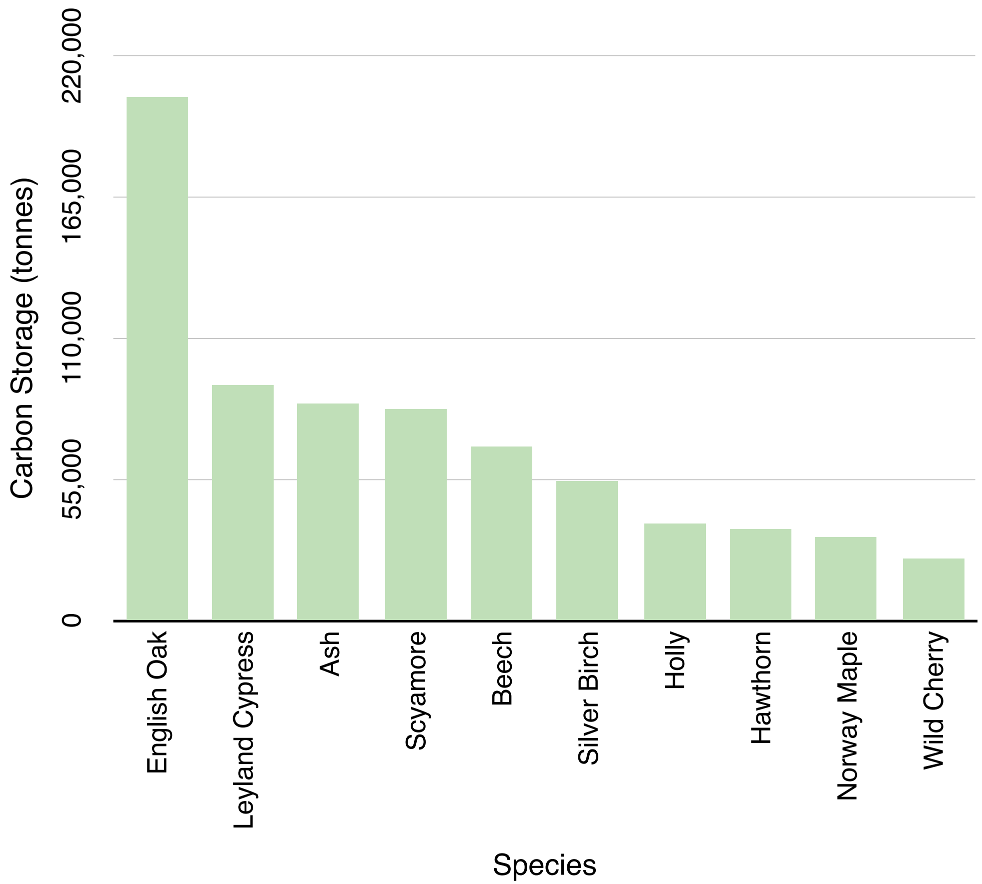

Figure 12: Ten most significant tree species for carbon storage in Birmingham, Coventry and Solihull.

[18] DBIES (2022)

[19] 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[20]. The West Midlands Combined Authority declared a Climate Emergency in 2019, setting a vision of being carbon neutral by 2041[21].

Birmingham, Coventry and Solihull's carbon production has been falling quickly over the past few years, however it still produces around 1.69 million tonnes of carbon each year (1.6 x the carbon storage and 50.9 x the annual sequestration rate of the trees in Birmingham, Coventry and Solihull). The carbon emitted equals approximately 0.98 tonnes per person in Birmingham, Coventry and Solihull. This comes from a range of sources, the highest of which are Domestic (35%), Transport (24%) and Industry (22%)[22].

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.

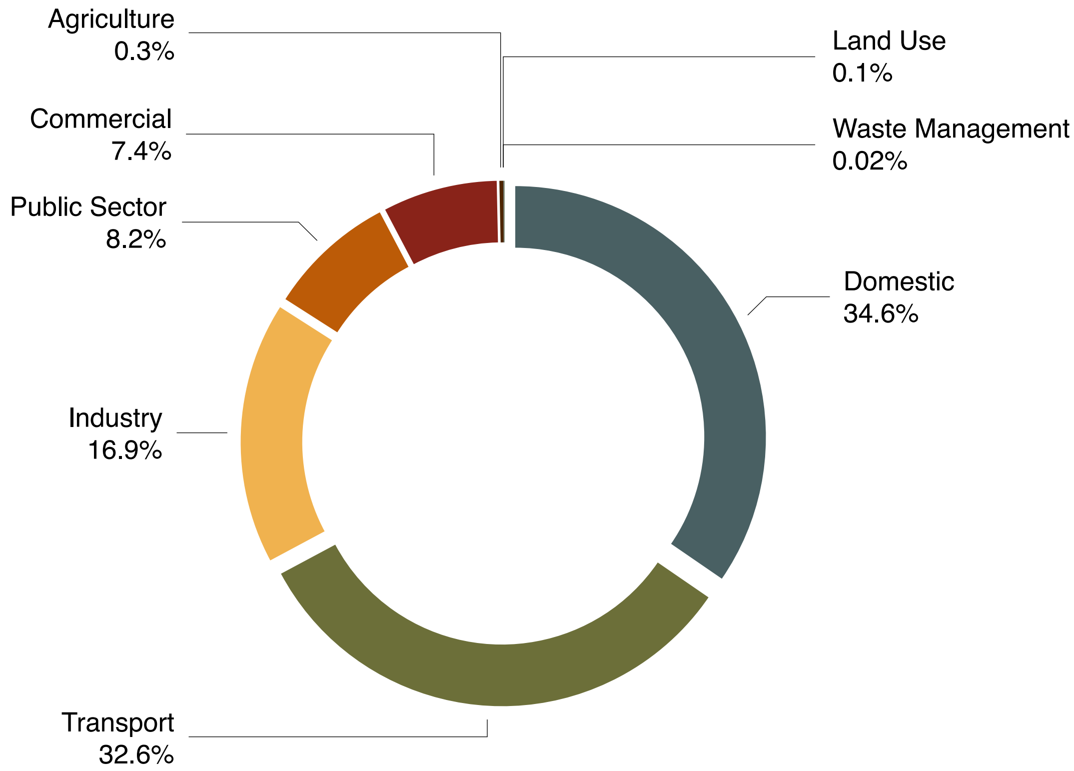

Figure 13: Sources of Birmingham, Coventry and Solihull's greenhouse gas emission in 2021

20 Local Government Association, 2020.

21 West Midlands Combined Authority, 2023

22 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 and best practice followed by the present custodians of Birmingham, Coventry and Solihull’s trees, with 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[23] 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 Birmingham, Coventry and Solihull, 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 study area 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 of the study area. The per annum value of the benefits provided by these services is calculated by multiplying by unit values (see Table 8). 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[2].

Table 8 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[24]

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[25]

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[2]

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

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

[23] Defra (2023)

[24] IPCC (2001)

[25] Office for National Statistics (2023)

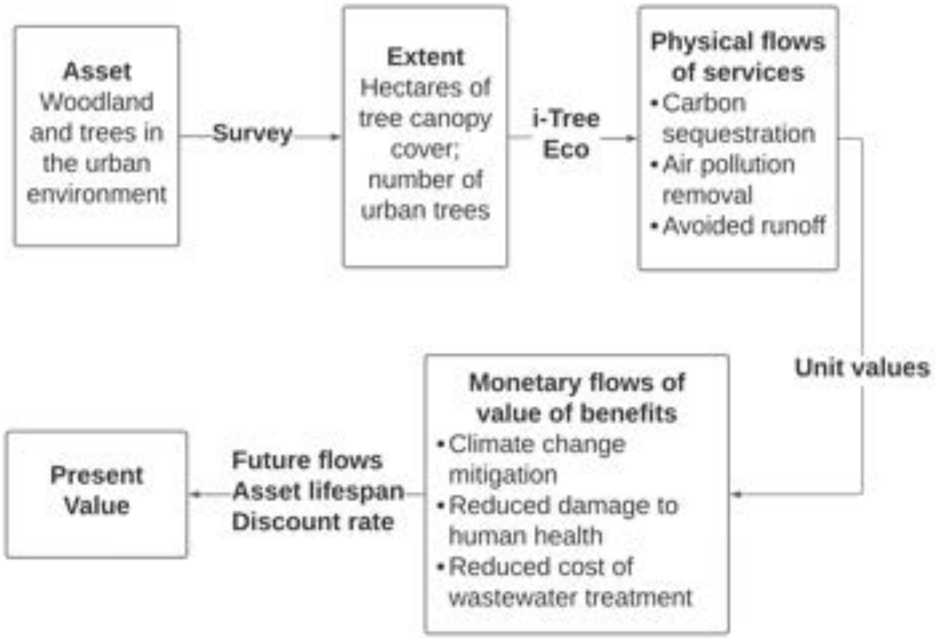

Figure 14: Logic chain applied to natural capital accounting for Birmingham, Coventry and Solihull.

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 8: 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[2]. The ability of any natural capital asset to deliver ecosystem services depends on the following:

- 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[26]. 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[27], 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. 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 44.

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 9 summarises the quantity, quality and spatial configuration of trees in the urban forests of Birmingham, Solihull and Coventry.

---

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

[27] Xiao et al, (2000)

Asset	Quantity / estimated number of trees	Quantity / estimated ha of tree canopy cover	Quality	Spatial configuration
Birmingham's urban trees	1,129,000	4,016	72.9% of trees in good or excellent condition	Study area is Birmingham City Council metropolitan district, classified as urban with major conurbation and predominantly urban*
Solihull's urban trees	1,260,000	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*
Coventry's urban trees	574,000	1,144	92.2% of trees in good or excellent condition	Study area is Coventry City Council metropolitan district, classified as urban with city and town and predominantly urban*

Table 9: Natural capital assets in the study area
*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[28], 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[29].

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[12].

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[30].

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[31]. Rainfall interception is dependent on 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

[28] HM Treasury (2008)

[29] HM Treasury (2023)

[30] Office for National Statistics (2022)

[31] Met Office Hadley Centre (2022)

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****: £22,630 (Birmingham), £13,341 (Coventry), £14,408 (Solihull) per tonne of NO_2 £167,746 (Birmingham), £96,592 (Coventry), £104,833 (Solihull) per tonne of $PM_{2.5}$ £16,616 (all) 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 10: 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)

guidance[32]. Table 10 summarises the details of calculations for each ecosystem service.

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 Birmingham, Solihull, and Coventry. Of these three ecosystem services, carbon sequestration makes the greatest contribution. The overall present value for the urban forest in the combined study area is £2.0 billion.

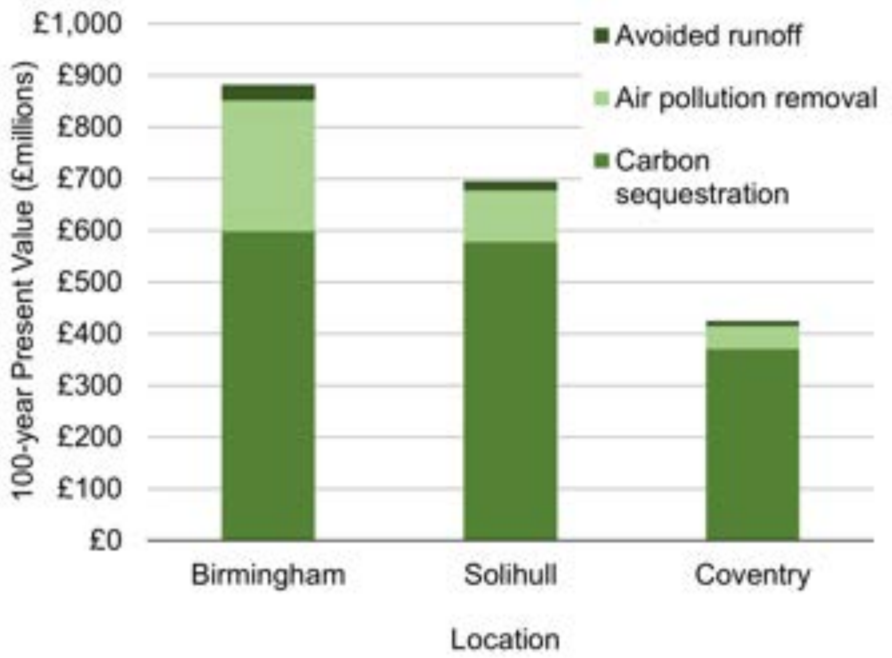

Figure 15: Contributions of carbon sequestration, air pollution removal, and avoided runoff to the 100-year present value of the urban forests in Birmingham, Solihull, and Coventry.

Of the three urban areas in the study area, Birmingham is the largest, covering 26,800 hectares, and has the highest canopy cover at 15% (4,106 hectares). Solihull's urban forest covers 2,336 hectares (13.1%), and Coventry's 1,114 hectares (11.6%). Figure 16 shows the present

32 Department for Energy Security and Net Zero (2023)

values per hectare of tree cover for the tree urban areas, showing that Coventry's urban trees are most valuable on a per-hectare basis.

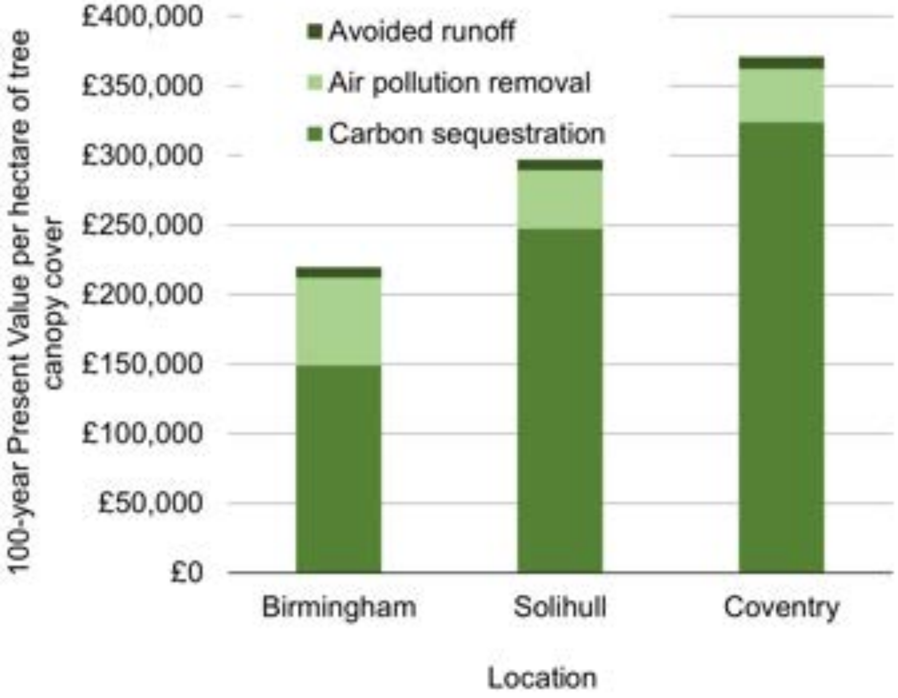

Figure 16: Per-hectare 100-year present values of carbon sequestration, air pollution removal, and avoided runoff in Birmingham, Solihull, and Coventry.

The £2.0 billion 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.

The present values presented herein assume no change in the urban forest over the next 100 years, which is unrealistic. Future benefit provision in the study area 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 the 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 Birmingham, Coventry and Solihull has an estimated public amenity asset value of £46.5 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 Birmingham, Coventry and Solihull, contributing 23.7% of the urban forest's amenity value. The next largest contributors were Ash, followed by Sycamore. Combined, these three species represent 37.8% of the total amenity value for Birmingham, Coventry and 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 19m high, 1.2m DBH Turkey Oak in excellent condition growing in a park in Coventry; it was estimated to have an amenity value of £348,000. The land use type containing the highest amenity value of trees was 'park', with 32% of the total value of the trees, and an estimated value of £10.8 billion when extrapolated for the whole of Birmingham, Coventry and Solihull. 'Residential' and 'transportation' were the next most important land-uses, contributing 23% and 12% to the total amenity value, respectively.

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

Species	Value of measured trees (£)	Value extrapolated across the area (£)	Proportion of total value (%)
English Oak	£8.35 million	£11.4 billion	23.7%
Ash	£2.5 million	£3.41 billion	7.1%
Sycamore	£2.46 million	£3.35 billion	7.0%
Beech	£1.68 million	£2.29 billion	4.8%
Leyland Cypress	£1.64 million	£2.24 billion	4.7%
Silver Birch	£1.47 million	£2.01 billion	4.2%
Lime	£1.14 million	£1.55 billion	3.2%
London Plane	£1.14 million	£1.55 billion	3.2%
Lawson Cypress	£862,000	£1.17 billion	2.5%
Lombardy Poplar	£848,000	£1.15 billion	2.4%

Table 11: CAVAT amenity value for the top ten most valuable tree species.

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

Land use	Value of measured trees per land use (£)	Value per land use extrapolated across the area (£)	Proportion of total value (%)
Forest	£9.58 million	£13 billion	27.2%
Park	£7.94 million	£10.8 billion	22.6%
Residential	£5.66 million	£7.71 billion	16.1%
Transportation	£2.89 million	£3.94 billion	8.2%
Institutional	£2.27 million	£3.09 billion	6.4%
Multi-family Residential	£1.83 million	£2.5 billion	5.2%
Vacant	£1.27 million	£1.73 billion	3.6%
Cemetery	£836,000	£1.14 billion	2.4%
Commercial/ Industrial	£756,000	£1.03 billion	2.1%
Other	£729,000	£992 million	2.1%
Agriculture	£724,000	£986 million	2.1%
Golf	£609,000	£830 million	1.7%
Multi-family	£54,800	£74.6 million	0.2%
Utility	£19,900	£27.1 million	0.1%

Table 12: CAVAT amenity value for each land use.

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[33].

The formula allows for tree suitability in the landscape and nursery prices. This explains why the value given for Ash is often comparably low - even though it is a widespread and common species in Birmingham, Coventry and Solihull 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 17.

The total replacement cost of all trees in Birmingham, Coventry and Solihull currently stands at £1.85 billion. English Oak trees are currently the species with the highest replacement value, on account of both their size and population, followed by Ash and Leyland Cypress. These three species of tree account for £585 million (31.6%) of the total replacement cost of the trees in Birmingham, Coventry and Solihull. A full list of trees with the associated replacement cost is given in appendix III.

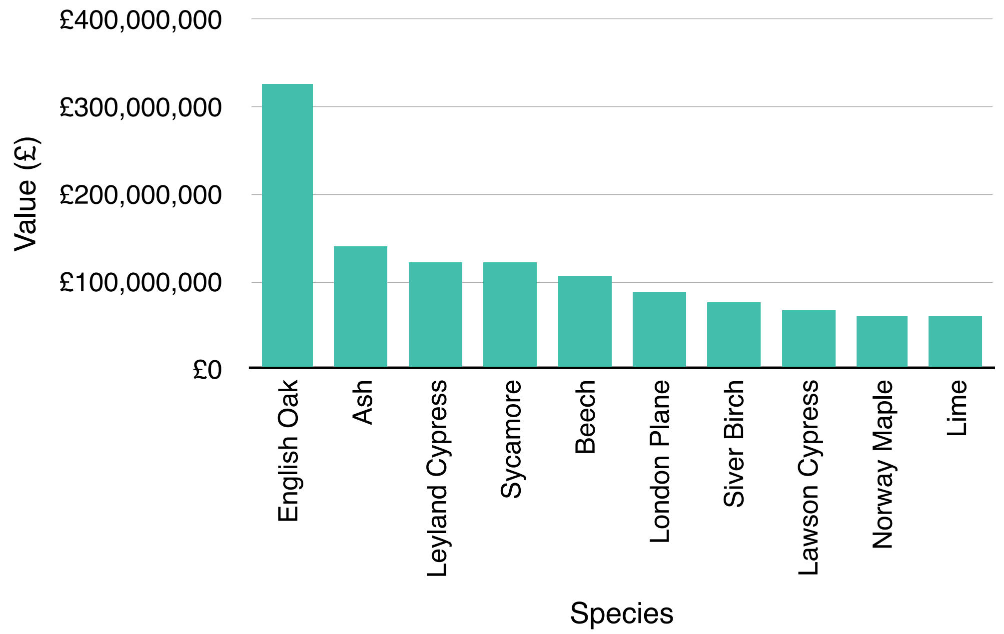

Figure 17: Replacement Cost of the 10 most valuable tree species in Birmingham, Coventry and Solihull.

33 Hollis (2007)

Potential Pest and Disease Impacts

Animal pests and microbial pathogens are a serious threat to urban forests and society, causing direct economic costs from damage, and impacting on ecosystem service provision[34]. It is likely that climate change will result in the introduction of pests and diseases not yet present in the UK[35]. 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[36]. 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 Birmingham, Coventry and Solihull, based on whether it affected a single tree genus shown in Table 13, or multiple genera in Table 14.

Prevalence	% of Community at Risk		
	0-25	26-50	>50
Not in UK			
Present in UK			
Present in Birmingham, Coventry and Solihull			

Table 13: Risk matrix used for the probability of a pest or disease, which affects a single tree genus, becoming prevalent in Birmingham, Coventry and Solihull.

Prevalence	% of Community at Risk		
	0-5	6-10	>10
Not in UK			
Present in UK			
Present in Birmingham, Coventry and Solihull			

Table 14: Risk matrix used for the probability of a pest or disease, which affects multiple tree genera, becoming prevalent in Birmingham, Coventry and Solihull.

[34] Kew Royal Botanical Garden (2017)

[35] Wainhouse and Inward (2016)

[36] Federickson-Matika and Riddell (2021)

This informed Table 15, which gives an overview of the existing and emerging risks to Birmingham, Coventry and 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[37]. 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, and would affect >0.01% of the area's trees.

The pest which could potentially have the greatest estimated impact across Birmingham, Coventry and Solihull's urban forest is the Asian Longhorn Beetle (though this is not currently present in the UK), which could affect 50% of its trees, worth £945 million. The greatest risk which is already present in the UK are threats to the Oak population from Acute Oak Decline and Oak Processionary Moth, which each threaten 10% of the total tree population valued at £350 million.

Figure 18: Symptoms of Acute Oak Decline (Source: Forest Research)

[37] 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	£350,000,000	10%
Asian Longhorn Beetle	Many broadleaf species	None (previous outbreaks contained)	£945,000,000	50%
Beech Leaf Disease	Mainly American Beech species but also others	None	£107,000,000	2%
Bronze Birch Borer	All Birch species	None	£82,600,000	9%
Ash Dieback	Many Ash species	Occurs in most parts of the UK	£139,000,000	9%
Citrus Longhorn Beetle	Many broadleaf species	None	£761,000,000	38%
Dothistroma Needle Blight	Many Pine species	Widespread	£26,800,000	3%
Elm Zigzag Saw Fly	Some Elm species	Present in SE England and East Midlands	£5,250,000	1%
Emerald Ash Borer	Common ash and Narrow-leaved Ash	None	£139,000,000	9%
Great Spruce Bark Beetle	Spruce species	Present	£13,200,000	4%
Horse Chestnut Leaf Miner	Horse Chestnut	Present in all parts of GB	£12,300	0%
Mountain Ash Ringspot	Rowan	Widespread through Scotland and the North. Likely present across the whole UK.	£53,900	2%
Oak Lace Bug	Oak species	None	£350,000,000	10%
Oak Processionary Moth	Oak species	Established in Greater London and some surrounding counties	£350,000,000	10%
Oriental Chestnut Gall Wasp	Sweet Chestnut	Around London and the South East	£4,420	0%
Phytopthora austrocedri	*Juniperus spp, Chamaecyparis lawsonia, Chamaecyparis nootkkatensis*	Scotland and England only	£69,800,000	2%

Table 15. The significance of a range of existing and emerging pests and diseases to Birmingham, Coventry and 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	£93,300,000	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	£37,800,000	3%
Plane Lace Bug	Plane species	None	£88,300,000	1%
Plane Wilt	Plane species	None	£88,300,000	1%
Rednecked Long-horn Beetle	Cherry species	None	£46,600,000	6%
Sirococcus tsugae	Cedar and Hemlock species	Yes	£13,700,000	0%
Sweet Chestnut Blight	Chestnut species	Yes but uncommon	£199,000	0%

Table 15. The significance of a range of existing and emerging pests and diseases to Birmingham, Coventry and 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 second most populous tree species in Birmingham, Coventry and Solihull and provides 8.6% 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 DiebackAction Plan Toolkit was developed. The Toolkit is an evolving document being updated with best practice for local authorities in tackling Ash Dieback[38]. 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 provided by a range of organisations, including the Tree Council, the Forestry Commission, Natural England, the Woodland Trust and local authorities.

[38] The Tree Council,. 2023

Figure 19: 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 20 shows the health of the 10 most common trees in Birmingham, Coventry and Solihull. Overall, tree health in Birmingham, Coventry and Solihull is excellent, with over 50% rated as excellent condition in all three areas reaching a high of 88.6% in Coventry. Overall condition is 70.5% excellent and a further 18.7% rated good or fair. 10.8% of trees rated as poor or worse. Approximately 5.1% are dying or already dead.

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

Over 75% of Ash trees in Birmingham, Coventry and Solihull are in an excellent or good condition. However, Ash is the second most common species and the resulting loss from an increased impact of Ash Dieback, as seen in other parts of the country, remains a high risk.

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. Replacement species should have roughly the same potential for ecosystem service provision as those which are lost.

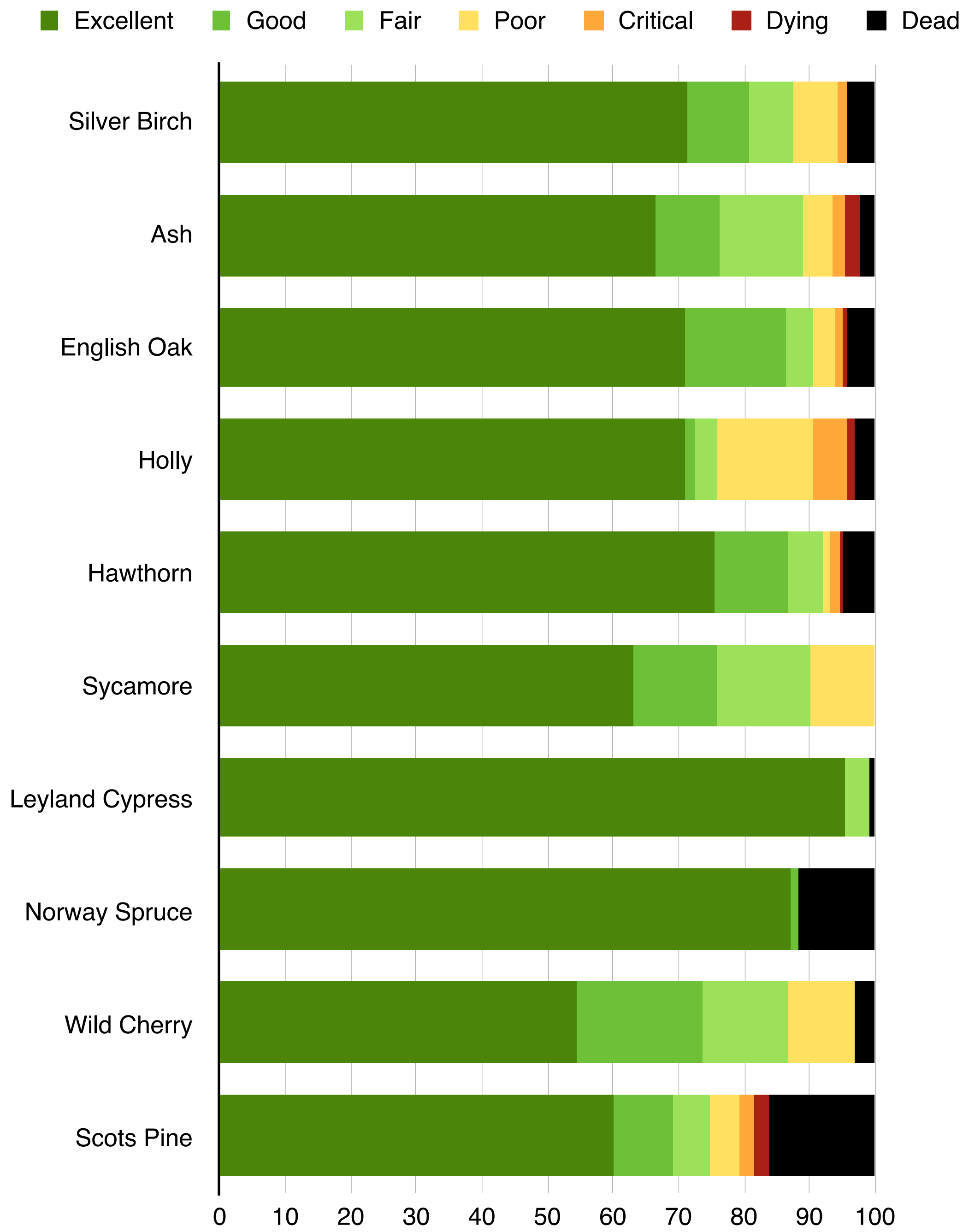

Figure 20: Condition of the 10 most common tree species in Birmingham, Coventry and Solihull

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 to maintain a healthy size diversity within the West Midlands 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 Birmingham, Coventry and Solihull's urban forest to all, emphasising the benefits provided through education 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 city would like to achieve with its urban forest and step to realise those goals.

Appendix I. Relative Tree Effects

The urban forest in Birmingham, Coventry and 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 832,000 family cars
- Annual C emissions from 341,700 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 18,720 family cars
- Annual nitrogen dioxide emissions from 8,439 single-family houses

Sulphur dioxide removal is equivalent to:

- Annual sulphur dioxide emissions from 58300 family cars
- Annual sulphur dioxide emissions from 154 single-family houses

Annual carbon sequestration is equivalent to:

- Annual C emissions from 25,900 family cars
- Annual C emissions from 10,600 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	8.6	15.3	23.9
Fraxinus excelsior	Common Ash	8.6	11.7	20.3
Betula pendula	Silver Birch	8.8	7.4	16.2
Acer pseudoplatanus	Sycamore	5.0	7.6	12.7
Ilex aquifolium	Holly	8.4	3.1	11.5
Crataegus monogyna	Hawthorn	7.4	2.8	10.2
x Hesperotropsis leylandii	Leyland Cypress	4.0	2.1	6.1
Acer platanoides	Norway Maple	2.0	4.1	6.1
Tilia x europaea	Common Lime	1.9	3.4	5.3
Fagus sylvatica	Common Beech	1.5	3.6	5.2
Prunus avium	Wild Cherry	3.0	2.0	5.0
Picea abies	Norway Spruce	3.8	1.0	4.9
Alnus glutinosa	Common Alder	2.1	2.5	4.6

Scientific Name	Common Name	% Population	% Leaf Area	Dominance value
Chamaecyparis lawsoniana	Lawson Cypress	1.9	2.4	4.3
Acer campestre	Field Maple	2.0	2.0	4.0
Pinus sylvestris	Scots Pine	2.2	1.2	3.5
Populus tremula	Aspen	1.8	1.4	3.2
Platanus x hybrida	London Plane	0.6	2.3	2.9
Tilia cordata	Small Leaved Lime	0.8	2.0	2.8
Thuja plicata	Western Red Cedar	1.7	0.9	2.6
Sorbus aucuparia	Rowan	1.8	0.8	2.6
Salix caprea	Goat Willow	1.3	1.2	2.5
Salix fragilis	Crack Willow	1.2	1.1	2.3
Tilia platyphyllos	Large Leaved Lime	0.5	1.6	2.1
Carpinus betulus	Common Hornbeam	0.5	1.4	1.8
Taxus baccata	Common Yew	0.6	1.1	1.8
Corylus avellana	Hazel	1.2	0.5	1.7
Prunus spinosa	Blackthorn	1.2	0.2	1.4

Scientific Name	Common Name	% Population	% Leaf Area	Dominance value
Malus domestica	Apple	1.0	0.3	1.3
Aesculus hippocastanum	Horse Chestnut	0.4	0.9	1.3
Sambucus nigra	Elder	1.0	0.2	1.2
Ulmus procera	English Elm	0.9	0.2	1.1
Betula pubescens	Downy Birch	0.6	0.5	1.1
Cupressus sempervirens	Italian Cypress	0.2	0.9	1.1
Acer saccharinum	Silver Maple	0.3	0.8	1.0
Populus nigra	Black Poplar	0.2	0.8	1.0
Quercus rubra	Red Oak	0.4	0.5	0.9
Ulmus glabra	Wych Elm	0.3	0.6	0.9
Populus nigra v. italica	Lombardy Poplar	0.5	0.4	0.9
Quercus petraea	Sessile Oak	0.5	0.3	0.9
Sorbus aria	Whitebeam	0.5	0.4	0.9
Alnus cordata	Italian Alder	0.4	0.4	0.8
Salix alba	White Willow	0.4	0.4	0.8

Scientific Name	Common Name	% Population	% Leaf Area	Dominance value
Prunus domestica	Plum	0.6	0.2	0.8
Sorbus intermedia	Swedish Whitebeam	0.5	0.2	0.7
Alnus incana	Grey Alder	0.4	0.3	0.7
Cedrus deodara	Deodar Cedar	0.3	0.3	0.7
Prunus cerasifera	Cherry Plum	0.4	0.2	0.6
Prunus laurocerasus	Cherry Laurel	0.4	0.2	0.6
Populus alba	White Poplar	0.1	0.4	0.6
Magnolia	Magnolia	0.4	0.2	0.5
Liriodendron tulipifera	Tulip Tree	<0.1	0.4	0.5
Pinus	Pine	0.4	<0.1	0.5
Quercus cerris	Turkey Oak	0.1	0.4	0.5
Chamaecyparis pisifera	Sawara Cypress	0.3	0.2	0.5
Robinia pseudoacacia	False Acacia	0.2	0.3	0.4
Malus sylvestris	Crab Apple	0.2	0.1	0.4
Pinus nigra	Austrian Pine	0.2	0.1	0.4

Scientific Name	Common Name	% Population	% Leaf Area	Dominance value
Prunus padus	Bird Cherry	0.1	0.1	0.3
Fraxinus angustifolia	Narrow-Leaved Ash	<0.1	0.2	0.3
Pyrus calleryana	Callery Pear	0.2	<0.1	0.2
Cotoneaster	Cotoneaster	0.1	<0.1	0.2
Eucalyptus gunnii	Cider Gum	<0.1	0.1	0.2
Pseudotsuga menziesii	Douglas Fir	<0.1	<0.1	0.2
Acer saccharum	Sugar Maple	<0.1	0.1	0.2
Castanea sativa	Sweet Chestnut	0.1	<0.1	0.2
Syringa vulgaris	Lilac	0.1	<0.1	0.2
Pyrus communis	Common Pear	<0.1	<0.1	0.2
Cedrus atlantica v. glauca	Atlas Cedar	<0.1	<0.1	0.1
Cupressus macrocarpa	Monterey Cypress	<0.1	<0.1	0.1
Betula utilis ssp. jacquemontii	West Himalayan Birch	<0.1	<0.1	0.1
Larix kaempferi	Japanese Larch	<0.1	<0.1	0.1
Cedrus atlantica	Atlantic Cedar	<0.1	<0.1	0.1

Scientific Name	Common Name	% Population	% Leaf Area	Dominance value
Laburnum anagyroides	Common Laburnum	<0.1	<0.1	0.1
Abies procera	Noble Fir	<0.1	<0.1	0.1
Pyracantha	Firethorn	<0.1	<0.1	0.1
Amelanchier x lamarckii	Juneberry	<0.1	<0.1	0.1
Salix babylonica	Weeping Willow	<0.1	<0.1	0.1
Platanus occidentalis	Western Plane	<0.1	<0.1	0.1
Abies koreana	Korean Fir	<0.1	<0.1	<0.1
Acer japonicum	Fullmoon Maple	<0.1	<0.1	<0.1
Acer negundo	Box Elder	<0.1	<0.1	<0.1
Acer palmatum	Palmate Maple	<0.1	<0.1	<0.1
Betula papyrifera	Paper Birch	<0.1	<0.1	<0.1
Corylus colurna	Turkish Hazel	<0.1	<0.1	<0.1
Crataegus laevigata	Midland Hawthorn	<0.1	<0.1	<0.1
Elaeagnus	Silverberry	<0.1	<0.1	<0.1
Eriobotrya japonica	Loquat	<0.1	<0.1	<0.1

Scientific Name	Common Name	% Population	% Leaf Area	Dominance value
Euonymus europaeus	European Spindle	<0.1	<0.1	<0.1
Juglans regia	Common Walnut	<0.1	<0.1	<0.1
Juniperus communis	Common Juniper	<0.1	<0.1	<0.1
Ligustrum obtusifolium	Amur Privet	<0.1	<0.1	<0.1
Liquidambar styraciflua	Sweet Gum	<0.1	<0.1	<0.1
Malus	Apple	<0.1	<0.1	<0.1
Morus nigra	Black Mulberry	<0.1	<0.1	<0.1
Olea europaea	Olive	<0.1	<0.1	<0.1
Populus x canadensis	Canadian Poplar	<0.1	<0.1	<0.1
Prunus Kanzan	Cherry 'Kanzan'	<0.1	<0.1	<0.1
Prunus serrula	Tibetan Cherry	<0.1	<0.1	<0.1
Prunus subhirtella	Winter-flowering Cherry	<0.1	<0.1	<0.1
Pterocarya pterocarpa	Caucasian Wingnut	<0.1	<0.1	<0.1
Salix cinerea	Grey Willow	<0.1	<0.1	<0.1

Scientific Name	Common Name	% Population	% Leaf Area	Dominance value
Salix pentandra	Bay Willow	<0.1	<0.1	<0.1
Salix viminalis	Common Osier Willow	<0.1	<0.1	<0.1
Sequoiadendron giganteum	Giant Redwood	<0.1	<0.1	<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 (£)
Betula pendula	Silver Birch	261,154	54,587	3,567	68,780	£76,183,134
Fraxinus excelsior	Common Ash	255,145	84,142	3,200	106,600	£138,930,587
Quercus robur	English Oak	255,141	204,240	5,184	139,658	£324,878,371
Ilex aquifolium	Holly	250,009	37,155	760	27,908	£34,265,076
Crataegus monogyna	Hawthorn	219,633	35,729	988	24,546	£50,194,002
Acer pseudoplatanus	Sycamore	148,960	81,853	2,304	74,004	£120,701,883
x Hesperotropsis leylandii	Leyland Cypress	117,266	91,635	3,501	19,537	£121,533,289
Picea abies	Norway Spruce	113,575	14,814	420	9,119	£13,242,298
Prunus avium	Wild Cherry	89,152	24,555	860	18,938	£32,638,287
Pinus sylvestris	Scots Pine	66,507	9,155	419	10,968	£22,185,116
Alnus glutinosa	Common Alder	62,122	11,825	461	21,756	£49,374,351
Acer campestre	Field Maple	59,288	18,879	289	19,406	£20,719,869
Acer platanoides	Norway Maple	58,237	31,859	1,149	37,581	£61,276,806
Tilia x europaea	Common Lime	57,400	17,826	667	33,087	£59,127,517
Chamaecyparis lawsoniana	Lawson Cypress	56,270	20,902	695	23,530	£65,504,612
Sorbus aucuparia	Rowan	53,899	10,134	509	7,336	£13,251,968
Populus tremula	Aspen	52,407	11,134	620	12,355	£6,295,110
Thuja plicata	Western Red Cedar	49,465	2,892	53	8,796	£22,169,923
Fagus sylvatica	Common Beech	45,605	67,940	419	35,214	£107,341,853
Salix caprea	Goat Willow	38,692	8,773	183	11,616	£29,966,603
Prunus spinosa	Blackthorn	36,197	3,214	195	1,898	£1,856,069
Salix fragilis	Crack Willow	34,757	13,558	452	10,174	£29,747,822
Corylus avellana	Hazel	34,236	3,353	118	4,754	£6,039,625
Malus domestica	Apple	29,841	4,433	283	2,736	£10,880,778
Sambucus nigra	Elder	28,400	2,319	60	1,831	£8,516,278
Ulmus procera	English Elm	26,912	3,164	112	2,263	£2,070,589
Tilia cordata	Small Leaved Lime	24,015	9,135	271	19,845	£23,253,778
Taxus baccata	Common Yew	18,626	7,225	130	11,195	£23,056,902
Platanus x hybrida	London Plane	17,153	23,470	368	22,177	£88,215,421

Species	Common Name	Estimated No. of Trees	Carbon Stored (tonnes)	Net Seq (tonnes/yr)	Avoided Runoff (m^3/yr)	Replacement Cost (£)
Prunus domestica	Plum	17,125	3,282	215	1,938	£3,821,636
Betula pubescens	Downy Birch	16,659	3,275	189	5,080	£6,141,072
Tilia platyphyllos	Large Leaved Lime	16,182	9,009	348	16,042	£38,500,839
Quercus petraea	Sessile Oak	16,178	1,544	48	3,128	£3,181,536
Sorbus intermedia	Swedish Whitebeam	14,694	2,198	124	2,305	£4,001,962
Sorbus aria	Whitebeam	14,228	5,754	77	3,813	£15,503,045
Carpinus betulus	Common Hornbeam	13,707	17,416	43	14,123	£50,064,839
Populus nigra v. italica	Lombardy Poplar	13,674	22,011	455	3,728	£15,147,425
Pinus	Pine	13,253	170	21	682	£432,973
Quercus rubra	Red Oak	13,233	4,285	183	4,918	£9,397,461
Alnus incana	Grey Alder	13,217	1,272	45	2,362	£3,255,971
Aesculus hippocastanum	Horse Chestnut	12,250	19,003	280	8,736	£11,965,112
Alnus cordata	Italian Alder	11,780	1,856	70	4,629	£5,871,179
Salix alba	White Willow	11,780	1,514	130	4,400	£9,691,007
Prunus cerasifera	Cherry Plum	11,749	2,370	135	2,308	£2,966,019
Magnolia	Magnolia	11,729	1,043	128	1,319	£2,414,838
Prunus laurocerasus	Cherry Laurel	11,275	2,401	128	2,249	£2,968,306
Cedrus deodara	Deodar Cedar	10,304	2,033	138	3,367	£4,578,799
Ulmus glabra	Wych Elm	10,285	2,290	142	5,117	£3,181,190
Chamaecyparis pisifera	Sawara Cypress	8,827	1,495	51	1,697	£3,835,646
Acer saccharinum	Silver Maple	7,837	3,296	142	6,700	£9,358,129
Malus sylvestris	Crab Apple	7,363	1,244	76	1,070	£2,967,795
Populus nigra	Black Poplar	7,363	12,601	294	7,934	£11,751,494
Pinus nigra	Austrian Pine	7,347	1,175	55	896	£4,203,890
Cupressus sempervirens	Italian Cypress	5,890	3,267	43	8,940	£5,464,830
Pyrus calleryana	Callery Pear	5,890	613	58	376	£1,330,525
Robinia pseudoacacia	False Acacia	4,892	2,381	126	2,407	£3,185,820
Prunus padus	Bird Cherry	4,418	1,230	16	1,299	£1,921,189
Castanea sativa	Sweet Chestnut	4,418	206	13	277	£198,999
Populus alba	White Poplar	4,410	3,776	150	3,930	£3,404,503
Cotoneaster	Cotoneaster	4,406	271	35	669	£343,948

Species	Common Name	Estimated No. of Trees	Carbon Stored (tonnes)	Net Seq (tonnes/yr)	Avoided Runoff (m^3/yr)	Replacement Cost (£)
Syringa vulgaris	Lilac	4,398	846	45	102	£1,811,356
Quercus cerris	Turkey Oak	3,419	6,692	78	3,178	£12,243,388
Cupressus macrocarpa	Monterey Cypress	2,945	1,193	5	384	£2,575,844
Pyrus communis	Common Pear	2,945	784	23	525	£1,652,308
Liriodendron tulipifera	Tulip Tree	2,945	2,316	120	4,359	£6,775,082
Laburnum anagyroides	Common Laburnum	2,942	1,096	37	162	£1,395,647
Pseudotsuga menziesii	Douglas Fir	2,942	233	7	825	£1,825,629
Larix kaempferi	Japanese Larch	2,937	188	8	265	£512,391
Amelanchier x lamarckii	Juneberry	2,937	55	15	56	£134,301
Pyracantha	Firethorn	2,937	102	12	64	£165,524
Eucalyptus gunnii	Cider Gum	2,444	1,915	112	1,035	£1,928,796
Liquidambar styraciflua	Sweet Gum	1,950	8	2	146	£83,773
Betula utilis ssp. jacquemontii	West Himalayan Birch	1,950	148	12	564	£195,689
Abies procera	Noble Fir	1,473	282	22	623	£1,186,580
Malus	Apple	1,473	89	14	71	£158,911
Fraxinus angustifolia	Narrow-Leaved Ash	1,473	494	30	2,136	£507,436
Betula papyrifera	Paper Birch	1,473	90	20	501	£120,632
Corylus colurna	Turkish Hazel	1,473	57	10	141	£112,472
Sequoiadendron giganteum	Giant Redwood	1,473	177	15	90	£175,813
Juglans regia	Common Walnut	1,473	116	19	135	£144,101
Ligustrum obtusifolium	Amur Privet	1,473	105	12	119	£122,442
Populus x canadensis	Canadian Poplar	1,473	48	5	110	£34,441
Platanus occidentalis	Western Plane	1,473	29	6	528	£127,339
Salix babylonica	Weeping Willow	1,473	44	8	536	£144,434
Acer saccharum	Sugar Maple	1,473	830	31	1,388	£1,611,600
Salix cinerea	Grey Willow	1,473	25	8	44	£89,665
Eriobotrya japonica	Loquat	1,473	4	1	6	£29,817
Elaeagnus	Silverberry	1,469	30	7	43	£60,846
Cedrus atlantica v. glauca	Atlas Cedar	1,469	984	39	798	£3,023,413
Euonymus europaeus	European Spindle	1,469	235	18	214	£60,888
Prunus serrula	Tibetan Cherry	1,469	21	12	2	£30,565

Species	Common Name	Estimated No. of Trees	Carbon Stored (tonnes)	Net Seq (tonnes/yr)	Avoided Runoff (m^3/yr)	Replacement Cost (£)
Olea europaea	Olive	1,469	32	5	118	£52,170
Juniperus communis	Common juniper	1,469	223	9	116	£414,946
Acer palmatum	Palmate Maple	1,469	100	5	213	£143,229
Crataegus laevigata	Midland Hawthorn	1,469	36	9	145	£47,013
Morus nigra	Black Mulberry	1,469	205	30	179	£473,516
Acer negundo	Box Elder	975	77	12	168	£227,547
Abies koreana	Korean Fir	975	24	5	28	£48,489
Prunus subhirtella	Winter-flowering Cherry	975	45	12	46	£44,804
Prunus Kanzan	Cherry 'Kanzan'	975	202	22	50	£333,010
Acer japonicum	Fullmoon Maple	975	190	11	137	£532,753
Salix pentandra	Bay Willow	975	580	42	5	£2,498,807
Cedrus atlantica	Atlantic Cedar	975	2,078	43	770	£6,104,829
Salix viminalis	Common Osier Willow	975	60	11	310	£56,675
Pterocarya pterocarpa	Caucasian Wingnut	975	32	5	26	£93,966

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[39]. 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[40].
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.

39 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[41]. 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[42 43] that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere[44].

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[45 46].

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

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

41 Baldocchi (1987), (1988)

42 Bidwell and Fraser (1972)

43 Lovett (1994)

44 Zinke (1967)

45 Hollis (2007)

46 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
Binh Nguyen
Manroop Basi
Rosa Mayer
Jade Smith
Neelam Ulhaq
Jeremy Monson
Vivien Bledea
Owen Brettle
Edward Cosnett
Amber
Charlotte Wilson
Cameron Gibson

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.

Met Office Hadley Centre (2022). UK Climate Projections: Headline Findings August 2022. Available at: https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/summaries/headline-findings

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.

This report is available online at: treeconomics.co.uk